

FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



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Documentation Roadmap

Preface

Purpose of this document

This document is intended for users of "FUJITSU Software Enterprise Postgres" (hereafter referred to as "FUJITSU Enterprise Postgres"), and explains how to read the manuals.

Structure of this document

The structure and content of this manual is shown below.

[Chapter 1 How to Read the Manuals](#)

This section explains the notational conventions in FUJITSU Enterprise Postgres manuals.

[Chapter 2 Trademarks](#)

This section explains the trademarks.

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Chapter 1 How to Read the Manuals

The FUJITSU Enterprise Postgres manuals use certain notational conventions and rules. Pay attention to these conventions and rules when reading the FUJITSU Enterprise Postgres manuals.

1.1 Intended Products

The manuals apply to the following products:

- FUJITSU Enterprise Postgres Advanced Edition

1.2 Abbreviations of Manual Titles

The following tables list abbreviations of the titles of manuals for FUJITSU Enterprise Postgres as they appear in the manuals.

Formal manual title	Abbreviation in FUJITSU Enterprise Postgres manuals
FUJITSU Enterprise Postgres Release Notes	Release Notes
FUJITSU Enterprise Postgres General Description	General Description
FUJITSU Enterprise Postgres Installation and Setup Guide for Server	Installation and Setup Guide for Server
FUJITSU Enterprise Postgres Installation and Setup Guide for Client	Installation and Setup Guide for Client
FUJITSU Enterprise Postgres Installation and Setup Guide for Server Assistant	Installation and Setup Guide for Server Assistant
FUJITSU Enterprise Postgres Operation Guide	Operation Guide
FUJITSU Enterprise Postgres Cluster Operation Guide (Database Multiplexing)	Cluster Operation Guide (Database Multiplexing)
FUJITSU Enterprise Postgres Security Operation Guide	Security Operation Guide
FUJITSU Enterprise Postgres Application Development Guide	Application Development Guide
FUJITSU Enterprise Postgres Connection Manager User's Guide	Connection Manager User's Guide
FUJITSU Enterprise Postgres Reference	Reference
FUJITSU Enterprise Postgres Java API Reference	Java API Reference
FUJITSU Enterprise Postgres Glossary	Glossary
FUJITSU Enterprise Postgres Messages	Messages
PostgreSQL 12.1 Documentation	PostgreSQL Documentation

1.3 System of Manuals and How to Use the Manuals

This section describes the system of manuals for FUJITSU Enterprise Postgres.

1.3.1 System of Manuals

FUJITSU Enterprise Postgres manuals

The table below shows the manuals on FUJITSU Enterprise Postgres.

Use/Purpose	Manual title	Content	When to read
Deciding whether to upgrade the product.	Release Notes	Overview of upgraded features and incompatibility information.	When learning about features upgraded from earlier versions and incompatibility information.
Acquiring an overview of the product and the basic information required for work and operation.	General Description	Description of all available functions associated with each intended purpose or use, and screenshots of operations.	When learning basic information and restrictions that system engineers and operators must know to actually operate the product.
Installing and setting up FUJITSU Enterprise Postgres correctly to enable its use.	Installation and Setup Guide for Server	Procedure for installing and setting up FUJITSU Enterprise Postgres.	When installing and setting up FUJITSU Enterprise Postgres.
Installing the FUJITSU Enterprise Postgres client function correctly to enable its use.	Installation and Setup Guide for Client	Installing the FUJITSU Enterprise Postgres client function.	When installing the FUJITSU Enterprise Postgres client function.
Installing and setting up the FUJITSU Enterprise Postgres Server Assistant.	Installation and Setup Guide for Server Assistant	Procedure for installing and setting up the FUJITSU Enterprise Postgres Server Assistant.	When installing and setting up the FUJITSU Enterprise Postgres Server Assistant.
Operating and managing FUJITSU Enterprise Postgres.	Operation Guide	Description of the tasks required in FUJITSU Enterprise Postgres management and operation.	When learning how to operate and manage the databases.
Performing switchover using database multiplexing mode.	Cluster Operation Guide (Database Multiplexing)	Description of the tasks required for database multiplexing operation.	When using database multiplexing mode to create operating environment for switchover and perform it.
Performing security operation.	Security Operation Guide	Description of the tasks required for security operations.	When using security features and performing security operation in FUJITSU Enterprise Postgres.
Applications using the interface provided by FUJITSU Enterprise Postgres.	Application Development Guide	Procedure for creating an application using embedded SQL, JDBC driver, ODBC driver.	When developing an application using the interface provided by FUJITSU Enterprise Postgres.
Performing high availability system using the Connection Manager feature.	Connection Manager User's Guide	Description of the features, setup, and usage of Connection Manager.	When using Connection Manager features by FUJITSU Enterprise Postgres.
Usage of FUJITSU Enterprise Postgres commands.	Reference	Description of the FUJITSU Enterprise Postgres commands expanded on from PostgreSQL.	When learning FUJITSU Enterprise Postgres command functions, options, and examples of use.
Learning the syntax of the JDBC API.	Java API Reference	Description of the syntax of the JDBC API.	When learning the syntax of the JDBC API.

Use/Purpose	Manual title	Content	When to read
Learning the meaning of the terms of FUJITSU Enterprise Postgres.	Glossary	Description of the terms used in the FUJITSU Enterprise Postgres manuals.	When checking the meaning of terms used in the FUJITSU Enterprise Postgres manuals.
Referring to messages from FUJITSU Enterprise Postgres and taking measures for them.	Messages	Description of each message and description of any measures to be taken for it.	When finding out the specific measures for dealing with messages from FUJITSU Enterprise Postgres.

PostgreSQL manual

The table below shows the manual on PostgreSQL-compatible features.

Use/Purpose	Manual title	Content	When to read
Learning about PostgreSQL features.	PostgreSQL Documentation	Official PostgreSQL documentation. Explains all features officially supported by the relevant version of PostgreSQL.	When learning how to use PostgreSQL.

1.3.2 Documentation Road Map

This section provides a documentation roadmap, broken down by user role.

Database administrator

The database administrator is a user who performs FUJITSU Enterprise Postgres installation and setup, and who operates and monitors the database.

Refer to the manuals in the table below, according to purpose:

	Purpose	Manual name	
Required reading	To learn about upgraded features and incompatibility information	Release Notes	
	To read an overview of the software	General Description	
	To perform installation and setup		Installation and Setup Guide for Server
			Cluster Operation Guide (Database Multiplexing)
			Connection Manager User's Guide
	To install the Server Assistant		Installation and Setup Guide for Server Assistant
	To operate and monitor		Operation Guide
			Security Operation Guide
			Cluster Operation Guide (Database Multiplexing)
Reference			

	Purpose	Manual name
	Using Connection Manager features	Connection Manager User's Guide
	Reference	Messages
		Glossary
Refer to as required	To learn about PostgreSQL features	PostgreSQL Documentation

Application developer

The application developer is a user who defines the database and develops applications.

Refer to the manuals in the table below, according to purpose:

	Purpose	Manual name
Required reading	To learn about upgraded features and incompatibility information	Release Notes
	To read an overview of the software	General Description
	To perform installation and setup	Installation and Setup Guide for Client
	To define a database	Operation Guide
	To develop applications	Application Development Guide
		Java API Reference
	Using Connection Manager features	Connection Manager User's Guide
Reference	Messages	
	Glossary	
Refer to as required	To learn about PostgreSQL features	PostgreSQL Documentation

1.4 Notational Conventions in the Manuals

Manual titles and product names in the manual are abbreviated.

This section explains the notational conventions for abbreviations and platform-specific information in the manuals.

1.4.1 Abbreviation of Product Names

The following table lists abbreviations of the names of products related to FUJITSU Enterprise Postgres as they appear in the manuals.

Formal name	Abbreviation
Red Hat(R) Enterprise Linux(R) 7 (for IBM Z), Red Hat(R) Enterprise Linux(R) 8 (for IBM Z) and SUSE Linux Enterprise Server 12 (for IBM Z)	Linux
Red Hat(R) Enterprise Linux(R) 7 (for IBM Z)	RHEL7
Red Hat(R) Enterprise Linux(R) 8 (for IBM Z)	RHEL8
SUSE Linux Enterprise Server 12 (for IBM Z)	SLES 12
Windows(R) 8.1, Windows(R) 8.1 Pro,	Windows(R)

Formal name	Abbreviation
Windows(R) 8.1 Enterprise, Windows(R) 10 Home, Windows(R) 10 Education, Windows(R) 10 Pro, Windows(R) 10 Enterprise, Microsoft(R) Windows Server(R) 2012 Datacenter, Microsoft(R) Windows Server(R) 2012 Standard, Microsoft(R) Windows Server(R) 2012 Essentials, Microsoft(R) Windows Server(R) 2012 Foundation, Microsoft(R) Windows Server(R) 2012 R2 Datacenter, Microsoft(R) Windows Server(R) 2012 R2 Standard, Microsoft(R) Windows Server(R) 2012 R2 Essentials, Microsoft(R) Windows Server(R) 2012 R2 Foundation, Microsoft(R) Windows Server(R) 2016 Datacenter, Microsoft(R) Windows Server(R) 2016 Standard and Microsoft(R) Windows Server(R) 2016 Essentials Microsoft(R) Windows Server(R) 2019 Datacenter, Microsoft(R) Windows Server(R) 2019 Standard and Microsoft(R) Windows Server(R) 2019 Essentials	
Internet Explorer(R) 11	Internet Explorer
Microsoft(R) Edge	Edge
Java Naming and Directory Interface	JNDI
Java(TM) 2 SDK, Standard Edition, Java(TM) 2 Platform, Enterprise Edition, Java(TM) Platform, Standard Edition and Java(TM) Development Kit	JDK
Java(TM) 2 Runtime Environment, Standard Edition and Java(TM) Runtime Environment	JRE
FUJITSU Enterprise Postgres Advanced Edition (64bit)	AE or FUJITSU Enterprise Postgres Advanced Edition
IBM mainframe (z14)	IBM z14
IBM mainframe (z15)	IBM z15

Remarks: The symbols (R) and (TM) may be omitted in this manual.

1.4.2 FUJITSU Enterprise Postgres Conventions

The naming conventions for the FUJITSU Enterprise Postgres product names and functions used in the FUJITSU Enterprise Postgres manuals are shown below.

1.4.2.1 Server

The names used in the manuals in explanations regarding FUJITSU Enterprise Postgres functions are shown below.

Product name	Name used in manuals
FUJITSU Enterprise Postgres Advanced Edition (64bit)	64-bit product

1.4.2.2 Client

The names used in the manuals in explanations regarding FUJITSU Enterprise Postgres client functions are shown below.

Product name	Name used in manuals
FUJITSU Enterprise Postgres Client (64bit)	64-bit product

1.4.3 Symbol Convention

The symbols shown below are used in the manuals.

Symbol	Meaning
[]	<p>These symbols indicate characters displayed in a window or dialog box or keyboard keys.</p> <p>Examples: [Setting] dialogue box, [File] menu, [Item name], [OK] button, [Enter] key.</p>

1.5 Notes about Manuals

This section contains notes about the FUJITSU Enterprise Postgres operating environments and manuals.

- Images in figures

The FUJITSU Enterprise Postgres manuals contain figures showing printouts for FUJITSU Enterprise Postgres to provide the reader an idea of what the printouts look like, but since the figures are only examples, they are incomplete.

- Explanatory examples

Most of the examples of databases in the FUJITSU Enterprise Postgres manuals are modeled after inventory control databases of retail stores. The design and contents of the databases in the examples are fictitious and do not represent any real database.

- UNIX release version number

This system conforms to UNIX System V Rel4.2MP.

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Glossary

Preface

Purpose of this document

This document explains FUJITSU Enterprise Postgres terminology.

Intended readers

This document is aimed at all users of FUJITSU Enterprise Postgres.

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Exportation/release of this document may require necessary procedures in accordance with the regulations of your resident country and/or US export control laws.

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Glossary

Arbitration command

A user command called when an abnormality is detected using operating system/server heartbeat monitoring in database multiplexing mode.

Arbitration server

A dedicated server on which the Server Assistant program is installed.

Archive log

Contains the history of updates made to the database, and is used during recovery.

Backup data storage destination

The directory that stores the backup data.

Client command

A command that is executed from the client machine and used. Also known as a client application.

Connection Manager

The replication operation to continue without knowing where the application is connected.

The Connection Manager feature improves the availability.

Data storage destination

The directory that stores the database clusters.

Database cluster

The database storage area on the database storage disk. Database clusters are a collection of databases managed by an instance.

Data masking

A feature that can change the returned data for queries generated by applications, to prevent exposing actual data.

Database multiplexing

Mechanism in which a database is made redundant on multiple servers, by transferring transaction logs (WAL) via the network to enable application jobs to be continued.

Database superuser

A user defined in the database with access privileges for all database objects.

Encoding

Indicates the character set.

Fencing

A process that isolates a database server with an unstable status from the cluster system in database multiplexing mode. This process is implemented as a fencing command.

Fencing command

A user command that implements fencing in database multiplexing mode.

Global Meta Cache

The Global Meta Cache feature cache the informations about system catalogs and table definitions information (meta cache) in shared memory. The meta cache on shared memory is called the Global Meta Cache (GMC).

Instance

A series of server processes for managing database clusters.

Instance administrator

The OS user account that owns the database cluster files and operates the database server processes.

Instance name

Indicates the instance name.

Masking policy

A method of changing data under specific conditions when it is returned for a query from an application. You can configure masking target, masking type, masking condition and masking format.

Mirrored transaction log

The log that mirrors the transaction log at the backup data storage destination.

Mirroring Controller arbitration process

A process that performs arbitration and fencing on the arbitration server.

Mirroring Controller monitoring process

A process that performs heartbeat monitoring of the Mirroring Controller process. If the Mirroring Controller process returns no response or is down, the Mirroring Controller monitoring process is restarted automatically.

Mirroring Controller process

A process that performs operating system/server and process heartbeat monitoring and disk abnormality monitoring between database servers. Additionally, the process issues arbitration requests to the arbitration server and executes arbitration commands.

Pgpool-II connection pooling

The connection pooling feature of Pgpool-II supported by FUJITSU Enterprise Postgres.

This feature maintains the connection established with the database server and reuses that connection each time a new connection with the same properties (user name, database, and protocol version) arrives. By reducing the connection overhead for the database server, throughput of the whole system is improved.

Pgpool-II failover

The automatic failover feature of Pgpool-II supported by FUJITSU Enterprise Postgres.

If any of the database servers crashes or can no longer be reached, this feature disconnects the server and continues operation on the remaining servers. The streaming replication feature of PostgreSQL is combined with Pgpool-II to achieve a high-availability system.

Pgpool-II load balancing

The load balancing feature of Pgpool-II supported by FUJITSU Enterprise Postgres.

This feature distributes reference queries to multiple database servers, improving throughput of the whole system. The database multiplexing feature or PostgreSQL streaming replication feature is combined with Pgpool-II to reduce the load on the database server.

Pgpool-II server

A server for using the failover, connection pooling, and load balancing features of Pgpool-II. It is a dedicated server that has a server program installed for using these features.

Primary server

The server that processes the main database jobs during multiplexed database operation.

Server Assistant

A feature that objectively determines the status of database servers as a third party, and if necessary, isolates affected databases if the database servers are unable to accurately ascertain their mutual statuses in database multiplexing mode, such as due to a network error between database servers, or server instability.

Server Assistant program

A program to be installed on the arbitration server.

Server command

A command used on the database server. Also known as a server application.

Standby server

A server that generates a replicated database synchronized with the primary server, and that can run as an alternative server in case the primary server fails during multiplexed database operation.

State transition command

A user command called when Mirroring Controller performs a state transition of a database server in database multiplexing mode. State transition commands include the post-switch command, pre-detach command, and post-attach command.

Transaction log

Contains the history of updates made to the database by transactions. Also known as the WAL (Write-Ahead Log).

Transaction log storage destination

The directory that stores the transaction log.

VCI (Vertical Clustered Index)

An index with columnar data structure suitable for aggregation.

WAL (Write-Ahead Log)

Has the same meaning as 'transaction log'.

WebAdmin program

A GUI-based program installed on a database server or a dedicated WebAdmin server, used to manage database instances.

WebAdmin server

By using the WebAdmin program on a different server to the database server, instances on multiple database servers can be managed from a dedicated WebAdmin server on which the WebAdmin program is installed.

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General Description

Preface

Purpose of this document

This document explains the FUJITSU Enterprise Postgres concepts to those who are to operate databases using it. This document explains the features of FUJITSU Enterprise Postgres.

Intended readers

This document is intended for people who are:

- Considering installing FUJITSU Enterprise Postgres
- Using FUJITSU Enterprise Postgres for the first time
- Wanting to learn about the concept of FUJITSU Enterprise Postgres
- Wanting to see a functional overview of FUJITSU Enterprise Postgres

Readers of this document are also assumed to have general knowledge of:

- Computers
- Jobs
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 FUJITSU Enterprise Postgres Basics](#)

Explains the features of FUJITSU Enterprise Postgres.

[Appendix A List of Features](#)

Lists the main features provided by FUJITSU Enterprise Postgres.

[Appendix B OSS Supported by FUJITSU Enterprise Postgres](#)

Explains the OSS supported by FUJITSU Enterprise Postgres.

[Appendix C Features that can be Used on Servers Other than the Database Server](#)

Explains features that can be used on servers other than the database server.

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Chapter 1 FUJITSU Enterprise Postgres Basics

FUJITSU Enterprise Postgres maintains the operating methods, interfaces for application development and SQL compatibility of PostgreSQL, while providing expanded features for enhanced reliability and operability.

This chapter explains the functionality extended by FUJITSU Enterprise Postgres.

Refer to "[Appendix A List of Features](#)" for feature differences between editions.

Additionally, FUJITSU Enterprise Postgres supports various open source software (OSS). Refer to "[Appendix B OSS Supported by FUJITSU Enterprise Postgres](#)" for information on OSS supported by FUJITSU Enterprise Postgres.

FUJITSU Enterprise Postgres has the following features:

- Flexible database recovery
Not only does FUJITSU Enterprise Postgres recover data to its most recent form when a failure occurs, which is essential for databases, but it can also recover to any point in time. Additionally, backup/recovery can be performed using any copy technology.

- Simple GUI-based installation and operation management
FUJITSU Enterprise Postgres uses GUI to simplify cumbersome database operations, and allows databases to be used intuitively.

- High reliability by using database multiplexing
Database multiplexing protects important data and enables highly reliable database operation.

- Seamless migration from Oracle databases
FUJITSU Enterprise Postgres provides a compatibility feature with Oracle databases that localizes the correction of existing applications and allows easy migration to FUJITSU Enterprise Postgres.

- Storage Data Protection using Transparent Data Encryption
Information can be protected from data theft by encrypting data to be stored in the database.

- Data masking for improved security
The data masking feature changes the returned data for queries from applications, to prevent exposing actual data. This improves security for handling confidential data such as personal information.

- Audit logs for improved security
Audit logs can be used to counter security threats such as unauthorized access and misuse of privileges for the database.

- Enhanced query plan stability
The following features can control SQL statement query plans:
 - Optimizer hints
 - Locked statisticsThese features are used for curbing performance deterioration caused by changes in SQL statement query plans, such as with mission-critical jobs that emphasize performance stability over improved SQL statement processing performance.

- Increased aggregation performance using the in-memory feature
The following features help speed up scans even when aggregating many rows.
 - Vertical Clustered Index (VCI)

- In-memory data

- High-speed data load
Data from files can be loaded at high speed into FUJITSU Enterprise Postgres tables using the high-speed data load feature.

- High availability by using Connection Manager
With the Connection Manager features, replication operation can be continued without being aware of the connection destination of the applications.

- Memory usage reduction by Global Meta Cache
The Global Meta Cache feature loads some of meta cache information in shared memory. This reduces overall system memory usage.

1.1 Flexible Database Recovery

Threats such as data corruption due to disk failure and incorrect operations are unavoidable in systems that use databases. The ability to reliably recover corrupted databases without extensive damage to users when such problems occur is an essential requirement in database systems.

FUJITSU Enterprise Postgres provides the following recovery features that flexibly respond to this requirement:

- Media recovery, which recovers up to the most recent point in time
- Point-in-time recovery, which can recover up to a specific point in time
- Backup/recovery that can integrate with various copy technologies

Media recovery, which recovers up to the most recent point in time

When a disk failure occurs, media recovery can recover data to how it was immediately before the failure.

In order to recover the database, FUJITSU Enterprise Postgres accumulates a history of database update operations, such as data additions and deletions, as an update log.

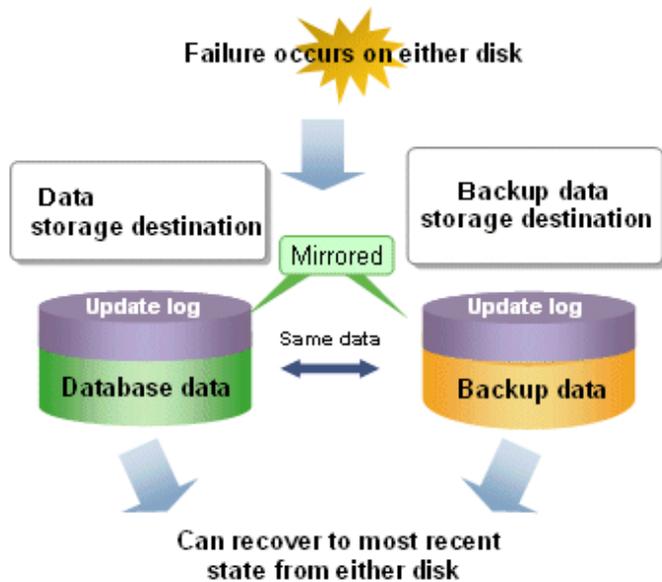
FUJITSU Enterprise Postgres retains a duplicate (mirror image) of the update log after backup execution on the data storage destination and on the backup data storage destination. Therefore, the data on one disk can be used to recover to the most recent state of the database even if a disk failure has occurred on the other.

Media recovery is executed using either a GUI tool provided with FUJITSU Enterprise Postgres (WebAdmin) or server commands.



Information

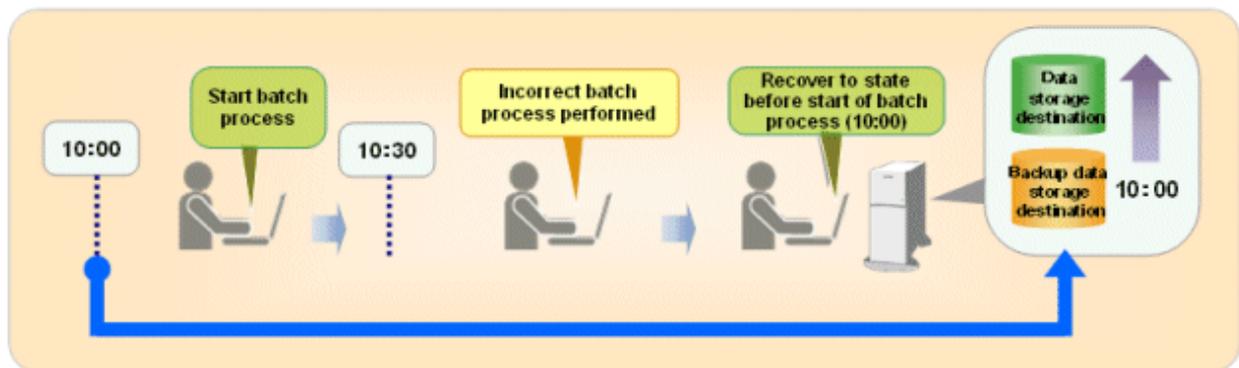
Recovery using WebAdmin requires less time and effort, since WebAdmin automatically determines the scope of the operation.



Point-in-time recovery, which can recover up to a specific point in time

Point-in-time recovery can be used to recover a database that has been updated by an incorrect operation, for example, by specifying any date and time before the incorrect operation.

Point-in-time recovery is executed using FUJITSU Enterprise Postgres server commands.



Backup data compression

Compressing and storing backup data reduces the amount of disk space required for backups.

It supports compression of backup data(database cluster and tablespace) and compression of archive logs in the update log.

Backup/recovery that can integrate with various copy technologies

It is possible to back up to the backup data storage destination, or to any backup destination using any copy technology implemented by user commands.

See

.....
 Refer to "Backup/Recovery Using the Copy Command" in the Operation Guide for information on backup/recovery using user commands.

1.2 Simple GUI-Based Installation and Operation Management

FUJITSU Enterprise Postgres provides WebAdmin, which is a GUI tool for a range of tasks, from database installation to operation management. This allows the databases to be used simply and intuitively.

WebAdmin can be used for FUJITSU Enterprise Postgres setup, creating and monitoring a streaming replication cluster, database backups, and for recovery. Depending on the configuration, WebAdmin can be used to manage FUJITSU Enterprise Postgres instances in a single server, or instances spread across multiple servers.

- Setup

To perform setup using WebAdmin, you must create an instance. An instance is a set of server processes that manage a database cluster (database storage area on the data storage destination disk). Instances can be created easily and with only minimal required input, because the tool automatically determines the optimal settings for operation.

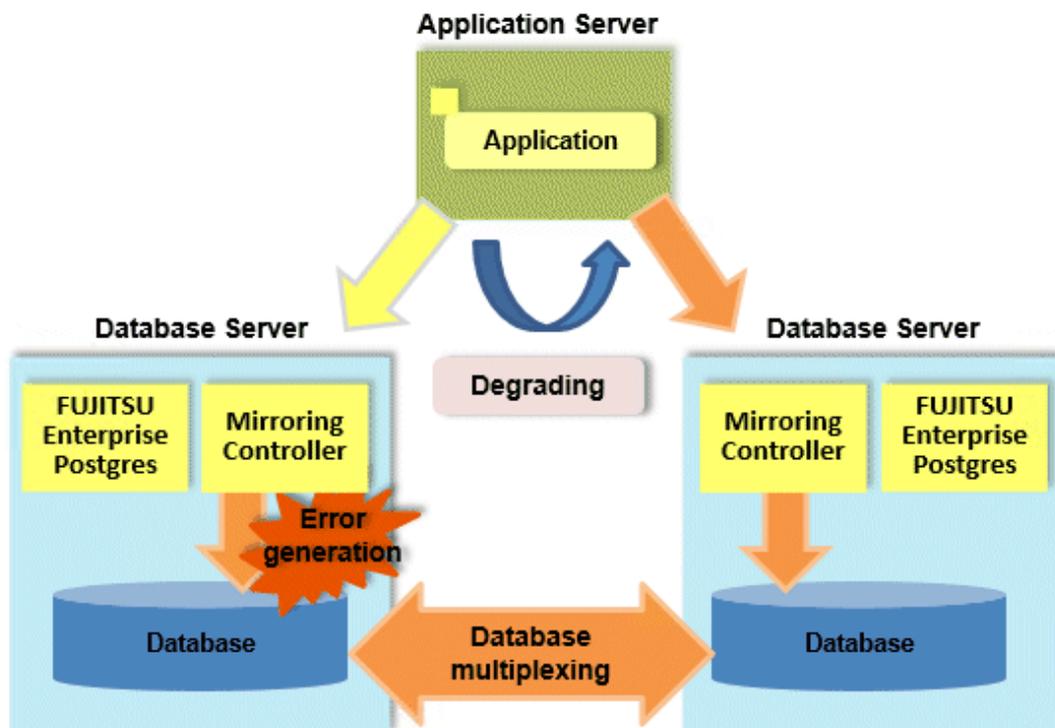
- Database backup/recovery

Database backup and recovery can be performed using simple GUI operations.

In particular, FUJITSU Enterprise Postgres can automatically identify and isolate the location of errors. This simplifies the recovery process and enables faster recovery.

1.3 High Reliability with Database Multiplexing

It is vital for systems that use databases to protect data from damage or loss caused by a range of factors such as hardware and software errors. Database multiplexing protects important data and enables highly reliable database operation.



FUJITSU Enterprise Postgres not only mirrors a database using the PostgreSQL streaming replication feature, but also provides simplified switchover and standby disconnection features as well as a feature to detect faults in elements that are essential for the continuity of database process, disk, network, and other database operations.

Even if a switchover is performed, the client automatically distinguishes between the primary and standby servers, so applications can be connected transparently regardless of the physical server.

The Mirroring Controller option enables the primary server (the database server used for the main jobs) to be switched automatically to the standby server if an error occurs in the former.

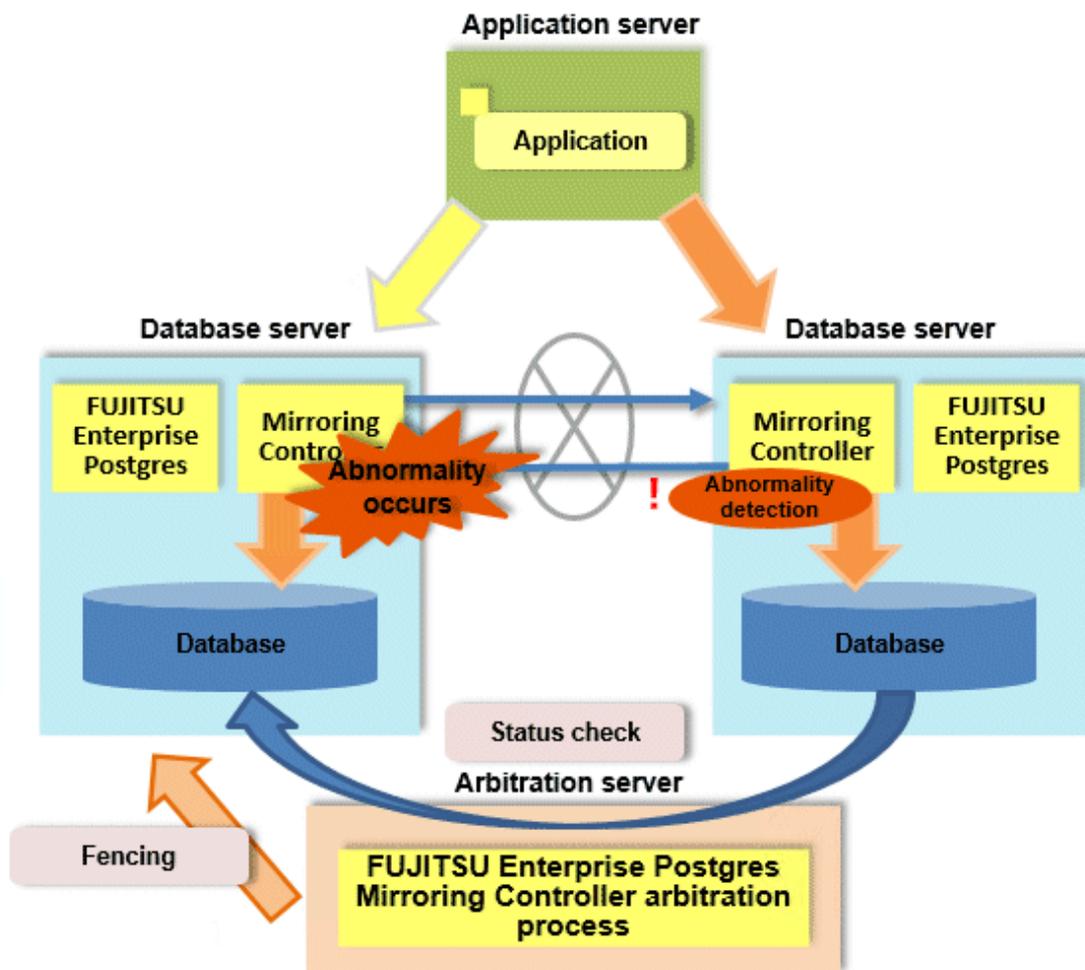
In addition, by using the data on the standby server, reference jobs such as data analysis and form output can be performed in parallel to the jobs on the primary server.

Operation using the arbitration server

Mirroring Controller may not be able to correctly determine the status of the other server if there is a network issue between database servers or a server is in an unstable state. As a result, both servers will temporarily operate as primary servers, so it may be possible to perform updates from either server.

The Server Assistant is a feature that objectively checks the status of database servers as a third party and isolates (fences) unstable servers in such cases.

In database multiplexing mode, the Server Assistant is made available by adding a new server (arbitration server) on which the Server Assistant is installed. Using an arbitration server can prevent the issue mentioned above (both servers temporarily operating as primary servers) and enables highly reliable operation.



 See

- Refer to "Database Multiplexing Mode" in the Cluster Operation Guide (Database Multiplexing) for information on the database multiplexing.

1.4 Seamless Migration from Oracle Databases

FUJITSU Enterprise Postgres supports Orafce, to provide compatibility with Oracle databases.

Using the compatibility feature reduces the cost of correcting existing applications and results in easy database migration.



Refer to "Compatibility with Oracle Databases" in the Application Development Guide for information on compatible features.

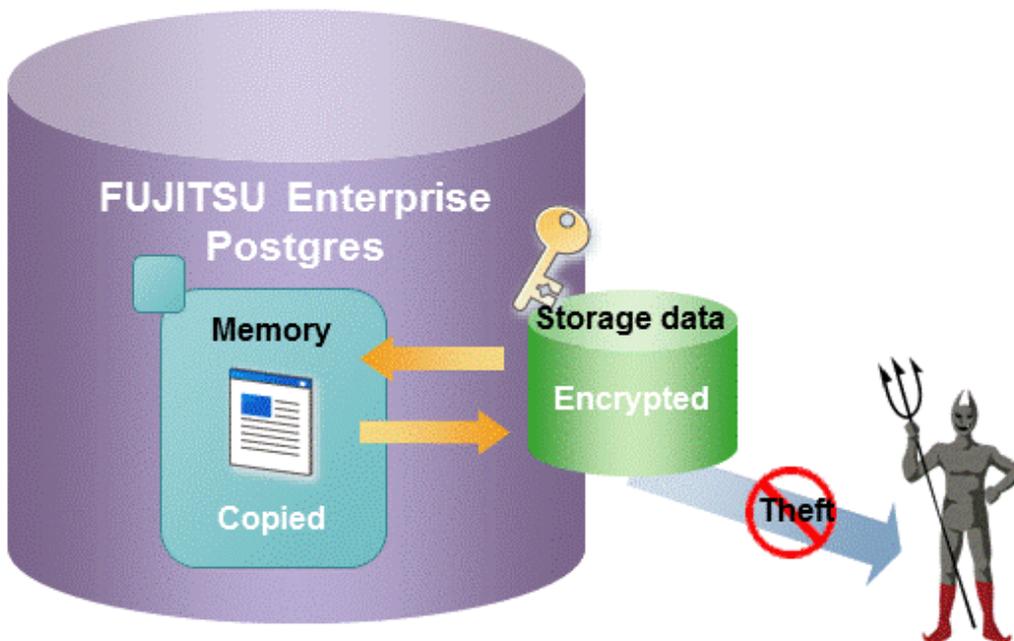
1.5 Storage Data Protection Using Transparent Data Encryption

The encryption of data to be stored in a database is essential under the following encryption requirements of PCI DSS (Payment Card Industry Data Security Standard), the data security standard of the credit industry:

- Confidential information (such as credit card numbers) can be encrypted.
- The encryption key and data are managed as separate entities.
- The encryption key is replaced at regular intervals.

To satisfy these requirements, FUJITSU Enterprise Postgres provides a transparent data encryption feature. Note that PostgreSQL uses an encryption feature called pgcrypto, which can also be used in FUJITSU Enterprise Postgres, but requires applications to be modified. Therefore, we recommend using FUJITSU Enterprise Postgres's transparent data encryption feature.

Key management in conjunction with the IBM Z hardware security module provides robust security.



Refer to "Protecting Storage Data Using Transparent Data Encryption" in the Operation Guide for information on stored data encryption.

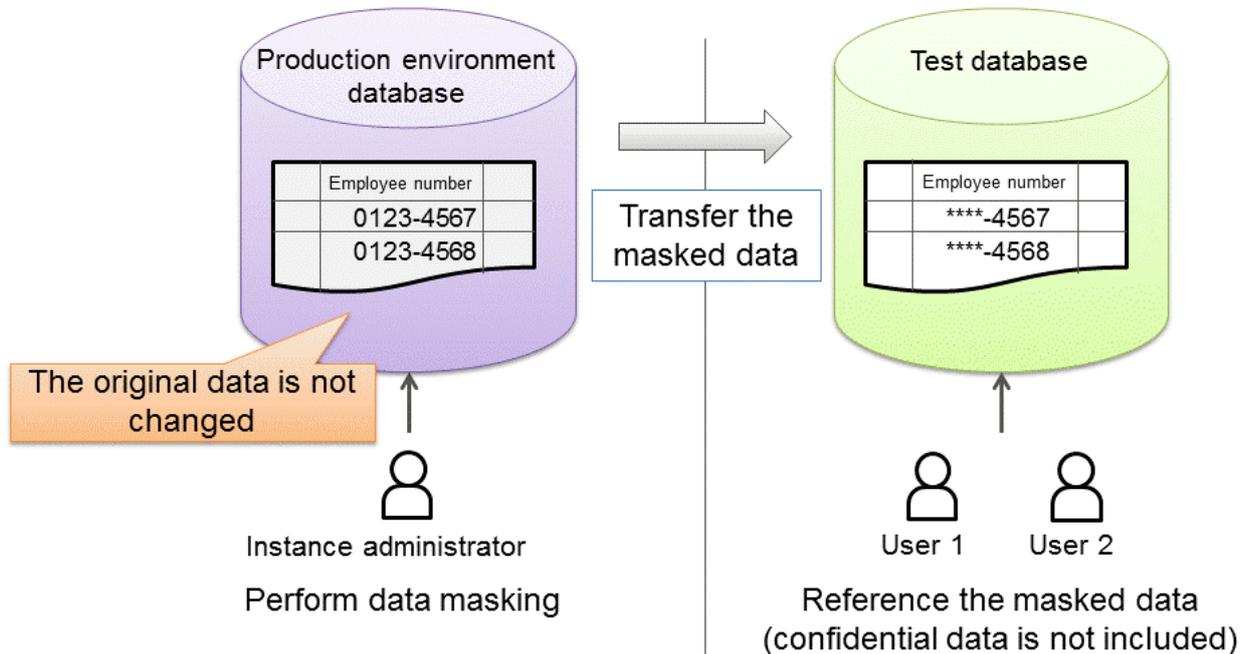
1.6 Data Masking for Improved Security

FUJITSU Enterprise Postgres provides a data masking feature that protects data to maintain security of data handled in systems.

The data masking feature changes the returned data for queries from applications and makes it available for reference without exposing the actual data.

For example, for a query of employee data, digits except the last four digits of an eight-digit employee number can be changed to "*" so that it can be used for reference.

Also, the data changed by the data masking feature can be transferred to a test database so that users who perform testing or development can reference the data. As production data should not be used in a test or development environment because of the risk of data leakage, this feature enables data that is similar to actual production data to be safely used in those environments.



See

Refer to "Data Masking" in the Operation Guide for information on data masking.

1.7 Security Enhancement Using Audit Logs

Details relating to database access can be retrieved in audit logs. The audit log feature can be used to counter security threats such as unauthorized access to the database and misuse of privileges.

In PostgreSQL, logs output as server logs can be used as audit logs by using the log output feature. There are, however, logs that cannot be analyzed properly, such as SQL runtime logs, which do not output the schema name. Additionally, because the output conditions cannot be specified in detail, log volumes can be large, which may lead to deterioration in performance.

The audit log feature of FUJITSU Enterprise Postgres enables retrieval of details relating to database access as an audit log by extending the feature to pgaudit. Additionally, audit logs can be output to a dedicated log file or server log. This enables efficient and accurate log monitoring.

See

Refer to "Audit Log Feature" in the Security Operation Guide for details.

1.8 Enhanced Query Plan Stability

FUJITSU Enterprise Postgres estimates the cost of query plans based on SQL statements and database statistical information, and selects the least expensive query plan. However, like other databases, FUJITSU Enterprise Postgres does not necessarily select the most suitable query plan. For example, it may suddenly select unsuitable query plan due to changes in the data conditions.

In mission-critical systems, stable performance is more important than improved performance, and changes in query plans case to be avoided. In this situation, the following features can stabilize query plans:

- Optimizer hints

You can use `pg_hint_plan` to specify a query plan in each individual SQL statement.

- Locked statistics

You can use `pg_dmb_stats` to lock statistical information per object, such as a database, schema, or table.



Refer to "Optimizer Hints" in the Application Development Guide for information on optimizer hints.

Refer to "Locked Statistics" in the Application Development Guide or information on locked statistics.



Use the features provided when FUJITSU Enterprise Postgres is installed for optimizer hints and locked statistical information. FUJITSU Enterprise Postgres does not support other similar open-source features.

1.9 Increased Aggregation Performance Using the In-memory Feature

FUJITSU Enterprise Postgres provides the in-memory feature, which uses columnar index and memory-resident data. This reduces disk I/Os and enhances aggregation performance.

Columnar index

Many aggregation processes may require a large portion of data in a particular column. However, traditional row data structure reads unnecessary columns, resulting in inefficient use of memory and CPU cache, and slower processing. FUJITSU Enterprise Postgres provides a type of columnar index, VCI (Vertical Clustered Index). This addresses the above issues, and enhances aggregation performance.

VCI provides the following benefits:

- Minimizes impact on existing jobs, and can perform aggregation using job data in real time.
- Provided as an index, so no application modification is required.
- Stores data also on the disk, so aggregation jobs can be quickly resumed using a VCI even if a failure occurs (when an instance is restarted).
- If the amount of memory used by VCI exceeds the set value, aggregation can still continue by using VCI data on the disk.

It also provides the features below:

- Disk compression
Compresses VCI data on the disk, minimizing required disk space. Even if disk access is required, read overhead is low.
- Parallel scan
Enhances aggregation performance by distributing aggregation processes to multiple CPU cores and then processing them in parallel.

In-memory data

The following features keep VCI data in memory and minimize disk I/Os on each aggregation process.

- Preload feature
Ensures stable response times by loading VCI data to memory before an application scans it after the instance is restarted.
- Stable buffer feature
Reduces disk I/Os by suppressing VCI data eviction from memory by other job data.

Purposes of this feature

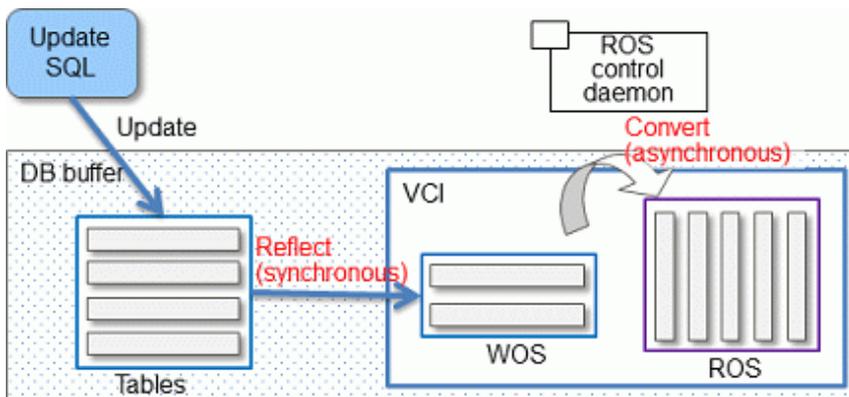
This feature has a data structure that can efficiently use the newly added resources, and aims to enhance the existing aggregation processing in normal operations to be faster than parallel scan. It shares the same purpose of enhancing aggregation performance with the parallel scan feature that is provided separately, but differs in that it speeds up nightly batch processes by utilizing available resources.

VCI architecture

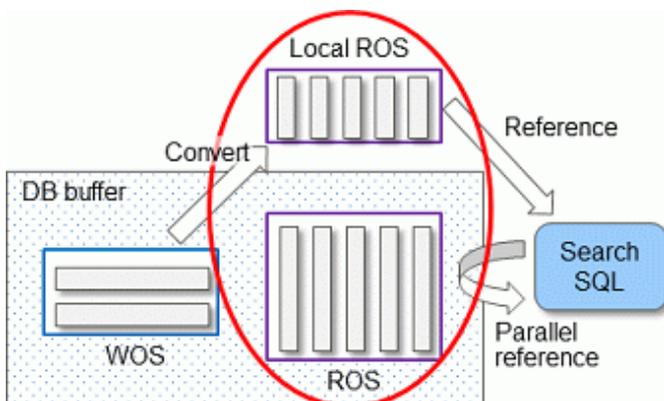
This section briefly explains VCI architecture as it contains basic terminology required, for example, when setting parameters.

Update and aggregation operations to enable real time use of job data are described.

VCI has write buffer row-based WOS (Write Optimized Store) in addition to the columnar data structure ROS (Read Optimized Store). Converting each update into a columnar index has a significant impact on the update process response times. Therefore, data is synchronously reflected to the row-based WOS when updating. After a certain amount of data is stored in WOS, the ROS control daemon asynchronously converts it to ROS. As above, the entire VCI is synchronized with the target table column, minimizing update overhead.



The same scan results can be obtained without a VCI by using WOS in conjunction with ROS. More specifically, WOS is converted to Local ROS in local memory for each aggregation process, and aggregated with ROS.



 See

Refer to "Installing and Operating the In-memory Feature" in the Operation Guide for information on installation and operation of VCI.

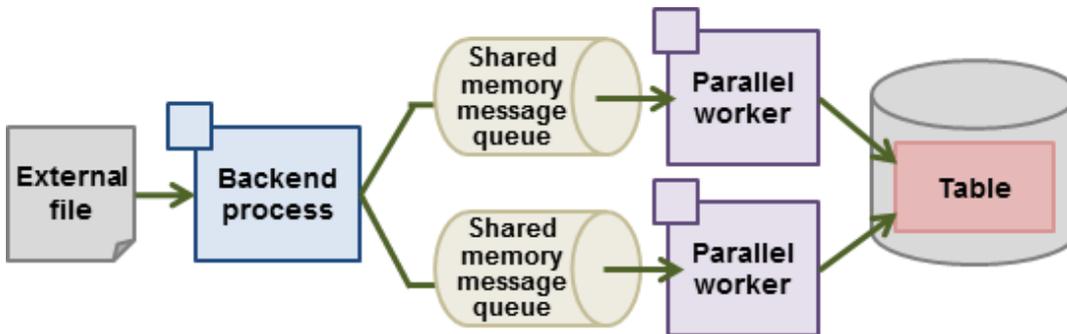
Refer to "Scan Using a Vertical Clustered Index (VCI)" in the Application Development Guide for information on scan using a VCI.

1.10 High-Speed Data Load

High-speed data load executes COPY FROM commands using multiple parallel workers. Because conversion of data from the external file to the appropriate internal format, table creation, and index creation are performed in parallel, it is possible to load large volumes of data at high speed.

Architecture of high-speed data load

High-speed data load is required for parameter setting and resource estimation, so a brief description of its architecture is provided below.



High-speed data load uses a single backend process collaborating with multiple parallel workers to perform data load in parallel. Data is exchanged between the backend process and parallel workers via shared memory message queues. The backend process distributes the loaded data of external files to multiple parallel workers. Each parallel worker then converts the data loaded from the shared memory message queue into the appropriate internal format, and inserts it into the table. If the table has indexes, their keys are extracted and inserted into the index page.



See

Refer to "High-Speed Data Load" in the Operation Guide for details.

1.11 High availability by using Connection Manager

The Connection Manager provides the following features. You can use these features to increase system availability.

Heartbeat monitoring feature

Detects kernel panics between the server running the client and the server running the instance, physical server failures, and inter-server network link downs, and notifies the client or instance. The client is notified as an error event through the SQL connection, and the instance will be notified in the form of a force collection of SQL connections with clients that are out of service.

Transparent connection support feature

When an application wants to connect to an instance of an attribute (Primary/Standby) configured with replication, it can do so without knowing which server the instance is running on.



Information

The available client drivers for Connection Manager are libpq (C language library) and ECPG (embedded SQL in C).



See

Refer to the Connection Manager User's Guide for details.

1.12 Memory usage reduction by Global Meta Cache

The Global Meta Cache feature cache the informations about system catalogs and table definitions information (It is called a meta cache.) in shared memory. The meta cache on shared memory is called the Global Meta Cache (GMC).

Without this feature, the meta cache was cached in per-process memory. Therefore, there was a problem increase in memory usage in environments with large databases and large numbers of connections. The Global Meta Cache feature enables sharing of meta caches on shared memory, thereby reducing overall system memory usage.

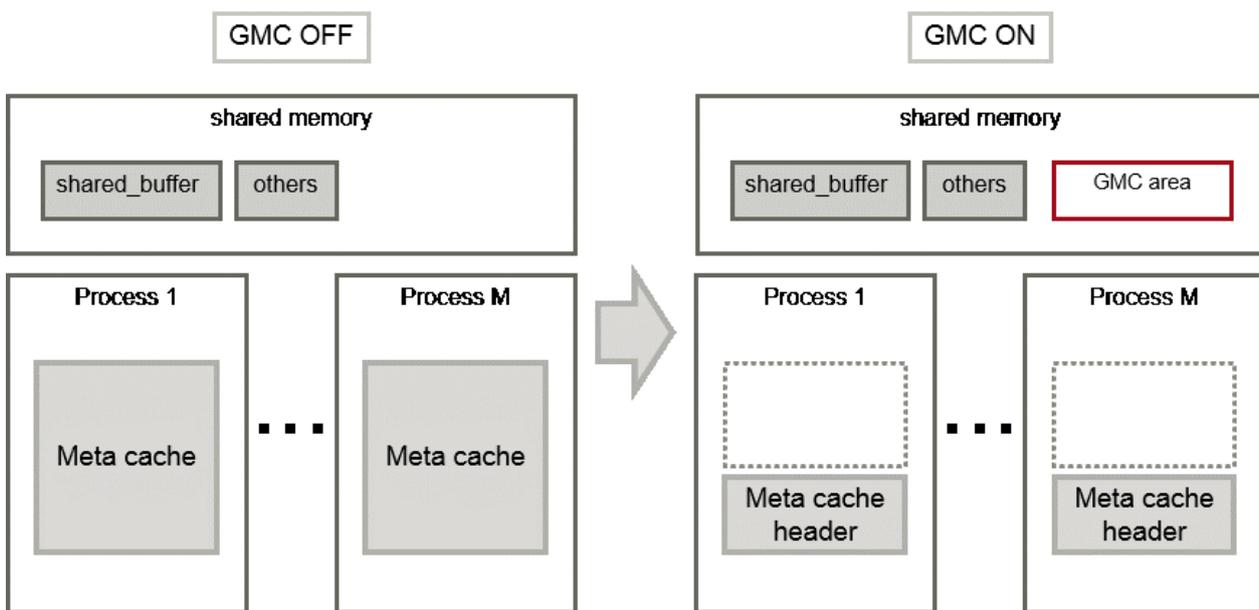
Meta cache

Processing a query involves parsing the query, creating the plan, executing the plan, and so on. PostgreSQL process accesses the system catalog to perform these steps. Once accessed, the system catalog tuples are cached in per-process memory. PostgreSQL also aggregates and caches the working information required to access tables and the system catalog information about those tables. The information cached in these memories is called a meta cache. Each process performs faster query processing by searching the meta cache instead of searching for the required tuples in the system catalog each time.

The meta cache usage increases in proportion to the number of tables and columns accessed. It is cached on a per-process basis, so the system's overall meta cache usage increases in proportion to the number of connections.

Architecture of Global Meta Cache Feature

Describes the architecture of the Global Meta Cache feature.



When the GMC feature is on, the per-process meta cache is cached in the GMC area on shared memory. Reference to the GMC area and process-specific work information is cached in the memory of each process. PostgreSQL process searches the meta cache for each process and accesses the GMC based on the reference information. If there is no reference information in the process's memory, it searches the GMC area. If the GMC area also does not have a corresponding meta cache, it accesses the system catalog to create meta cache.

Also, sharing the meta cache does not cause any loss of data consistency. If the system catalog or table definition changes while a transaction is running, the cache deletion or creation does not affect outside of the process running the transaction. After the transaction commits, the GMC area cache is deleted or created. If other transactions are referencing the cache when GMC is tried to be deleted, the deletion is deferred until there are no more references. After a commit, a new transaction sees the new cache instead of the old one.

See

Global Meta Cache feature is disabled by default. Refer to "Global Meta Cache" in the Operation Guide for information how to decide whether introduce it or not and usage.

Appendix A List of Features

The following table lists the main features provided by FUJITSU Enterprise Postgres.

Category	Feature
Fujitsu-developed software technology	WebAdmin (Rapid setup, One-click recovery)
Improved reliability and availability	Database multiplexing
	Backup/recovery using user commands
	Backup data compression
	Connection Manager
Application development	Embedded SQL integration
	Java integration
	ODBC integration
	Features compatible with Oracle databases
Security	Storage data encryption
	Data masking
	Audit log
Performance	In-memory feature
	High-speed data load
	Global Meta Cache
Performance tuning	Optimizer hints
	Fixed statistical information

Appendix B OSS Supported by FUJITSU Enterprise Postgres

The OSS supported by FUJITSU Enterprise Postgres is listed below.

OSS name	Version and level	Description	Reference
PostgreSQL	12.1	Database management system	PostgreSQL Documentation
orafce	3.8.0	Oracle-compatible SQL features	"Compatibility with Oracle Databases" in the Application Development Guide
Pgpool-II	4.1	Failover, connection pooling, load balancing, etc.	"Pgpool-II" in the Installation and Setup Guide for Server
oracle_fdw	2.2.0	Connection to the Oracle database server	"oracle_fdw" in the Installation and Setup Guide for Server
pg_statsinfo	12.0	Collection and accumulation of statistics	"pg_statsinfo" in the Installation and Setup Guide for Server
pg_hint_plan	12.1.3.5	Tuning (statistics management, query tuning)	- "pg_hint_plan" in the Installation and Setup Guide for Server - "Optimizer Hints" in the Application Development Guide
pg_dbms_stats	1.3.11		- "pg_dbms_stats" in the Installation and Setup Guide for Server - "Locked Statistics" in the Application Development Guide
pg_repack	1.4.5	Table reorganization	"pg_repack" in the Installation and Setup Guide for Server
pg_rman	1.3.9	Backup and restore management	"pg_rman" in the Installation and Setup Guide for Server
pgBadger	11.1	Log analysis	"pgBadger" in the Installation and Setup Guide for Server
pg_bigm	1.2	Full-text search (multibyte)	"pg_bigm" in the Installation and Setup Guide for Server
PostgreSQL JDBC driver	42.2.8	JDBC driver	"JDBC Driver" in the Application Development Guide
psqlODBC	12.01.0000	ODBC driver	"ODBC Driver" in the Application Development Guide

Appendix C Features that can be Used on Servers Other than the Database Server

This chapter explains the configuration and operating environment of features to be installed and used on servers other than the database server when used in conjunction with the FUJITSU Enterprise Postgres database server.

In this chapter, FUJITSU Enterprise Postgres programs are referred to as server programs.

Below are features to be installed and used on servers other than the database server:

- WebAdmin
- Server Assistant
- Pgpool-II (failover, connection pooling, and load balancing)

C.1 WebAdmin

If there is only one database server, WebAdmin is normally installed on the same server as the database (the WebAdmin program can be installed at the same time as the server program).

If there are multiple database servers, database server instances can be managed collectively if a dedicated WebAdmin server is used. In this case, the WebAdmin program is installed on the WebAdmin server, and the server program and WebAdmin program are installed on the database server.



See

- Refer to "[1.2 Simple GUI-Based Installation and Operation Management](#)" for information on WebAdmin.
- Refer to "Determining the Preferred WebAdmin Configuration" in the Installation and Setup Guide for Server for information on the server configuration when using WebAdmin.
- Refer to "Required Operating System" in the Installation and Setup Guide for Server for information on the operating environment of WebAdmin.

C.2 Server Assistant

To use the Server Assistant, the Server Assistant program is installed on a dedicated server (arbitration server).



See

- Refer to "Overview of Database Multiplexing Mode" in the Cluster Operation Guide (Database Multiplexing) for information on the Server Assistant and the server configuration.
- Refer to "Required Operating System" in the Installation and Setup Guide for Server Assistant for information on the operating environment of the Server Assistant.

C.3 Failover, Connection Pooling, and Load Balancing Features of Pgpool-II

Pgpool-II is software that is placed between the database server and database client to relay the connection.

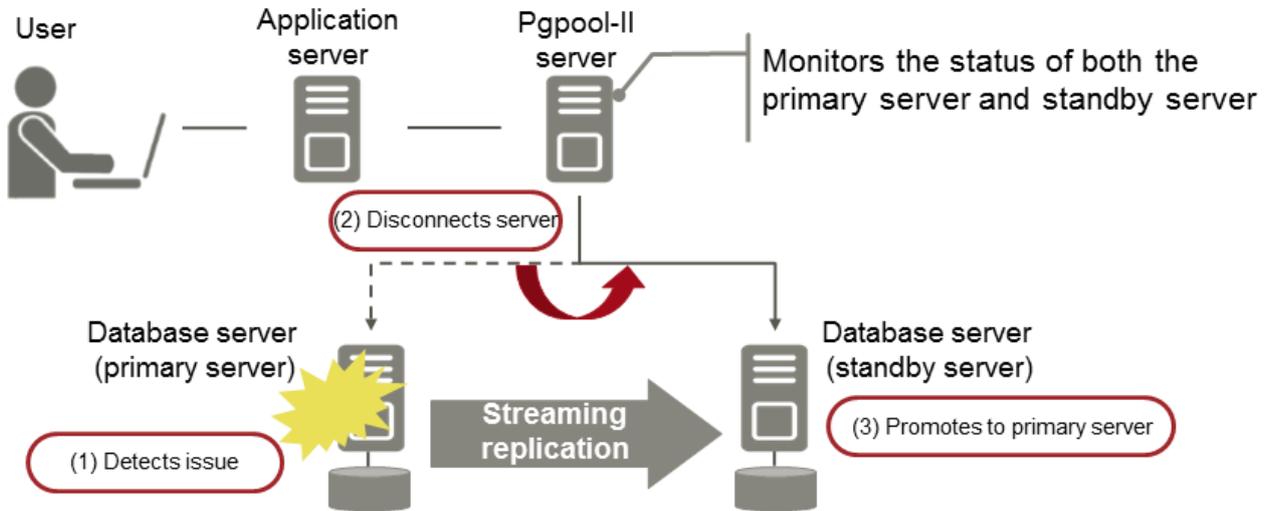
Pgpool-II provides the failover, connection pooling, and load balancing features for use during streaming replication.

Failover

In PostgreSQL, a database can be made redundant (building a high availability system) using synchronous streaming replication.

If the database server of either the primary server or standby server fails or is no longer accessible when using synchronous streaming replication, jobs will stop.

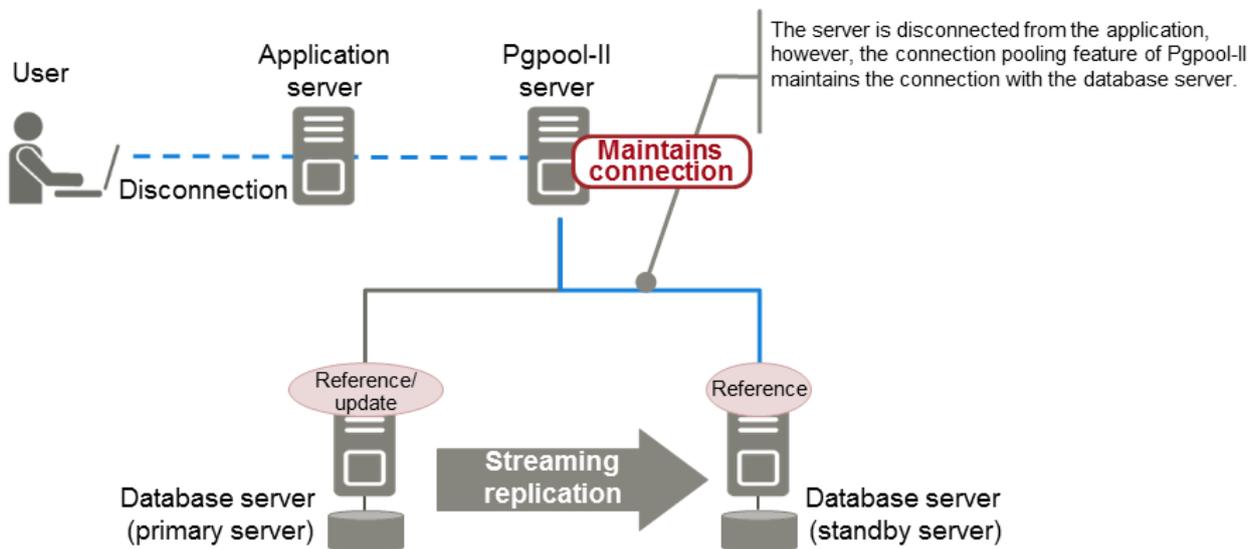
Failover monitors the status of each database and automatically disconnects the server when an error occurs. As a result, jobs can continue uninterrupted on the remaining server.



Connection pooling

This feature maintains (pools) the connection established with the database server, and reuses that connection each time a new connection with the same properties (user name, database, and protocol version) arrives.

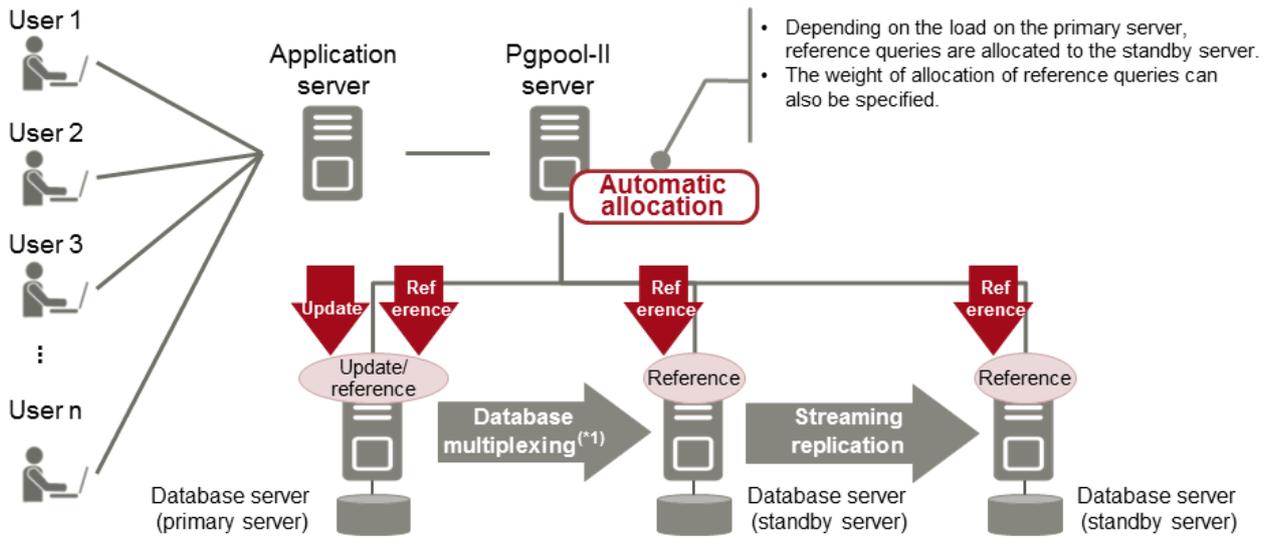
Connection pooling reduces the connection overhead for the database server, improving throughput of the whole system.



Load balancing

This feature distributes reference queries to multiple database servers, improving throughput of the whole system.

By combining load balancing with the FUJITSU Enterprise Postgres database multiplexing feature or the PostgreSQL streaming replication feature, load on the database server is reduced.



*1: The arbitration server used during database multiplexing has been omitted from this document.

See

- Refer to "System configuration when using Pgpool-II" in the Installation and Setup Guide for Server for information on the server configuration when using Pgpool-II.
- Refer to "Required Operating System" in the Installation and Setup Guide for Server for information on the operating environment of Pgpool-II.

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Release Notes

Linux

J2UL-2625-02ZLZ0(00)

February 2021

Preface

Purpose of this document

This document provides release information for FUJITSU Enterprise Postgres.

Structure of this document

This document is structured as follows:

[Chapter 1 New Features and Improvements](#)

Explains the new features and improvements in this version.

[Chapter 2 Compatibility Information](#)

Provides information regarding compatibility.

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Chapter 1 New Features and Improvements

This chapter explains FUJITSU Enterprise Postgres new features and improvements added in this version.

Table 1.1 New features and improvements

Version and level	Classification	Feature
12 SP1	Backup	Compression support for the pgx_dmpall command
12	OSS	PostgreSQL Rebase
		Update of OSS Provided
	Platform enhancement	Additional Operating System Support for Server Feature
		Additional Operating System Support for Client Feature
		Additional Operating System Support for Server Assistant Feature
	Operation	Database Multiplexing Improvements
		Connection Manager
		IBM Z Hardware Security Module Integration with Transparent Data Encryption
	Performance	Global Meta Cache
VACUUM/TRUNCATE Improvements		

1.1 Features Added in 12 SP1

This section explains new features and improvements in FUJITSU Enterprise Postgres 12 SP1.

1.1.1 Backup

This section explains the new feature related to Backup:

- [Compression support for the pgx_dmpall command](#)

1.1.1.1 Compression support for the pgx_dmpall command

The `pgx_dmpall` command supports the compression of backup data.

This can reduce the required disk space.

1.2 Features Added in 12

This section explains new features and improvements in FUJITSU Enterprise Postgres 12.

1.2.1 OSS

This section explains the new feature related to OSS:

- [PostgreSQL rebase](#)
- [Update of OSS provided](#)

1.2.1.1 PostgreSQL Rebase

The PostgreSQL version that FUJITSU Enterprise Postgres is based on is 12.1.



See

Refer to "PostgreSQL Version Used for FUJITSU Enterprise Postgres" in the Installation and Setup Guide for Server for details.

1.2.1.2 Update of OSS Provided

The OSS provided by FUJITSU Enterprise Postgres have been updated.



See

Refer to "OSS Supported by FUJITSU Enterprise Postgres" in the General Description for details.

1.2.2 Platform Enhancement

This section explains the new features related to platform enhancement:

- Additional operating system support for server
- Additional operating system support for client
- Additional operating system support for server assistant

1.2.2.1 Additional Operating System Support for Server Feature

The following additional operating system is supported:

- RHEL8



See

Refer to "Required Operating System" in the Installation and Setup Guide for Server for details.

1.2.2.2 Additional Operating System Support for Client Feature

The following additional operating system is supported:

- RHEL8



See

Refer to "Required Operating System" in the Installation and Setup Guide for Client for details.

1.2.2.3 Additional Operating System Support for Server Assistant Feature

The following additional operating system is supported:

- RHEL8



See

Refer to "Required Operating System" in the Installation and Setup Guide for Server Assistant for details.

1.2.3 Operation

This section explains the new feature related to OSS:

- Database Multiplexing Improvements
- Connection Manager
- IBM Z Hardware Security Module Integration with Transparent Data Encryption

1.2.3.1 Database Multiplexing Improvements

The database multiplexing introduces the following new features.

- Heartbeat monitoring of database processes

Monitoring retries no longer occur when a database process is detected as down.



See

Refer to "Server Configuration File for the Database Servers" in the Cluster Operation Guide (Database Multiplexing) for details.

- Faster detection time for heartbeat monitoring of the operating system or server

For database degradation using the arbitration server, if the database servers are unable to check their mutual statuses (due to a network error between database servers or server instability), then the database server queries the arbitration server for the status of the other database server.

Previously, when an arbitration server received a query, it inquired about the state of the other database server, but now the arbitration server can respond immediately to the query from the database server by periodically heartbeating the database server. Accordingly, reduced error detection time in heartbeat monitoring of the operating system or server.



See

Refer to "Tuning Abnormality Monitoring for Operations that Use an Arbitration Server for Automatic Degeneration" in the Cluster Operation Guide (Database Multiplexing) for details.

- WebAdmin Mirroring Controller integration

You can now set the heartbeat_error_action parameter to specify what happens when a heartbeat error is detected in the heartbeat monitoring of the operating system or server during Mirroring Controller setup in WebAdmin. You can also edit the settings after you set up Mirroring Controller. Accordingly, the database operation using WebAdmin becomes more flexible.



See

Refer to "Mirroring Controller Configuration" in the Cluster Operation Guide (Database Multiplexing) for details.

1.2.3.2 Connection Manager

With the Connection Manager features, replication operation can be continued without being aware of the connection destination of the applications.

The Connection Manager provides the following capabilities:

- When a client error occurs, force a reclaim of the SQL connection with the client.
- When a server error occurs, the application is notified as a SQL error.
- Applications connect to the appropriate server without being aware of the server state (Primary, Standby).



See

Refer to Connection Manager User's Guide for details.

1.2.3.3 IBM Z Hardware Security Module Integration with Transparent Data Encryption

Master encryption key management for transparent data encryption is provided by the IBM Z Hardware Security Module for added security. It eliminates the need to reserve a server for keystore and password management.



.....
Refer to "Protecting Storage Data Using Transparent Data Encryption" in the Operation Guide.
.....

1.2.4 Performance

This section explains the new feature added to improve performance:

- Global Meta Cache
- VACUUM/TRUNCATE improvements

1.2.4.1 Global Meta Cache

Before FUJITSU Enterprise Postgres 11, information about system catalogs and table definitions was cached in per-process memory. You can cache some of this information in shared memory by using the Global Meta Cache feature. This reduces overall system memory usage.



.....
Refer to "Memory usage reduction by Global Meta Cache" in the General Description for details.
.....

1.2.4.2 VACUUM/TRUNCATE Improvements

If VACUUM/TRUNCATE truncates empty pages and relation indexes at the end of a transaction, or if relations are truncated, improve processing time by doing the following:

- Reduce the number of scan loops when deleting a relation buffer
- Reduce the number of shared buffer scans

This reduces WAL apply time independent of the size of the shared buffer.

Chapter 2 Compatibility Information

This chapter explains incompatible items and actions required when migrating from an earlier version to FUJITSU Enterprise Postgres 12 SP1. Check compatibility before migrating and take the appropriate action.

2.1 Installation/Setup Incompatibility

Item	Pre-migration version	
	11	12
Removing Operating System Support	Y	Y
Changing the way OSS is set up	Y	N
Modifying Pgpool-II Installation Handling	Y	N
Changing Core and Log File Paths when Instance is Created with WebAdmin	Y	N
Renaming WebAdmin Services	Y	N

Y: Incompatibility exists

2.1.1 Removing Operating System Support

Incompatibility

In FUJITSU Enterprise Postgres 12 SP1 or later, the following operating systems have been removed.

- SLES 12 SP4

Action method

None.

2.1.2 Changing the Way OSS is Set Up

Incompatibility

FUJITSU Enterprise Postgres 12 and later do not place OSS extension modules in the executable directory. The OSS extension modules must be placed in the executable directory when you set up OSS.

Refer to "Setting Up and Removing OSS" in the Installation and Setup Guide for Server for details.

Action method

None.

2.1.3 Modifying Pgpool-II Installation Handling

Incompatibility

For FUJITSU Enterprise Postgres 12 and later, Pgpool-II is not automatically installed when you install the server. Therefore, if you want to take advantage of Pgpool-II, install it separately from the server installation.

The extension modules required for the database server are shipped with the server program. You should set up Pgpool-II on the database server side, even if Pgpool-II is to be used on a different server than the database server.

Refer to "Setting Up and Removing OSS" in the Installation and Setup Guide for Server for details.

Action method

None.

2.1.4 Changing Core and Log File Paths when Instance is Created with WebAdmin

Incompatibility

In FUJITSU Enterprise Postgres 12 and later, change the core and log file paths when creating an instance in WebAdmin.

FUJITSU Enterprise Postgres 11

Log File Path: `/var/tmp/fsep_<version>/instanceAdminUser_<instanceNamePortNumber>/log`

Core File Path: `/var/tmp/fsep_<version>/instanceAdminUser_<instanceNamePortNumber>/core`

version: product version_ edition_ architecture

[Example]

Log File Path: `/var/tmp/fsep_110_AE_64/naomi_myinst27599/log`

Core File Path: `/var/tmp/fsep_110_AE_64/naomi_myinst27599/core`

FUJITSU Enterprise Postgres 12

Log File Path: `/var/tmp/fsep_<version>/instanceAdminUser_<instanceNamePortNumber>/log`

Core File Path: `/var/tmp/fsep_<version>/instanceAdminUser_<instanceNamePortNumber>/core`

version: product version_ WA_ architecture

[Example]

Log File Path: `/var/tmp/fsep_120_WA_64/naomi_myinst27599/core`

Core File Path: `/var/tmp/fsep_120_WA_64/naomi_myinst27599/log`

Action method

None.

2.1.5 Renaming WebAdmin Services

Incompatibility

In FUJITSU Enterprise Postgres 12 and later, change the service name registered when you set up WebAdmin.

FUJITSU Enterprise Postgres 11

`fsep_xSPz_<edition>_64_WebAdmin_Port1`

`fsep_xSPz_<edition>_64_WebAdmin_Port2`

FUJITSU Enterprise Postgres 12

`fsep_xSPz_WA_64_WebAdmin_Port1`

`fsep_xSPz_WA_64_WebAdmin_Port2`

Action method

None.

2.2 Application Migration Incompatibility

Item	Pre-migration version	
	11	12
Changed to Error when Running an Operator or Function that Returns non Data Types for Masking Type	Y	N

Y: Incompatibility exists

2.2.1 Changed to Error when Running an Operator or Function that Returns non Data Types for Masking Type

Incompatibility

In FUJITSU Enterprise Postgres 12, changed to error when running an operator or function that returns non Data Types for Masking type.

FUJITSU Enterprise Postgres 11

In the following cases, the operator or function in 3) may be executed without masking.

This is an incorrect result because the data containing the masking column is performed without masking.

- 1) Create a Masking policy. and
- 2) Execute a SELECT statement. and
- 3) Execute an operator or function in the SELECT statement of 2). and
- 4) The operator or function argument of 3) includes a subquery. and
- 5) The operator or function argument of 3) contains the column to be protected created in 1). and
- 6) The operator or function of 3) returns a type not listed in "Data Types for Masking" in "Operation Guide".

FUJITSU Enterprise Postgres 12 or later

Operator or function results of 3) in the following error.

```
ERROR: The output data type is incompatible with the confidential policy.  
HINT: Data type of the result value(s) produced by expression/function using confidential columns  
is not supported by Data masking module. Consider removing confidential columns from such  
expressions/functions.
```

This is correct because the operator or function returns a data type not listed in "Data Types for Masking" in "Operation Guide".

Action method

Do one of the following to ensure that the results are identical to those of FUJITSU Enterprise Postgres 11:

- 1) Modify the Masking policy to prevent masking from being performed for the user executing the SQL.
- 2) Modify SQL to not use operators or functions that return types not listed in "Data Types for Masking" in "Operation Guide".

2.3 Operation Migration Incompatibility

Item	Pre-migration version	
	11	12
Mirroring Controller no longer retries to monitor database processes when they are detected as down	Y	N
Changing the Name and Parameter Name of the Mirroring Controller Post-Promote Command	Y	N
Changing Mirroring Controller User Command Input Values	Y	N

Y: Incompatibility exists

2.3.1 Mirroring Controller no Longer Retries to Monitor Database Processes when they are Detected as Down

Incompatibility

For the FUJITSU Enterprise Postgres Mirroring Controller, change the heartbeat monitoring of the database process so that it does not retry monitoring when it detects down.

Action method

None.

2.3.2 Changing the Name and Parameter Name of the Mirroring Controller Post-Promote Command

Incompatibility

In the FUJITSU Enterprise Postgres 12 Mirroring Controller, change the name of the post-promote command, which is the state transition command, and the parameter name in the server configuration file that specifies the post-promote command.

FUJITSU Enterprise Postgres 11

- Command Name
post-promote command
- The parameter name in the server configuration file that specifies the post-promote command
post_promote_command

FUJITSU Enterprise Postgres 12 or later

- Command Name
post-switch command
- The parameter name in the server configuration file that specifies the post-promote command
post_switch_command

Action method

The `post_promote_command` parameter in the server configuration file continues to be available in FUJITSU Enterprise Postgres 12 and later. If specified in the server configuration file, it acts as a post-switch command. You cannot specify the `post_promote_command` and `post_switch_command` parameters at the same time.

2.3.3 Changing Mirroring Controller User Command Input Values

Incompatibility

Arguments (Fixed value: `primarycenter`) have been added to the following user commands:

- Fencing command of the database server
- Arbitration command
- Post-switch command
- Pre-detach command
- Post-attach command

Action method

If you are checking the number of arguments in a user command, increase the number of arguments by one.

2.4 oracle_fdw Incompatibility

Item	Pre-migration version	
	11	12
Changing the Oracle Client Version	Y	N

Y: Incompatibility exists

2.4.1 Changing the Oracle Client Version

Incompatibility

FUJITSU Enterprise Postgres 12 change the version of the Oracle client used to build oracle_fdw to 11.2.

Action method

Use Oracle client version 11.2 or later.

Also, if a file named libclntsh.so.11.1 does not exist in OCI library, create a symbolic link named libclntsh.so.11.1.

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Installation and Setup Guide for Server

Preface

Purpose of this document

The FUJITSU Enterprise Postgres database system extends the PostgreSQL features and runs on the Linux platform. This document describes how to install and set up "FUJITSU Enterprise Postgres".

Intended readers

This document is intended for those who install and operate FUJITSU Enterprise Postgres. Readers of this document are assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of Installation](#)

Describes the installation types and procedures

[Chapter 2 Operating Environment](#)

Describes the operating environment required to use FUJITSU Enterprise Postgres

[Chapter 3 Installation](#)

Describes how to perform a new installation of FUJITSU Enterprise Postgres

[Chapter 4 Setup](#)

Describes the setup to be performed after installation

[Chapter 5 Uninstallation](#)

Describes how to uninstall FUJITSU Enterprise Postgres

[Appendix A Recommended WebAdmin Environments](#)

Describes the recommended WebAdmin environment.

[Appendix B Setting Up and Removing WebAdmin](#)

Describes how to set up and remove WebAdmin

[Appendix C WebAdmin Disallow User Inputs Containing Hazardous Characters](#)

Describes characters that are not allowed in WebAdmin.

[Appendix D Configuring Parameters](#)

Describes FUJITSU Enterprise Postgres parameters.

[Appendix E Estimating Database Disk Space Requirements](#)

Describes how to estimate database disk space requirements

[Appendix F Estimating Memory Requirements](#)

Describes the formulas for estimating memory requirements

[Appendix G Quantitative Limits](#)

Describes the quantity range

[Appendix H Configuring Kernel Parameters](#)

Describes the settings for kernel parameters

[Appendix I Determining the Preferred WebAdmin Configuration](#)

Describes the two different configurations in which WebAdmin can be used and how to select the most suitable configuration

[Appendix J System Configuration when using Pgpool-II](#)

Describes the system configuration when using Pgpool-II.

[Appendix K Supported contrib Modules and Extensions Provided by External Projects](#)

Lists the PostgreSQL contrib modules and the extensions provided by external projects supported by FUJITSU Enterprise Postgres.

[Appendix L Procedure when Modifying the JRE Installation](#)

Describes the procedures to follow when modifying the JRE installation.

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Chapter 1 Overview of Installation

This chapter provides an overview of FUJITSU Enterprise Postgres installation.

1.1 Features that can be Installed

Each FUJITSU Enterprise Postgres feature is installed on the machine that was used to build the database environment.

The basic features of FUJITSU Enterprise Postgres (server feature, client feature) can be installed.

1.2 Installation Types

The following installation types are available for FUJITSU Enterprise Postgres:

- New installation
- Reinstallation
- Multi-version installation

1.2.1 New Installation

In initial installation, FUJITSU Enterprise Postgres is installed for the first time.

1.2.2 Reinstallation

Perform reinstallation to repair installed program files that have become unusable for any reason.

1.2.3 Multi-Version Installation

FUJITSU Enterprise Postgres products can be installed on the same server if the product version (indicated by "x" in "x SPz") is different from that of any version of the product that is already installed.

1.3 Uninstallation

Uninstallation removes the system files of the installed FUJITSU Enterprise Postgres.

Chapter 2 Operating Environment

This chapter describes the operating environment required to use FUJITSU Enterprise Postgres.



See

Refer to "Operating Environment" in the Installation and Setup Guide for Client when installing the FUJITSU Enterprise Postgres client feature at the same time.

2.1 Required Operating System

One of the operating systems shown below is required in order to use FUJITSU Enterprise Postgres. Check and use minor version, which is certified and currently supported by Red Hat or SUSE for the target IBM z / Linux One hardware.

- RHEL7.7 or later minor version
- RHEL8.1 or later minor version
- SLES 12 SP5



Note

The sepgsql module, which is a PostgreSQL extension, can be used in RHEL7 and RHEL8.



Information

- The following packages are required for operations on RHEL7.

Package name	Remarks
alsa-lib	-
audit-libs	-
dstat	Required when using parallel scan.
glibc	-
libgcc	-
libc	Provides collation support. Install 50.x.
libmemcached	Required when using Pgpool-II.
libstdc++	-
libtool-ltdl	Required when using ODBC drivers.
llvm	Required when using the JIT compiler. It is recommended to use "llvm-toolset-7.0" published on the Red Hat Software Collections. Install 7.0.x. FUJITSU Enterprise Postgres 12 uses runtime compilation by default. If you do not want to use runtime compilation, turn off the jit parameter in postgresql.conf. You do not need to install llvm if you turn off the jit parameter.

Package name	Remarks
	Failure to install llvm without turning off the jit parameter may result in an error when executing SQL. For more information about runtime compilation, see "Just-in-Time Compilation (JIT)" in the PostgreSQL Documentation.
ncurses-libs	-
net-tools	-
nss-softokn-freebl	-
opencryptoki	Required if transparent data encryption is used in conjunction with a hardware security module. Install 3.12.1 or later into default directory.
pam	Required when using PAM authentication.
perl-libs	Required when using PL/Perl. Install 5.16.
python3	Required when using PL/Python based on Python 3. Install 3.7.x.
libseltlinux	Required for sepgsql.
tcl	Required when using PL/Tcl. Install 8.5.
xz-libs	-
zlib	
java-1.8.0-openjdk	Required when using the database multiplexing and WebAdmin. Use build 1.8.0_212-b04 or later for s390x architecture.

- The following packages are required for operations on RHEL8.

Package name	Remarks
alsa-lib	-
audit-libs	-
cyrus-sasl-lib	-
pcp-system-tools	Required when using parallel scan.
glibc	-
libnsl	-
libcicu	Provides collation support. Install 60.x.
libgcc	-
libmemcached	Required when using Pgpool-II.
libstdc++	-
libtool-ldtl	Required when using ODBC drivers.
llvm	Version 8.0.x of llvm is required to run SQL with runtime compilation (just-in-time compilation). Install the "llvm-libs" exposed by Application Streams. FUJITSU Enterprise Postgres 12 uses runtime compilation by default. If you do not want to use runtime compilation, turn off the jit parameter in postgresql.conf. You do not need to install llvm if you turn off the jit parameter.

Package name	Remarks
	<p>Failure to install llvm without turning off the jit parameter may result in an error when executing SQL. For more information about runtime compilation, see "Just-in-Time Compilation (JIT)" in the PostgreSQL Documentation.</p> <p>Note:</p> <p>If JIT compilation using LLVM is performed on RHEL8, a verbose server message is logged one or more times on first query execution, for each associated database connection.</p> <p><Message></p> <p>ORC error: No callback manager available for s390x-ibm-linux</p> <p>This error message results from a known deficiency in one of the features of the LLVM library for IBM Z, but this feature is not used by the server and the error does not otherwise affect LLVM operation.</p> <p>To prevent this message from being logged, JIT compilation may be disabled, by setting the value "off" to the configuration variable "jit".</p>
ncurses-libs	-
net-tools	-
nss-softokn-freebl	-
opencryptoki	<p>Required if transparent data encryption is used in conjunction with a hardware security module.</p> <p>Install 3.12.1 or later into default directory.</p>
pam	Required when using PAM authentication.
perl-libs	<p>Required when using PL/Perl.</p> <p>Install 5.26.</p>
python3	<p>Required when using PL/Python based on Python 3.</p> <p>Install 3.7.x.</p>
redhat-lsb	-
libselinux	Required for sepysql.
tcl	<p>Required when using PL/Tcl.</p> <p>Install 8.6.</p>
unzip	-
xz-libs	-
zlib	-
java-1.8.0-openjdk	<p>Required when using the database multiplexing and WebAdmin.</p> <p>Use build 1.8.0_222-b10 or later for s390x architecture.</p>

- The following packages are required for operations on SLES 12.

Package name	Remarks
alsa-lib	-
audit-libs	-
dstat	Required when using parallel scan.
glibc	-

Package name	Remarks
libgcc	-
libcicu	Provides collation support. Install 52.
libmemcached	Required when using Pgpool-II.
libstdc++	-
libtool-ltdl	Required when using ODBC drivers.
llvm	Install version 7.0.x of llvm to run SQL with runtime compilation (just-in-time compilation) and add the directory where the shared library libLLVM-*.so is located to the environment variable LD_LIBRARY_PATH. FUJITSU Enterprise Postgres 12 uses runtime compilation by default. If you do not want to use runtime compilation, turn off the jit parameter in postgresql.conf. You do not need to install llvm if you turn off the jit parameter. Failure to install llvm without turning off the jit parameter may result in an error when executing SQL. For more information about runtime compilation, see "Just-in-Time Compilation (JIT)" in the PostgreSQL Documentation.
LLVM-libs	Install version 7.0.x
ncurses-libs	-
net-tools	-
nss-softokn-freebl	-
opencryptoki	Required if transparent data encryption is used in conjunction with a hardware security module. Install 3.10 or later into default directory.
pam	Required when using PAM authentication.
perl-libs	Required when using PL/Perl. Install 5.18.
python3	Required when using PL/Python based on Python 3. Install 3.7.x.
sysstat	Required when using pgx_fjqssinf command. Set up the sar command after installation.
tcl	Required when using PL/Tcl. Install 8.6.
xz-libs	-
zlib	-
java-1.8.0-openjdk	Required when using the database multiplexing and WebAdmin. Use build 1.8.0_181-b13 or later for s390x architecture.

2.2 Related Software

There is no exclusive Software.

The following table lists servers that can be connected to the Linux client.

Table 2.1 Connectable servers

OS	Product name
Linux	FUJITSU Software Enterprise Postgres Advanced Edition 11 or later

2.3 Excluded Software

There are no exclusive products.

2.4 Required Patches

There are no required patches.

2.5 Hardware Environment

The following hardware is required to use FUJITSU Enterprise Postgres.

Memory

At least 512 MB of memory is required.

Hardware security module

If transparent data encryption is used in conjunction with a hardware security module, the IBM Z Crypto Express Adapter Card must support either the CCA coprocessor or the EP11 coprocessor.



Note

In z/VM, the virtual cryptographic devices which are available to transparent data encryption must be only dedicated("APDED").

2.6 Disk Space Required for Installation

The following table shows the disk space requirements for new installation of FUJITSU Enterprise Postgres. If necessary, increase the size of the file system.

Table 2.2 Disk space required for installation

Directory	Required disk space (Unit: MB)
/etc	1
Installation destination of the server	168
Installation destination of WebAdmin	176
Installation destination of the client	106
Installation destination of PgPool	4

2.7 Supported System Environment

This section describes the supported system environment.

2.7.1 TCP/IP Protocol

FUJITSU Enterprise Postgres supports version 4 and 6 (IPv4 and IPv6) of TCP/IP protocols.



Do not use link-local addresses if TCP/IP protocol version 6 addresses are used.

2.7.2 File System

All file systems with a POSIX-compliant interface are supported.

However, for stable system operation, the disk where the database is deployed must use a highly reliable file system. Consider this aspect when selecting the file system to be used.

The recommended file system is "ext4".

2.8 PostgreSQL Version Used for FUJITSU Enterprise Postgres

FUJITSU Enterprise Postgres is based on PostgreSQL 12.1.

2.9 Notes on Using Streaming Replication

To use streaming replication, build the primary server and all standby servers using the same FUJITSU Enterprise Postgres version (*1).

*1: The product version is indicated by "x" in the notation "x SPz".



Streaming replication cannot be used in combination with Open Source PostgreSQL. It should also be used between instances running on same architecture (i.e. an instance running on Intel64 should not be used to stream instance running on s390x)

Chapter 3 Installation

This chapter explains each of the installation procedures of FUJITSU Enterprise Postgres.

3.1 Pre-installation Tasks

Check the system environment below before installing FUJITSU Enterprise Postgres.

Check the disk space

Ensure that there is sufficient disk space to install FUJITSU Enterprise Postgres.

Refer to "[2.6 Disk Space Required for Installation](#)" for information on the required disk space.

Reconfigure the disk partition if disk space is insufficient.

Set JAVA_HOME

Ensure that Open JRE 8 is installed, and export the JAVA_HOME environment variable.

```
#export JAVA_HOME="OpenJre8InstallDir"
```

Refer to "[Appendix L Procedure when Modifying the JRE Installation](#)" for information on modifying JRE after installation.

Determine the preferred WebAdmin configuration

WebAdmin can be installed in two configurations:

- Single-server
- Multiserver



See

Refer to "[Appendix I Determining the Preferred WebAdmin Configuration](#)" for details.

Determining the Pgpool-II System Configuration

The system configuration when using Pgpool-II is as follows:

- Place on database server
- Place on application server
- Place on dedicated server



See

Refer to "[Appendix J System Configuration when using Pgpool-II](#)".

3.2 Run Installation

Install according to the following procedure:



Note

- The following characters can be used as input values:
Alphanumeric characters, hyphens, commas and forward slashes

- information is stored:

```
webAdminInstallFolder/data/fepwa
```

Follow the procedure below to perform the backup.

1. Stop the WebAdmin server. Refer to "[B.1.3 Stopping the Web Server Feature of WebAdmin](#)" for details.
2. Back up the following folder:

```
webAdminInstallFolder/data/fepwa
```

Replace the above folder with the backed up folder when the reinstallation is complete.

1. Stop applications and programs

If the installation method is the following, all applications and programs that use the product must be stopped:

- Reinstallation

Before starting the installation, stop the following:

- Applications that use the product
- Instance
- Web server feature of WebAdmin

Execute the WebAdminStop command to stop the Web server feature of WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin
# ./WebAdminStop
```

- Mirroring Controller

Execute the mc_ctl command with the stop mode option specified and stop the Mirroring Controller.

Example

```
$ mc_ctl stop -M /mdir/inst1
```

- pgBadger
- Pgpool-II

2. Change to the superuser

Run the following command to switch to the superuser on the system.

```
$ su -
Password:*****
```

3. Mount the DVD drive

Insert the server program DVD into the DVD drive, and run the command given below.

Example

```
# mount -t iso9660 -r -o loop /dev/dvd /media/dvd
```

Here /dev/dvd is the device name for the DVD drive (which may vary depending on your environment), and /media/dvd is the mount point (which may need to be created before calling the command).



If the DVD was mounted automatically using the automatic mount daemon (autofs), "noexec" is set as the mount option, so the installer may fail to start. In this case, use the mount command to remount the DVD correctly, and then run the installation. Note that the mount options of a mounted DVD can be checked by executing the mount command without any arguments.

4. Run the installation

Select and install the following packages (rpm) with the rpm command.

Feature Name	Operating System	Package (Path)
Server	RHEL7	SERVER/Linux/packages/r70s390x/FJSVfsep-SV-*.rpm
	RHEL8	SERVER/Linux/packages/r80s390x/FJSVfsep-SV-*.rpm
	SLES 12	SERVER/Linux/packages/SUSE12s390x/FJSVfsep-SV-*.rpm
WebAdmin	RHEL7	WEBADMIN/Linux/packages/r70s390x/FJSVfsep-WAD-*.rpm
	RHEL8	WEBADMIN/Linux/packages/r80s390x/FJSVfsep-WAD-*.rpm
	SLES 12	WEBADMIN/Linux/packages/SUSE12s390x/FJSVfsep-WAD-*.rpm
Client	RHEL7	CLIENT64/Linux/packages/r70s390x/FJSVfsep-CL-*.rpm
	RHEL8	CLIENT64/Linux/packages/r80s390x/FJSVfsep-CL-*.rpm
	SLES 12	CLIENT64/Linux/packages/SUSE12s390x/FJSVfsep-CL-*.rpm
Pgpool-II	RHEL7	PGPOOL2/Linux/packages/r70s390x/FJSVfsep-POOL2-*.rpm
	RHEL8	PGPOOL2/Linux/packages/r80s390x/FJSVfsep-POOL2-*.rpm
	SLES 12	PGPOOL2/Linux/packages/SUSE12s390x/FJSVfsep-POOL2-*.rpm

*is the version, OS, etc.

Example

In the following example, /media/dvd is the name of the mount point where the DVD is mounted.

Below is an example of new installation on RHEL7.

```
# cd /media/dvd/SERVER/Linux/packages/r70s390x
# rpm -ivh FJSVfsep-SV-12-1201-0.e17.s390x.rpm
```

Below is an example of new installation on RHEL8.

```
# cd /media/dvd/SERVER/Linux/packages/r80s390x
# rpm -ivh FJSVfsep-SV-12-1201-0.e18.s390x.rpm
```

Below is an example of new installation on SLES 12.

```
# cd /media/dvd/SERVER/Linux/packages/SUSE12s390x
# rpm -ivh FJSVfsep-SV-12-1201-0.s390x.rpm
```

Below is an example of reinstallation on RHEL7.

```
# cd /media/dvd/SERVER/Linux/packages/r70s390x
# rpm -ivh --replacepks FJSVfsep-SV-12-1201-0.e17.s390x.rpm
```

Below is an example of reinstallation on RHEL8.

```
# cd /media/dvd/SERVER/Linux/packages/r80s390x
# rpm -ivh --replacepkgs FJSVfsep-SV-12-1201-0.el8.s390x.rpm
```

Below is an example of reinstallation on SLES 12.

```
# cd /media/dvd/SERVER/Linux/packages/SUSE12s390x
# rpm -ivh --replacepkgs FJSVfsep-SV-12-1201-0.s390x.rpm
```



If you perform reinstallation, and an installation prefix (in the `--prefix` option of the `rpm` command) was used for the new installation, you must use the same prefix.

5. Setting Up WebAdmin

When using WebAdmin, use the `WebAdminSetup` command to set up WebAdmin. Refer to "[B.1 Setting Up WebAdmin](#)" for information on the WebAdmin setup procedure.

6. Set the installation environment to be used by Mirroring Controller

When using Database Multiplexing, use the `mc_update_jre_env` command to set the installation environment to be used by Mirroring Controller.

Example

```
# export JAVA_HOME="OpenJRE8InstallDir"
# /opt/fsepv<x>server64/bin/mc_update_jre_env
```

Chapter 4 Setup

This chapter describes the setup procedures to be performed after installation completes.

4.1 Operating Method Types and Selection

This section describes how to operate FUJITSU Enterprise Postgres.

There are two methods of managing FUJITSU Enterprise Postgres operations - select one that suits your purposes:

The Operation Guide describes the operating method using WebAdmin, and the equivalent operating method using the server commands.

Simple operation management using a web-based GUI tool (WebAdmin)

Suitable when using frequently used basic settings and operations for operation management.

This method allows you to perform simple daily tasks such as starting the system before beginning business, and stopping the system when business is over, using an intuitive operation.

Usage method

Usage is started by using WebAdmin to create the instance.

By using an external scheduler and the `pgx_dmpall` command, periodic backups can be performed, which can then be used in recovery using WebAdmin.



Do not use a server command other than `pgx_dmpall` and `pgx_keystore` or a server application. Operation modes that use server commands and server applications cannot be used in conjunction with WebAdmin. If used, WebAdmin will not be able to manage the instances correctly.

In addition, to perform a backup by copy command from the `pgx_dmpall` command, select the operating method using the server commands.

To compress the backup in WebAdmin operations, use the `pgx_dmpall` command.

Refer to Reference and the PostgreSQL Documentation for information on server commands and server applications.

Advanced operation management using server commands

An overview of the operating method using the GUI, and its relationship with the operating method using the server commands, are shown below.

Refer to the Operation Guide for details.

Operation		Operation with the GUI	Operation with commands
Setup	Creating an instance	WebAdmin is used. The server machine capacity, and the optimum parameter for operations using WebAdmin, are set automatically.	The configuration file is edited directly using the <code>initdb</code> command.
	Creating a standby instance	WebAdmin is used. WebAdmin performs a base backup of the source instance and creates a standby instance.	A standby instance is created using the <code>pg_basebackup</code> command.
	Changing the configuration files	WebAdmin is used.	The configuration file is edited directly.
Starting and stopping an instance		WebAdmin is used.	The <code>pg_ctl</code> command is used.

Operation		Operation with the GUI	Operation with commands
Creating a database		None.	This is defined using the psql command or the application after specifying the DDL statement.
Backing up the database		WebAdmin, or the pgx_dmpall command, is used.	It is recommended that the pgx_dmpall command be used. Recovery to the latest database can be performed.
Database recovery		WebAdmin is used.	To use the backup that was performed using the pgx_dmpall command, the pgx_rcvall command is used.
Monitoring	Database errors	The status in the WebAdmin window can be checked.	The messages that are output to the database server log are monitored.
	Disk space	The status in the WebAdmin window can be checked. A warning will be displayed if the free space falls below 20%.	This is monitored using the df command of the operating system, for example.
	Connection status	None.	This can be checked referencing pg_stat_activity of the standard statistics view from psql or the application.



See

Refer to "Periodic Operations" and "Actions when an Error Occurs" in the Operation Guide for information on monitoring and database recovery.

4.2 Preparations for Setup

This section describes the preparation required before setting up FUJITSU Enterprise Postgres.

4.2.1 Creating an Instance Administrator

Decide which OS user account will be assigned the instance administrator role. You can assign it to a new user or to an existing one, but you cannot assign it to the OS superuser (root).

The following example shows an OS user account with the name "fsepuser" being assigned the instance administrator role.

Example

```
# useradd fsepuser
# passwd fsepuser
```



Note

The following note applies if using WebAdmin for operations:

- If the password is changed for the user account of the instance administrator, set the changed password using ALTER ROLE WITH ENCRYPTED PASSWORD. This will encrypt the password with the default MD5 algorithm. To encrypt the password with the SCRAM-SHA-256 algorithm, set the password encryption parameter to "scram-sha-256" using SET password_encryption = 'scram-sha-256' prior to using the ALTER ROLE function.

The following note applies if using Transparent data Encryption in Hardware-based Keystores:

- OS user account who is assigned the instance administrator role must belong to the 'pkcs11' group since FUJITSU Enterprise Postgres runs as Cryptoki application in order to work in conjunction with the IBM Z Hardware Security Module.
When using WebAdmin, OS user account who logs in to WebAdmin must belong to the 'pkcs11' group as effective group.
-

4.2.2 Preparing Directories for Resource Deployment

Prepare the directories required when creating instances.

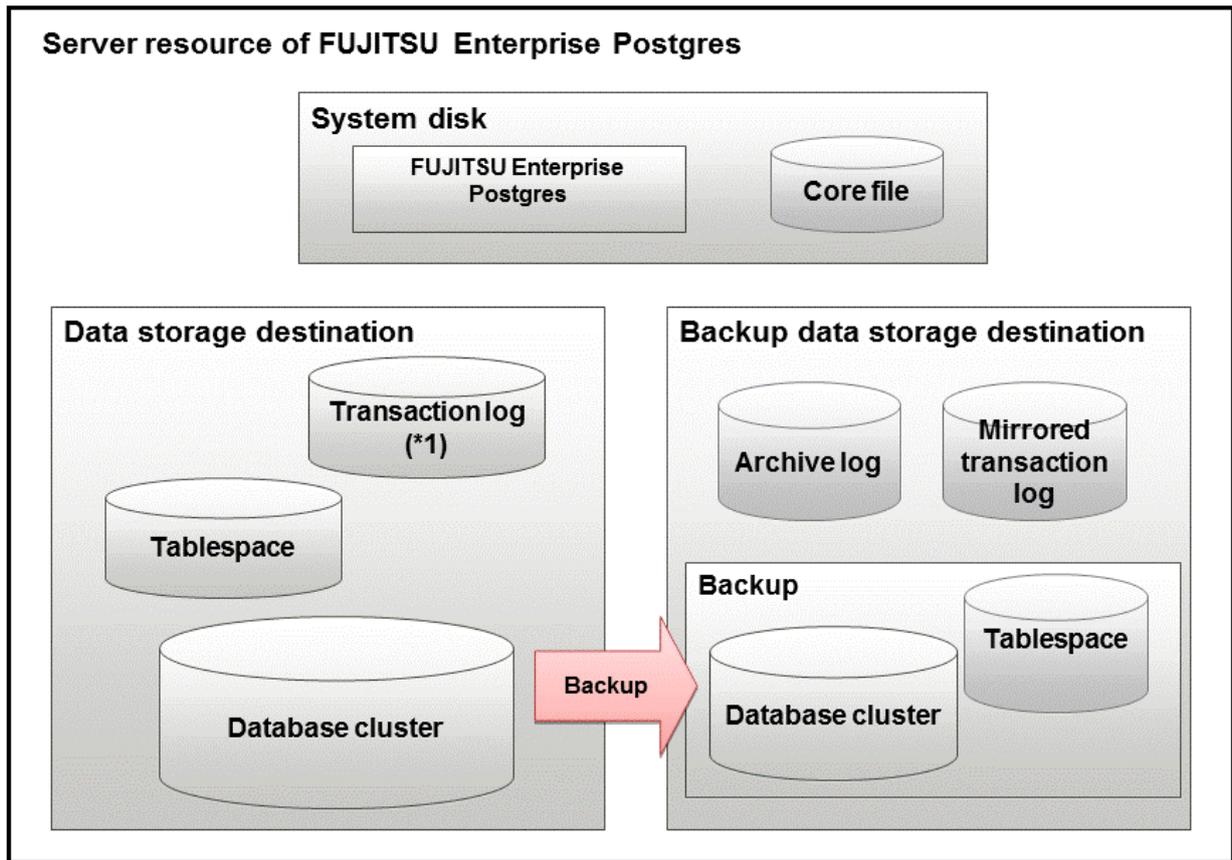
Considerations when deploying resources

The disk configuration on the resource deployment destination is important, because it affects not only recovery following disk corruption, but normal operation as well. The points for determining the disk configuration are as follows:

1. If the backup data storage destination and the data storage destination are both lost, it will not be possible to recover the data, so deploy them to separate disks.
2. To shorten the recovery time following a single disk fault, deploy the system disk and data storage destination to separate disks.
3. The backup data storage destination requires at least double the capacity of the data storage destination, so deploy it to the disk with the most space available.
4. When large amounts of data are updated, the write-to load for the data storage destination, transaction log storage destination, and backup data storage destination (mirrored transaction log) will also be great. For this reason, deploy them to separate disks, out of consideration for performance.



When using the volume manager provided by the operating system, be aware of which physical disk the file system has been created on, for example, by deploying the data storage destination and the backup data storage destination to separate disks.



*1: To distribute the I/O load, place the transaction log on a different disk from the data storage destination.

Resource	Role
Database cluster	The area where the database is stored. It is a collection of databases managed by an instance.
Tablespace	Stores table files and index files in a separate area from the database cluster. Specify a space other than that under the database cluster.
Transaction log	Stores log information in preparation for a crash recovery or rollback. This is the same as the WAL (Write Ahead Log).
Archive log	Stores log information for recovery
Mirrored transaction log (mirrored WAL)	Enables a database cluster to be restored to the state immediately before an error even if both the database cluster and transaction log fail when performing backup/recovery operations using the <code>pgx_dmpall</code> command or WebAdmin.
Corefile	FUJITSU Enterprise Postgres process corefile output when an error occurs with a FUJITSU Enterprise Postgres process.

Examples of disk deployment

The following are examples of disk deployment:

Number of disks	Disk	Deployment
3	System disk	FUJITSU Enterprise Postgres program
		Corefile

Number of disks	Disk	Deployment
	Connected physical disk	Data storage destination, transaction log storage destination
	Connected physical disk	Backup data storage destination
2	System disk	FUJITSU Enterprise Postgres program
		Corefile
		Data storage destination, transaction log storage destination
	Connected physical disk	Backup data storage destination

Proposal for disk deployment using WebAdmin

To generate an instance using WebAdmin, we recommend an optimum deployment that takes into account the status of all disks at the time of instance generation, and items 1 to 3 in the "Considerations when deploying resources" subheading above, based on the limitations below (note that a different deployment can also be specified).

- The mount point does not include national characters
- The instance administrator has the proper permissions to read and write on the mount point

Preparing directories

The directories to be prepared depend on the way that you create the instances.

The following shows the directories that need to be prepared:

Directory to be prepared	Using WebAdmin	Using the initdb command
Data storage destination	Y (*1)	Y
Backup data storage destination	O (*1) (*4)	O
Transaction log storage destination	O (*1) (*2)	O
Corefile output destination	N (*3)	O

Y: Required

O: Optional

N: Not required

*1: WebAdmin automatically creates a directory

*2: The default is to create in a directory in the data storage destination. When it is necessary to distribute the I/O load for the database data and the transaction log, consider putting the transaction log storage destination on a different disk from the data storage destination

*3: The corefile path is as follows:

```
/var/tmp/fsep_version/instanceAdminUser_instanceNamePortNumber/core
```

version: product version_WA_architecture

instanceAdminUser: operating system user name

PortNumber: port number specified when creating the instance

Example:

```
/var/tmp/fsep_120_WA_64/naomi_myinst27599/core
```

Note that resources placed in /var/tmp that have not been accessed for 30 days or more will be deleted by the default settings of the operating system. Consider excluding them from deletion targets or changing the output destination in the operating system settings.

To change the output destination, configure the core_directory and the core_contents parameters in postgresql.conf. Refer to "Parameters" in the Operation Guide for information on the settings for these parameters.

*4: This directory is required when instance backup is enabled.



- The directories must meet the following conditions:
 - The directory owner must be the OS user account that you want to be the instance administrator
 - The directory must have write permission
 - The directory must be empty
- It is not possible to use a directory mounted by NFS (Network File System) when using WebAdmin.

Example

The following example shows the OS superuser creating /database/inst1 as the directory for storing the database data and changing the owner of the directory to the OS user account "fsepuser".

```
# mkdir -p /database/inst1
# chown -R fsepuser:fsepuser /database/inst1
# chmod 700 /database/inst1
```

4.2.3 Estimating Resources

Estimate the resources to be used on the FUJITSU Enterprise Postgres.

Refer to "[Appendix E Estimating Database Disk Space Requirements](#)" for information on estimating database disk space requirements.

Refer to "[Parameters automatically set by WebAdmin according to the amount of memory](#)" when creating multiple instances with WebAdmin.

Refer to "[Appendix F Estimating Memory Requirements](#)" when creating instances with the initdb command, to estimate memory usage.

4.2.4 Configuring Corefile Names

If a process crashes, a corefile for the process will be generated by the operating system. If a corefile is generated with the same name as an existing corefile generated for a different process, the newly-generated corefile will overwrite the previously dumped corefile. To prevent this, configure a unique corefile name for each crash by appending the process ID, program name, and datetime.

Corefile names can be configured using the "kernel.core_pattern" and "kernel.core_uses_pid" kernel parameters.

Refer to the "man page" in "core(5)" for information on how to use these parameters.

Note that with regard to the location for storing corefiles, the operating system settings take precedence over the core_directory parameter of postgresql.conf.

If you specify systemd-coredump as the core_pattern, the core file is not placed in the location specified by the core_directory parameter. See the systemd-coredump (8) man page for the location of core files.

Use coredumpctl to retrieve core files. For more information about using coredumpctl, see the coredumpctl (1) man page.

4.3 Creating Instances

There are two methods that can be used to create an instance:

- [4.3.1 Using WebAdmin](#)
- [4.3.2 Using the initdb Command](#)

Creating multiple instances

Multiple instances can be created.

The memory allocated needs to be adjusted when multiple instances are created with WebAdmin (refer to "[Parameters automatically set by WebAdmin according to the amount of memory](#)" for details).

Features that cannot be set up using WebAdmin

The "Storage data protection using transparent data encryption" feature cannot be set up using WebAdmin.

To set up this feature in an instance created by WebAdmin, perform the additional setup tasks detailed in "Storage Data Protection using Transparent Data Encryption" in the Operation Guide.

Note

- Instances created using the `initdb` command (command line instances) can be managed using WebAdmin, however, they must first be imported into WebAdmin. Refer to "[4.3.1.4 Importing Instances](#)" for details.
- Always use WebAdmin to delete instances that were created or imported using WebAdmin. Because WebAdmin management information cannot be deleted, WebAdmin will determine that the instance is abnormal.
- Databases with the names 'template0' and 'template1' are automatically created when an instance is created. These databases are used as the templates for databases created later. Furthermore, a default database with the name 'postgres' is automatically created, which will be used with FUJITSU Enterprise Postgres commands. It is important that you do not delete these databases created by default.

4.3.1 Using WebAdmin

This section describes how to create an instance using WebAdmin.

WebAdmin must be set up correctly before it can be used. Refer to "[B.1 Setting Up WebAdmin](#)" for details. Additionally, if WebAdmin needs to be configured to use an external repository database, refer to "[B.3 Using an External Repository for WebAdmin](#)" for details.

It is recommended to use the following browsers with WebAdmin:

- Internet Explorer 11
- Microsoft Edge (Build41 or later)

WebAdmin will work with other browsers, such as Firefox and Chrome, however, the look and feel may be slightly different.

Configure your browser to allow cookies and pop-up requests from the server on which FUJITSU Enterprise Postgres is installed.

Refer to "[Appendix A Recommended WebAdmin Environments](#)" for information on how to change the pop-up request settings and other recommended settings.

Note

- WebAdmin does not run in Windows(R) safe mode.
- If the same instance is operated from multiple WebAdmin windows, it will not work correctly.
- If the same instance is operated from multiple WebAdmin versions, it will not work correctly. Always use the latest version of WebAdmin for instance operations.
- For efficient use of WebAdmin, it is recommended not to use the browser [Back] and [Forward] navigation buttons, the [Refresh] button, and context-sensitive menus, including equivalent keyboard shortcuts.
- Copying and pasting the WebAdmin URLs are not supported. Additionally, bookmarking of WebAdmin URLs is not supported.
- It is recommended to match the language between the instance server locale and WebAdmin.
- WebAdmin supports only one language: English.
- It is recommended to change the WebAdmin language setting from the instance details page only.
- It is recommended to operate WebAdmin using the WebAdmin launcher.
- WebAdmin uses the labels "Data storage path", "Backup storage path" and "Transaction log path" to indicate "data storage destination", "backup data storage destination" and "transaction log storage destination" respectively. In this manual these terms are used interchangeably.

- If the browser was not operated for a fixed period (about 30 minutes), the session will time out and the login page will be displayed again for the next operation.
- Port access permissions
If a port is blocked (access permissions have not been granted) by a firewall, enable use of the port by granting access. Refer to the vendor document for information on how to grant port access permissions.
Consider the security risks carefully when opening ports.
- When creating or importing an instance in WebAdmin, set the `log_directory` parameter in `postgresql.conf` to `'/var/tmp/fsep_version/instanceAdminUser_instanceNamePortNumber/log'`. Note that resources placed in `/var/tmp` that have not been accessed for 30 days or more will be deleted by the default settings of the operating system. Therefore, consider excluding instances created using WebAdmin from deletion targets in the operating system settings if you need to stop those instances for a long time.

4.3.1.1 Logging in to WebAdmin

This section describes how to log in to WebAdmin.

Startup URL for WebAdmin

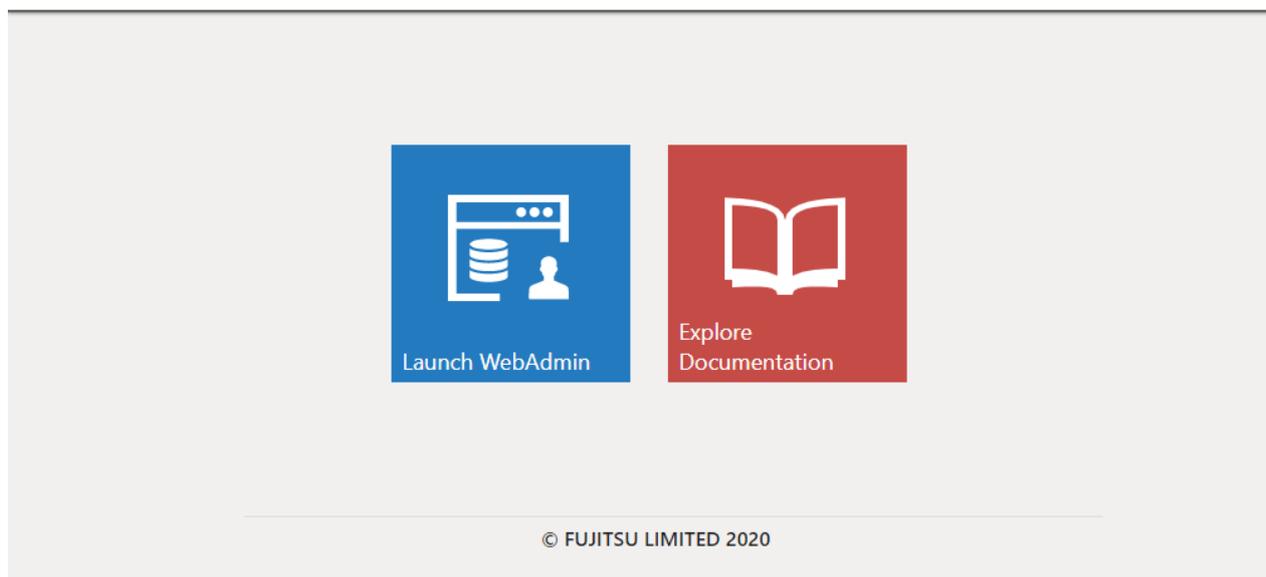
In the browser address bar, type the startup URL of the WebAdmin window in the following format:

```
http://hostNameOrIpAddress:portNumber/
```

- *hostNameOrIpAddress*: Host name or IP address of the server where WebAdmin is installed.
- *portNumber*: Port number of WebAdmin. The default port number is 27515.

The startup URL window shown below is displayed. From this window you can log in to WebAdmin or access the product documentation.

FUJITSU Enterprise Postgres



Logging in to WebAdmin

Click [Launch WebAdmin] in the startup URL window to start WebAdmin and display the login window. Enter the instance administrator user ID (operating system user account name) and password, and log in to WebAdmin. User credential (instance administrator user ID and password) should not contain hazardous characters. Refer to "[Appendix C WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".

4.3.1.2 Creating an Instance

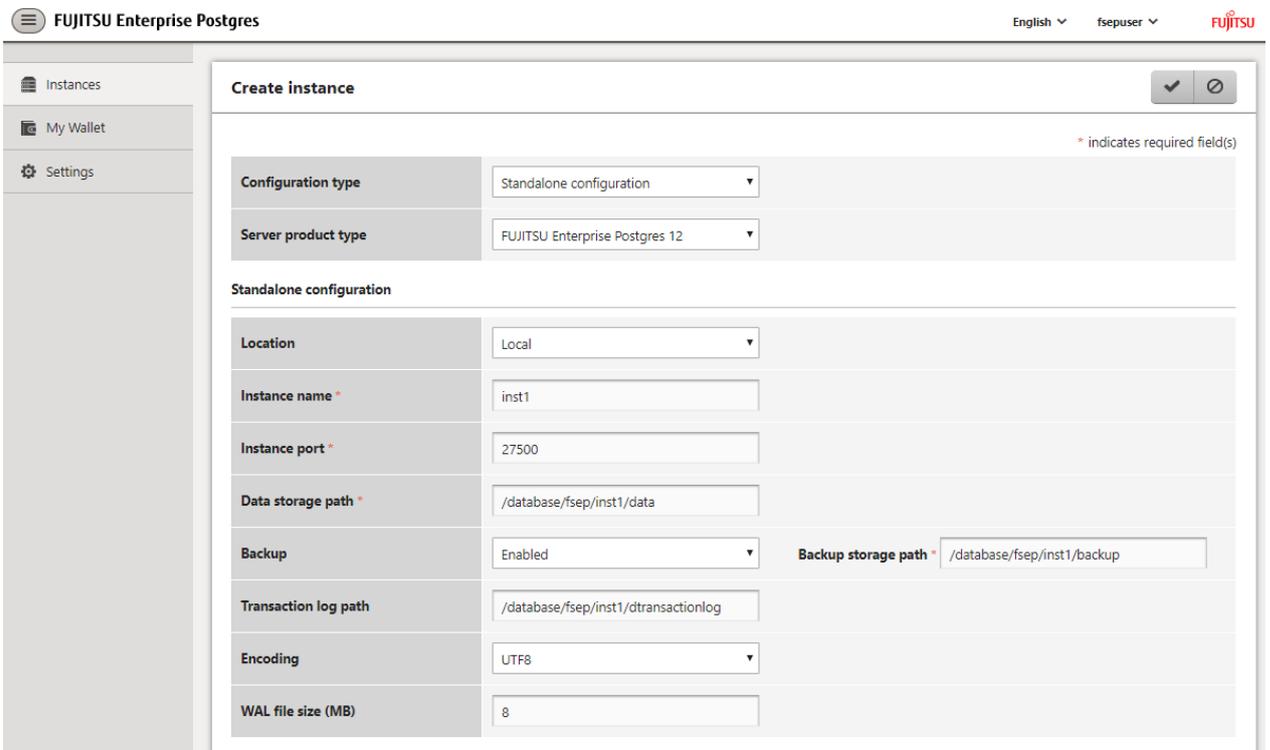
This section describes how to create an instance.

Information

WebAdmin calculates values using the formula indicated in "Managing Kernel Resources" under "Server Administration" in the PostgreSQL Documentation, and configures these in the kernel parameters. Refer to "[Appendix H Configuring Kernel Parameters](#)" for information on configuring parameter names.

Refer to "[Appendix D Configuring Parameters](#)" for information on the postgresql.conf values required to derive the set values.

1. Start WebAdmin, and log in to the database server.
2. In the [Instances] tab, click .
3. Enter the information for the instance to be created.



Enter the following items:

- [Configuration type]: Whether to create a standalone instance or an instance that is part of a cluster.
- [Server product type]: Sets which of the following instances to create:
 - FUJITSU Enterprise Postgres 11 Instances
 - FUJITSU Enterprise Postgres 12 Instances

The default is "FUJITSU Enterprise Postgres 12".

WebAdmin can create and manage instances compatible with the following, but new functionality in FUJITSU Enterprise Postgres 12 may not support the instance or it may be disabled.

- FUJITSU Enterprise Postgres 11
- [Location]: Whether to create the instance in the server that the current user is logged into, or in a remote server. The default is "Local", which will create the instance in the server machine where WebAdmin is currently running.

- [Instance name]: Name of the database instance to manage
The name must meet the conditions below:
 - Maximum of 16 characters
 - The first character must be an ASCII alphabetic character
 - The other characters must be ASCII alphanumeric characters
- [Instance port]: Port number of the database server
- [Data storage path]: Directory where the database data will be stored
- [Backup]: Whether to enable or disable the WebAdmin backup feature. The default is "Enabled". Select "Disabled" to disable all backup and restore functionality for the instance. If "Enabled" is selected, enter the following item:
 - [Backup storage path]: Directory where the database backup will be stored
- [Transaction log path]: Directory where the transaction log will be stored
- [Encoding]: Database encoding system
- [WAL file size]: Allow the WAL file size to be set when creating an instance. The default is 16 MB if the field is blank. The size specified must be a power of 2 between 1 and 1024. This option is not available for standby instances.

If "Remote" is selected for [Location], enter the following additional items:

- [Host name]: Name of the host where the instance is to be created
- [Operating system credential]: Operating system user name and password for the remote machine where the instance is to be created
- [Remote WebAdmin port for standalone]: Port in which WebAdmin is accessible in the remote machine

Note

- Refer to "[4.2.2 Preparing Directories for Resource Deployment](#)" - "Considerations when deploying resources" for information on points to consider when determining the data storage path, backup storage path, and transaction log path.
- The following items can be modified after the instance has been created.
 - Instance name
 - Port number
 - Backup storage path

Refer to "[Editing instance information](#)" for details.

- Do not specify directories that include symbolic link or multibyte characters when specifying the data storage destination or backup data storage destination.
- In the instance that is created using WebAdmin, the locale of the character set to be used in the database, and the locale of the collating sequence, are fixed using C.
- For enhanced security, WebAdmin encrypts the superuser password using SCRAM-SHA-256 authentication.
- Host name and Operating system credential (Operating system user name and password) should not contain hazardous characters. Refer to "[Appendix C WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".

4. Click to create the instance.

If the instance is created successfully, a message indicating the same will be displayed.

5. The instance will be started when it is created successfully.

The screenshot displays the FUJITSU Enterprise Postgres WebAdmin interface. The left sidebar contains navigation options: Instances, My Wallet, and Settings. The main content area shows details for an instance named 'inst1' (osboxes:27500). The 'Summary' section includes:

Title	inst1 (osboxes:27500)
Server type	FUJITSU Enterprise Postgres AE Linux 64-bit
Version	PostgreSQL 12.1
Server up time	8 minutes, 9 seconds
Encoding	UTF8
Instance type	Standalone

The 'Storage summary' section includes:

Data storage status	Normal
Data storage path	/database/fsep/inst1/data
Backup storage status	Normal
Backup storage path	/database/fsep/inst1/backup/backup
Backup time	2019-09-11 09:59:14

A diagram illustrates the data flow from 'Data storage' to 'Backup storage'.

6. Back up the basic information that was set

Back up the WebAdmin management information periodically to ensure operational continuity when a fault occurs on the system disk. Follow the procedure below to perform the backup.

- Stop the WebAdmin server. Refer to "[B.1.3 Stopping the Web Server Feature of WebAdmin](#)" for details.
- Back up the following directory:

```
webAdminInstallDir/data/feowa
```

4.3.1.3 Changing Instance Settings

You can change the information that is set when an instance is created.

Change the following settings to suit the operating and management environment for FUJITSU Enterprise Postgres.

- [Instance configuration](#)
 - Character encoding
 - Communication
 - SQL options
 - Memory
 - Streaming replication
- [Changing client authentication information](#)
- [Editing instance information](#)

Information

These settings are the same as the parameters that can be set in the files shown below. Refer to "[Appendix D Configuring Parameters](#)" for information on the equivalence relationship between the item name and the parameter.

- postgresql.conf
- pg_hba.conf

Note

The files shown below can also be modified directly, however if a parameter not described in "[Appendix D Configuring Parameters](#)" was edited by mistake, WebAdmin may not run correctly.

- postgresql.conf
- pg_hba.conf

Instance configuration

1. Start WebAdmin and log in to the database server.
2. In the [Instances] tab, click .
3. Click  to change the configuration.
4. Click  to save your changes.

See

Select a client-side encoding system that can be converted to/from the database encoding system. Refer to "Automatic Character Set Conversion Between Server and Client" in "Server Administration" in the PostgreSQL Documentation for information on the encoding system combinations that can be converted.

Changing client authentication information

1. Start WebAdmin and log in to the database server.
2. In the [Instances] tab, click .

Click  to register new authentication information.

To change authentication information, select the information, and then click .

To delete authentication information, select the information, and then click .

Note

When creating the instance, do not delete the entry below, because it is a connection required for WebAdmin to monitor the operational status of the database:

Type=local, Database=all, User=all, and Method=md5

Editing instance information

Use the [Edit instance] page to modify the following items for an instance:

- Instance name
- Port number

- Backup storage path

1. In the [Instances] tab, click . The [Edit instance] page is displayed.

2. Modify the relevant items.

If [Backup storage path] is changed, [Backup management] is enabled. Select the required option:

Retain existing backup: Create a backup in [Backup storage path] and retain the existing backup in its original location.

Copy existing backup to new path: Copy the existing backup to [Backup storage path]. A new backup will not be created. The existing backup will be retained in its original location.

Move existing backup to new path: Move the existing backup to [Backup storage path]. A new backup will not be created.

Remove existing backup: Create a backup in [Backup storage path]. The existing backup will be removed.

3. Click  to save your changes.

Note

- The [Edit instance] page is also displayed when the user selects 'Navigate to the "Edit instance" page' from the [Anomaly Error] dialog box. Refer to "Anomaly Detection and Resolution" in the Operation Guide for information on what takes place when an anomaly is detected.

- When [Instance name] or [Instance port] is modified, the `log_directory` and `core_directory` parameters in `postgresql.conf` are updated. Also, the specified directories are created if they do not exist.

Refer to “[4.3.1.4 Importing Instances](#)” for information on the format of these directories.

4.3.1.4 Importing Instances

Instances can be created using WebAdmin, or via the command line using the `initdb` command. Instances created using the `initdb` command (command line instances) can be managed using WebAdmin, however, they must first be imported into WebAdmin.

This section explains how to import command line instances into WebAdmin.

1. In the [Instances] tab, click . The [Import instance] page is displayed.

2. Enter the information for the instance being imported. Refer to "[4.3.1.2 Creating an Instance](#)" for information on the items that need to be entered.

3. Click  to import the instance.

Note

- Importing neither starts nor stops the instance.

- The following restrictions apply to instance import:

- Any instance already managed by WebAdmin cannot be imported again.

- The `postgresql.conf` file must be located in the same directory as [Data storage path].

- Read/write permissions are required for [Data storage path].

- The location specified in `postgresql.conf` for the following files must not have been changed:

- `hba_file`

- `ident_file`

- If the instance is part of a cluster that is monitored by Mirroring Controller, WebAdmin will be unable to detect the Mirroring Controller settings.

- Instances making use of Mirroring Controller functionality should not be imported, because subsequent operations on those instances may cause unexpected and undesirable side-effects.

- It is not possible to import and operate an instance that uses a directory mounted by Network File System (NFS).
- You must make the following changes to the parameters in postgresql.conf prior to importing the instance in WebAdmin.

Parameter	Requirements
port	The port parameter should be uncommented.

The log_directory and core_directory parameters in postgresql.conf are updated during import. Also, the specified directories are created if they do not exist.

The format of these directories is as follows:

log_directory: '/var/tmp/fsep_version/instanceAdminUser_instanceNamePortNumber/log'

core_directory: '/var/tmp/fsep_version/instanceAdminUser_instanceNamePortNumber/core'

version: product version_WA_architecture

instanceAdminUser: operating system user name

PortNumber: port number specified when creating the instance

Examples:

log_directory: '/var/tmp/fsep_120_WA_64/naomi_myinst27599/log'

core_directory: '/var/tmp/fsep_120_WA_64/naomi_myinst27599/core'

- When a standby instance is imported, a valid entry, using the IP address of the standby instance, must exist in the pg_hba.conf file of the master instance to allow the standby instance to connect to the master instance.
- When a standby instance is imported, the value for "host" in the primary_conninfo parameter of postgresql.auto.conf should match the host name of the master instance.
- When a standby instance is imported, you cannot specify "passfile" in the primary_conninfo parameter of postgresql.auto.conf. Be sure to specify "password".
- Instances created by other operating systems cannot be imported.
- If a instance is being imported while it is running, WebAdmin will encrypt the superuser password using SCRAM-SHA-256 authentication.

4.3.2 Using the initdb Command

This section describes the procedure to create an instance using the initdb command.



Note

If a port is blocked (access permissions have not been granted) by a firewall, enable use of the port by granting access. Refer to the vendor document for information on how to grant port access permissions.

Consider the security risks carefully when opening ports.

4.3.2.1 Editing Kernel Parameters

Refer to "[Appendix H Configuring Kernel Parameters](#)" prior to editing these settings.

After the settings are complete, check the command specifications of the relevant operating system and restart the system if required.

4.3.2.2 Creating an Instance

Create an instance, with the database cluster storage destination specified in the PGDATA environment variable or in the -D option. Furthermore, the user that executed the initdb command becomes the instance administrator.

Note

- Instances created using the initdb command (command line instances) can be managed using WebAdmin, however, they must first be imported into WebAdmin. Refer to "4.3.1.4 Importing Instances" for details.
- If creating multiple instances, ensure that there is no duplication of port numbers or the directories that store database clusters.

See

Refer to "initdb" in "Reference" in the PostgreSQL Documentation for information on the initdb command.

The procedure to create an instance is described below.

1. Use the OS user account that you want as the instance administrator.

Connect with the server using the OS user account that you want as the instance administrator.

You cannot use the OS superuser (root).

The following example shows the OS superuser connected to the server being changed to the OS user account "fseuser".

Example

```
# su fseuser
```

2. Configure the environment variables

Configure the environment variables in the server with the newly created instance.

Set the following environment variables:

- PATH environment variables
Add the installation directory "/bin".
- MANPATH environment variables
Add the installation directory "/share/man".
- LD_LIBRARY_PATH environment variables
Add the installation directory "/lib".

Example

The following example configures environment variables when the installation directory is "/opt/fsepv<x>server64".

Note that "<x>" indicates the product version.

sh, bash

```
$ PATH=/opt/fsepv<x>server64/bin:$PATH ; export PATH
$ MANPATH=/opt/fsepv<x>server64/share/man:$MANPATH ; export MANPATH
$ LD_LIBRARY_PATH=/opt/fsepv<x>server64/lib:$LD_LIBRARY_PATH ; export LD_LIBRARY_PATH
```

csh, tcsh

```
$ setenv PATH /opt/fsepv<x>server64/bin:$PATH
$ setenv MANPATH /opt/fsepv<x>server64/share/man:$MANPATH
$ setenv LD_LIBRARY_PATH /opt/fsepv<x>server64/lib:$LD_LIBRARY_PATH
```

3. Create a database cluster

Create the database cluster with the `initdb` command, specifying the storage destination directory.

Specify the transaction log storage destination and the locale setting option as required.

Example

```
$ initdb -D /database/inst1 --waldir=/transaction/inst1 --lc-collate="C" --lc-ctype="C" --encoding=UTF8
```

Point

In some features, instance names are requested, and those names are required to uniquely identify the instance within the system. These features allow names that conform to WebAdmin naming conventions, so refer to the following points when determining the names:

- Maximum of 16 characters
- The first character must be ASCII alphabetic character
- The other characters must be ASCII alphanumeric characters

Note

- To balance I/O load, consider deploying the transaction log storage destination to a disk device other than the database cluster storage destination and the backup data storage destination.
- Specify "C" or "POSIX" for collation and character category. Performance deteriorates if you specify a value other than "C" or "POSIX", although the behavior will follow the rules for particular languages, countries and regions. Furthermore, this may need to be revised when running applications on systems with different locales.
For example, specify as follows:

```
initdb --locale="C" --lc-messages="C"  
initdb --lc-collate="C" --lc-ctype="C"
```

- Specify the same string in the `LANG` environment variable of the terminal that starts FUJITSU Enterprise Postgres as was specified in `lc-messages` of `initdb` (`lc_messages` of `postgresql.conf`). If the same string is not specified, messages displayed on the terminal that was started, as well as messages output to the log file specified in the `-l` option of the `pg_ctl` command or the `postgres` command used for startup, may not be output correctly.
- Specify an encoding system other than `SQL_ASCII` for the database. If `SQL_ASCII` is used, there is no guarantee that the encryption system for data in the database will be consistent, depending on the application used to insert the data.

See

Refer to "Locale Support" in "Localization" in "Server Administration" in the PostgreSQL Documentation for information on locales.

4. Set port number.

Specify a port number in the port parameter of `postgresql.conf`. Ensure that the specified port number is not already used for other software. If a port number is not specified, "27500" is selected.

Register the specified port numbers in the `/etc/services` file if WebAdmin is used to create other instances. WebAdmin uses the `/etc/services` file to check if port numbers specified as available candidates have been duplicated.

Register any name as the service name.

5. Set the corefile output destination.

Specify the output destination of the corefile, which can later be used to collect information for investigation, by setting the `core_directory` and `core_contents` parameters of `postgresql.conf`.



See

Refer to "Parameters" in the Operation Guide for information on the settings for these parameters.

6. Set the backup storage destination.

Specify the backup data storage destination and other backup settings when backup is to be performed as a provision against database errors.



See

Refer to "Backup Methods" in the Operation Guide for information on specifying backup settings.

7. Start an instance.

Start with the start mode of the pg_ctl command.

If either of the following conditions are met, the message "FATAL:the database system is starting up(11189)" may be output.

- An application, command, or process connects to the database while the instance is starting
- An instance was started without the -W option specified

This message is output by the pg_ctl command to check if the instance has started successfully.

Therefore, ignore this message if there are no other applications, commands, or processes that connect to the database.

Example

```
$ pg_ctl start -D /database/inst1
```



See

Refer to "pg_ctl" in "Reference" in the PostgreSQL Documentation for information on the pg_ctl command.



Note

If the -W option is specified, the command will return without waiting for the instance to start. Therefore, it may be unclear as to whether instance startup was successful or failed.

4.4 Configuring Remote Connections

This section describes the settings required when connecting remotely to FUJITSU Enterprise Postgres from a database application or a client command.

4.4.1 When an Instance was Created with WebAdmin

Settings related to connection

The default is to accept connections from remote computers to the database.

Change "listen_addresses" in postgresql.conf to modify the default behavior.

Refer to "[Appendix D Configuring Parameters](#)" for information on postgresql.conf.

Client Authentication Information settings

The following content is set by default when WebAdmin is used to create an instance.

- Authentication of remote connections from local machines is performed.

When changing Client Authentication Information, select [Client Authentication] from [Setting], and then change the settings.

4.4.2 When an Instance was Created with the initdb Command

Connection settings

The default setting only permits local connections from the client to the database. Remote connections are not accepted.

Change "listen_addresses" in postgresql.conf to perform remote connection.

All remote connections will be allowed when changed as shown below.

Example

```
listen_addresses = '*'
```

Also, configure the parameters shown below in accordance with the applications and number of client command connections.

Parameter name	Parameter description
superuser_reserved_connections	Number of connections reserved for database maintenance, for example backup or index rebuilding. If you need to simultaneously perform a large number of processes that exceed the default value, change this value accordingly.
max_connections	Set the value as: <i>numberOfSimultaneousConnectionsToInstance</i> + superuser_reserved_connections

Client authentication information settings

When trying to connect from a client to a database, settings are required to determine whether the instance permits connections from the client - if it does, then it is possible to make settings to determine if authentication is required.



See

.....
Refer to "The pg_hba.conf File" in "Server Administration" in the PostgreSQL Documentation for details.
.....

4.5 Other Settings

This section describes settings that are useful for operations.

4.5.1 Error Log Settings

This section explains the settings necessary to monitor errors in applications and operations, and to make discovering the causes easier.

Make error log settings only when instances are created with the initdb command.

When creating instances with WebAdmin, these settings are already made and hence do not need to be set.

Furthermore, some parameters are used by WebAdmin, and if changed, may cause WebAdmin to no longer work properly. Refer to "[Appendix D Configuring Parameters](#)" for details.



Note

.....
Set the output destination for the system log to the server log so that it cannot be viewed by administrators of other instances.
.....

Application errors are output to the system log or server log. The output destination directory for the system log and server log should have access permissions set so that they cannot be viewed by people other than the instance administrator.
.....

Edit the following parameters in postgresql.conf:

Parameter name	Parameter description	How to enable the settings
syslog_ident	Used to specify labels to attach to messages, so that these can be identified when output to the system log if more than one FUJITSU Enterprise Postgres is used.	reload option of the pg_ctl mode
logging_collector	Specify "on" to ensure that messages are output by FUJITSU Enterprise Postgres to the server log file. The server log file is created in the pg_log directory in the database cluster.	restart option of the pg_ctl mode
log_destination	Specify "stderr,syslog" to output messages from FUJITSU Enterprise Postgres to the screen and either the system log or the event log.	reload option of the pg_ctl mode
log_line_prefix	Specify information to be added at the start of messages output by an instance. This information is useful for automatic monitoring of messages. You can output the SQLSTATE value, output time, executing host, application name, and user ID. Refer to "What To Log" in the PostgreSQL Documentation for details. Example: log_line_prefix = '%e: %t [%p]: [%l-1] user = %u,db = %d,remote = %r app = %a '	reload option of the pg_ctl mode

Point

- If you want fewer application errors being output to the system log, refer to "When To Log" and "What To Log" in the PostgreSQL Documentation for information on how to reduce the output messages.
- If you want to separate errors output from other software, refer to "Where To Log" in the PostgreSQL Documentation to change the output destination to the server log file rather than the system log.

4.5.2 Configuring Automatic Start and Stop of an Instance

You can automatically start or stop an instance when the operating system on the database server is started or stopped.

Use the following procedure to configure automatic start and stop of an instance.

Note that, if an instance is started in a failover operation, the cluster system will control the start or stop, therefore this feature should not be used. Also, when performing database multiplexing, refer to "Enabling Automatic Start and Stop of Mirroring Controller and Multiplexed Instances" in the Cluster Operation Guide (Database Multiplexing).

Note that "<x>" in paths indicates the product version.

If using an rc script

1. Set the OS user account of the instance administrator

If you logged in using the OS user account of the instance administrator, set the environment variables required for starting the instance.

2. Copy the shell script and set access permissions

Copy the sample shell script (stored in the location shown below) to /etc/init.d, then set and register the access rights. After that, revise the shell script according to the target instance.

fujitsuEnterprisePostgresInstallDir/share/rc_fsepsvoi.sample

The content to be revised is as follows:

- In the "SYMDATA" variable, set the data storage destination.
- In the "SYMUSER" variable, set the OS user account of the instance administrator mentioned in step 1.

- Ensure that the file name in "/var/lock/subsys" of the "LOCKFILE" variable is the same as the shell script name.

Example

In the following example, the installation directory is "/opt/fsepv<x>server64", and the shell script has been created as "rc_fsepsvoi_inst1".

```
# cp /opt/fsepv<x>server64/share/rc_fsepsvoi.sample /etc/init.d/rc_fsepsvoi_inst1
# chmod 755 /etc/init.d/rc_fsepsvoi_inst1
```

3. Register and enable automatic start and stop

As the OS superuser, execute the chkconfig command to register and enable the script.

Execute "chkconfig --add" to register the script, and execute "chkconfig --level" to set the run level and enable the script.

Example

```
# chkconfig --add rc_fsepsvoi_inst1
# chkconfig --level 35 rc_fsepsvoi_inst1 on
```

If using systemd



When you start an instance using systemd, you should wait for time correction, network setup, and so on.

1. Create a unit file

Copy the unit file sample stored in the directory below, and revise it to match the target instance.

fujitsuEnterprisePostgresInstallDir/share/fsepsvoi.service.sample

Example

In the following example, the installation directory is "/opt/fsepv<x>server64", and the instance name is "inst1".

```
# cp /opt/fsepv<x>server64/share/fsepsvoi.service.sample /usr/lib/systemd/system/
fsepsvoi_inst1.service
```

Revise the underlined portions of the options below in the unit file.

Section	Option	Specified value	Description
Unit	Description	FUJITSU Enterprise Postgres <u><i>instanceName</i></u>	Specifies the feature overview. Specifies the name of the target instance. (*1)
Service	ExecStart	/bin/bash -c ' <u><i>installDir</i></u> /bin/pgx_symstd start <u><i>installDir dataStorageDestinationDir</i></u> '	Command to be executed when the service is started.
	ExecStop	/bin/bash -c ' <u><i>installDir</i></u> /bin/pgx_symstd stop <u><i>installDir dataStorageDestinationDir</i></u> '	Command to be executed when the service is stopped.
	ExecReload	/bin/bash -c ' <u><i>installDir</i></u> /bin/pgx_symstd reload <u><i>installDir dataStorageDestinationDir</i></u> '	Command to be executed when the service is reloaded
	User	<u>User</u>	OS user account of the instance administrator.
	Group	<u>Group</u>	Group to which the instance administrator user belongs.

*1: The instance name should be as follows:

If WebAdmin is used to create the instance: *instanceName*

If the `initdb` command is used to create the instance: *nameThatIdentifiesTheInstance*

The naming conventions for the instance name or for identifying the instance are as follows:

- Up to 16 bytes
 - The first character must be an ASCII alphabetic character
 - The other characters must be ASCII alphanumeric characters
2. Enable automatic start and stop

As the OS superuser, use the `systemctl` command to enable automatic start and stop.

Example

```
# systemctl enable fsepsvoi_inst1.service
```

4.5.3 Settings when Using the Features Compatible with Oracle Databases

To use the features compatible with Oracle databases, create a new instance and execute the following command for the "postgres" and "template1" databases:

```
CREATE EXTENSION oracle_compatible;
```

Features compatible with Oracle databases are defined as user-defined functions in the "public" schema created by default when database clusters are created, so they can be available for all users without the need for special settings.

For this reason, ensure that "public" (without the double quotation marks) is included in the list of schema search paths specified in the `search_path` parameter.

There are also considerations for use the features compatible with Oracle databases. Refer to "Precautions when Using the Features Compatible with Oracle Databases" in the Application Development Guide for details.

4.6 Setting Up and Removing OSS

This section explains how to set up OSS supported by FUJITSU Enterprise Postgres.

If you want to use OSS supported by FUJITSU Enterprise Postgres, follow the setup procedure.

If you decide not to use the OSS supported by FUJITSU Enterprise Postgres, follow the removing procedure.



Information

- In this section, the applicable database that enables the features of each OSS is described as "postgres".
- Execute `CREATE EXTENSION` for the "template1" database also, so that each OSS can be used by default when creating a new database.

Refer to "OSS Supported by FUJITSU Enterprise Postgres" in the General Description for information on OSS other than those described below.

4.6.1 oracle_fdw

4.6.1.1 Setting Up oracle_fdw

1. Add the path of the OCI library to the environment variable. The available version of the OCI library is 11.2 or later. Add the installation path of the OCI library to the `LD_LIBRARY_PATH` environment variable.
2. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/oracle_fdw/* /opt/fsepv<x>server64
```

3. If a file named libclntsh.so.11.1 does not exist in your OCI library, create a symbolic link with the name libclntsh.so.11.1 to libclntsh.so.xx.1 (xx is the version of the OCI library).

```
# ln -s libclntsh.so.12.1 libclntsh.so.11.1
```

4. Restart FUJITSU Enterprise Postgres.
5. Execute CREATE EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# CREATE EXTENSION oracle_fdw;  
CREATE EXTENSION
```

Information

- If the OCI library is not installed on the server, install it using the Oracle client or Oracle Instant Client. Refer to the relevant Oracle manual for information on the installation procedure.
- If the version of the OCI library is updated, change the path of the OCI library in the LD_LIBRARY_PATH environment variable to the updated path. Also, re-create the symbolic link named libclntsh.so.11.1 if necessary.

Note

This feature cannot be used on instances created in WebAdmin. It can only be used via server commands.

4.6.1.2 Removing oracle_fdw

1. Execute DROP EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# DROP EXTENSION oracle_fdw CASCADE;  
DROP EXTENSION
```

2. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/oracle_fdw
```

4.6.2 pg_bigm

4.6.2.1 Setting Up pg_bigm

1. Set the postgresql.conf file parameters.
Add "pg_bigm" to the shared_preload_libraries parameter.
2. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/pg_bigm/* /opt/fsepv<x>server64
```

3. Restart FUJITSU Enterprise Postgres.
4. Execute CREATE EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# CREATE EXTENSION pg_bigm;  
CREATE EXTENSION
```

4.6.2.2 Removing pg_bigm

1. Execute DROP EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# DROP EXTENSION pg_bigm CASCADE;  
DROP EXTENSION
```

2. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```



Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pg_bigm
```

3. Set the postgresql.conf file parameters.
Delete "pg_bigm" to the shared_preload_libraries parameter.
4. Restart FUJITSU Enterprise Postgres.

4.6.3 pg_hint_plan

4.6.3.1 Setting Up pg_hint_plan

1. Set the postgresql.conf file parameters.
Add "pg_hint_plan" to the "shared_preload_libraries" parameter.
2. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/pg_hint_plan/* /opt/fsepv<x>server64
```

3. Restart FUJITSU Enterprise Postgres.
4. Run CREATE EXTENSION for the database that uses this feature.
The target database is described as "postgres" here.
Use the psql command to connect to the "postgres" database.

```
postgres=# CREATE EXTENSION pg_hint_plan;  
CREATE EXTENSION
```



See

Refer to "Optimizer Hints" in the Application Development Guide for details.

4.6.3.2 Removing pg_hint_plan

1. Execute DROP EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# DROP EXTENSION pg_hint_plan CASCADE;  
DROP EXTENSION
```

2. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pg_hint_plan
```

3. Set the postgresql.conf file parameters.
Delete "pg_hint_plan" to the shared_preload_libraries parameter.
4. Restart FUJITSU Enterprise Postgres.

4.6.4 pg_dbms_stats

4.6.4.1 Setting Up pg_dbms_stats

1. Set the postgresql.conf file parameter.
Add "pg_dbms_stats" to the "shared_preload_libraries" parameter.
2. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/pg_dbms_stats/* /opt/fsepv<x>server64
```

3. Restart FUJITSU Enterprise Postgres.
4. Run CREATE EXTENSION for the database that will use this feature.
The target database is described as "postgres" here.
Use the psql command to connect to the "postgres" database.

```
postgres=# CREATE EXTENSION pg_dbms_stats;  
CREATE EXTENSION
```

See

Refer to "Optimizer Hints" in the Application Development Guide for details.

4.6.4.2 Removing pg_dbms_stats

1. Execute DROP EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# DROP EXTENSION pg_dbms_stats CASCADE;  
DROP EXTENSION
```

2. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pg_dbms_stats
```

3. Set the postgresql.conf file parameters.
Delete "pg_dbms_stats" to the shared_preload_libraries parameter.
4. Restart FUJITSU Enterprise Postgres.

4.6.5 pg_repack

4.6.5.1 Setting Up pg_repack

1. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/pg_repack/* /opt/fsepv<x>server64
```

2. Execute CREATE EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# CREATE EXTENSION pg_repack;  
CREATE EXTENSION
```

4.6.5.2 Removing pg_repack

1. Execute DROP EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# DROP EXTENSION pg_repack CASCADE;  
DROP EXTENSION
```

2. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pg_repack
```

4.6.6 pg_rman

4.6.6.1 Setting Up pg_rman

1. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/pg_rman/* /opt/fsepv<x>server64
```

2. Restart FUJITSU Enterprise Postgres.

Information

Before initialization of the backup catalog, it is recommended to set the parameters below in postgresql.conf. Refer to the pg_rman manual (http://ossc-db.github.io/pg_rman/index-ja.html) for details.

- log_directory
- archive_mode
- archive_command

Note

This feature cannot be used on instances created in WebAdmin. It can only be used via server commands.

4.6.6.2 Removing pg_rman

1. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pg_rman
```

2. Restart FUJITSU Enterprise Postgres.

4.6.7 pg_statsinfo

4.6.7.1 Setting Up pg_statsinfo

1. Set the postgresql.conf file parameters.
 - Add "pg_statsinfo" to the shared_preload_libraries parameter.
 - Specify the log file name for the log_filename parameter.
2. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/pg_statsinfo/* /opt/fsepv<x>server64
```

3. Restart FUJITSU Enterprise Postgres.

Information

Note that `pg_statsinfo` forcibly overwrites the settings below.

- `log_destination`
"csvlog" is added and "stderr" is deleted.
- `logging_collector`
"on" is set.

Note

This feature cannot be used on instances created in WebAdmin. It can only be used via server commands.

4.6.7.2 Removing `pg_statsinfo`

1. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pg_statsinfo
```

2. Set the `postgresql.conf` file parameters.
 - Delete "pg_statsinfo" to the `shared_preload_libraries` parameter.
 - Delete the log file name for the `log_filename` parameter.
3. Restart FUJITSU Enterprise Postgres.

4.6.8 pgBadger

4.6.8.1 Setting Up pgBadger

1. Set the `postgresql.conf` file parameters.
Set the parameters so that the information required for analysis is output to the server log.
Refer to "Documentation" in the pgBadger website (<https://pgbadger.darold.net/>) for details.
The pgBadger material is stored under `/opt/fsepv<x>server64/OSS/pgbadger`.
2. Restart FUJITSU Enterprise Postgres.

4.6.8.2 Removing pgBadger

1. Set the `postgresql.conf` file parameters.
Restores information you specified during Setup.
2. Restart FUJITSU Enterprise Postgres.

4.6.9 Pgpool-II

4.6.9.1 Setting Up Pgpool-II

1. As superuser, run the following command:

```
$ su -  
Password:*****  
# cp -r /opt/fsepv<x>server64/OSS/Pgpool-II/* /opt/fsepv<x>server64
```

2. Execute CREATE EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# CREATE EXTENSION pgpool_recovery;  
CREATE EXTENSION
```

3. Set the postgresql.conf file parameters.
Specify the path to pg_ctl for the pgpool.pg_ctl parameter.
4. Restart FUJITSU Enterprise Postgres.



The online recovery feature of Pgpool-II cannot be used on instances created in WebAdmin. It can only be used via server commands.

4.6.9.2 Removing Pgpool-II

1. Execute DROP EXTENSION for the database that will use this feature.
Use the psql command to connect to the "postgres" database.

```
postgres=# DROP EXTENSION pgpool_recovery CASCADE;  
DROP EXTENSION
```

2. As superuser, run the following command:

```
$ su -  
Password:*****  
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```



The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/Pgpool-II
```

3. Set the postgresql.conf file parameters.
Delete the pg_ctl path for the pgpool.pg_ctl parameter.
4. Restart FUJITSU Enterprise Postgres.

4.7 Integration with Message-Monitoring Software

To monitor messages output by FUJITSU Enterprise Postgres using software, configure the product to monitor SQLSTATE, instead of the message text - this is because the latter may change when FUJITSU Enterprise Postgres is upgraded.

Configure FUJITSU Enterprise Postgres to output messages in a format that can be read by the message-monitoring software by specifying "%e" in the log_line_prefix parameter of postgresql.conf to output the SQLSTATE value.

A setting example is shown below - it outputs the output time, executing host, application name, and user ID, in addition to the SQLSTATE value.

Example

```
log_line_prefix = '%e: %t [%p]: [%l-1] user = %u,db = %d,remote = %r app = %a '
```



See

Refer to "What To Log" in the PostgreSQL Documentation for information on how to configure the settings.

4.8 Deleting Instances

This section explains how to delete an instance.

- [4.8.1 Using WebAdmin](#)
- [4.8.2 Using Server Commands](#)



Note

- Always use WebAdmin to delete instances that were created or imported using WebAdmin. Because WebAdmin management information cannot be deleted, WebAdmin will determine that the instance is abnormal.
- If you have set automatic start and stop of the instance, execute the following commands to disable the script and cancel registration.

If using rc

```
chkconfig nameOfShellScriptForAutomaticStartAndStop off
chkconfig --del nameOfShellScriptForAutomaticStartAndStop
rm /etc/init.d/nameOfShellScriptForAutomaticStartAndStop
```

Example

```
# chkconfig rc_fsepsvoi_inst1 off
# chkconfig --del rc_fsepsvoi_inst1
# rm /etc/init.d/rc_fsepsvoi_inst1
```

If using systemd

```
systemctl disable nameOfUnitFileThatPerformsAutomaticStartAndStop

rm /usr/lib/systemd/system/nameOfUnitFileThatPerformsAutomaticStartAndStop
```

Example

```
# systemctl disable fsepsvoi_inst1.service
# rm /usr/lib/systemd/system/fsepsvoi_inst1.service
```

4.8.1 Using WebAdmin

This section explains how to delete an instance using WebAdmin.

Use the following procedure to delete an instance.

1. Stop the instance

In the [Instances] tab, select the instance to stop and click .

2. Back up files.

Before deleting the instance, back up any required files under the data storage destination, the backup data storage destination, and the transaction log storage destination.

3. Delete the instance

In the [Instances] tab, select the instance to delete and click .

Note

Deleting an instance deletes only the following lowest-level directories. If they are not required, delete them manually.

- Data storage destination
- Backup data storage destination
- Transaction log storage destination (if different from the data storage destination)

4.8.2 Using Server Commands

This section explains how to delete an instance using server commands.

Use the following procedure to delete an instance.

1. Stop the instance

Execute the stop mode of the `pg_ctl` command.

An example is shown below:

Example

```
$ pg_ctl stop -D /data/inst1
```

2. Back up files.

Before deleting the instance, back up any required files under the data storage destination, the backup data storage destination, and the transaction log storage destination.

3. Delete the instance

Use a standard UNIX tool (the `rm` command) to delete the following directories:

- Data storage destination
- Backup data storage destination
- Transaction log storage destination (if a directory different from the data storage directory was specified)

Chapter 5 Uninstallation

This chapter describes the procedure for uninstalling FUJITSU Enterprise Postgres.

5.1 Run Uninstallation

Uninstall according to the following procedure:

Note that "xSPz" in sample windows indicates the version and level of products to uninstall and "<x>" in paths indicates the product version.



- All files and directories in the installation directory are deleted during uninstallation. If user files have been placed in the installation directory, back them up before uninstallation if necessary.
- To reinstall FUJITSU Enterprise Postgres after it was uninstalled, and reuse an instance that was already created so that it can be managed from WebAdmin, back up the directory shown below in which the WebAdmin instance management information had been defined before uninstalling FUJITSU Enterprise Postgres, and then restore the backed up directory to its original location once FUJITSU Enterprise Postgres has been reinstalled.

Follow the procedure below to perform the backup.

1. Stop the WebAdmin server. Refer to "[B.1.3 Stopping the Web Server Feature of WebAdmin](#)" for details.
2. Back up the following directory:

```
webAdminInstallDir/data/fepwa
```

1. Delete the operation information

If the FUJITSU Enterprise Postgres operation information has been registered in the operating system or another middleware product, for example, then it must be deleted. Cases in which deletion is required are as follows:

- If you have set automatic start and stop of the instance, execute the following commands to disable the script and cancel registration.

If using an rc script

```
chkconfig nameOfShellScriptForAutomaticStartAndStop off
chkconfig --del nameOfShellScriptForAutomaticStartAndStop
rm /etc/rc.d/init.d/nameOfShellScriptForAutomaticStartAndStop
```

Example

```
# chkconfig rc_fsepsvoi_inst1 off
# chkconfig --del rc_fsepsvoi_inst1
# rm /etc/rc.d/init.d/rc_fsepsvoi_inst1
```

If using systemd

```
systemctl disable nameOfUnitFileThatPerformsAutomaticStartAndStop

rm /usr/lib/systemd/system/nameOfUnitFileThatPerformsAutomaticStartAndStop
```

Example

```
# systemctl disable fsepsvoi_inst1.service
# rm /usr/lib/systemd/system/fsepsvoi_inst1.service
```

2. Stop applications and programs

Before starting the uninstallation, stop the following:

- Applications that use the product

- Instance

Using WebAdmin

In the [Instances] tab, select the instance to stop and click .

Using server commands

Execute the pg_ctl command in stop mode.

```
$ /opt/fsepv<x>server64/bin/pg_ctl stop -D /database/inst1
```

- Web server feature of WebAdmin

Execute the WebAdminStop command to stop the Web server feature of WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin
# ./WebAdminStop
```

- Mirroring Controller

Execute the mc_ctl command with the stop mode option specified and stop the Mirroring Controller.

Example

```
$ mc_ctl stop -M /mdir/inst1
```

- pgBadger
- Pgpool-II

3. Change to the superuser

Run the following command to switch to the superuser on the system.

```
$ su -
Password:*****
```

4. Remove WebAdmin setup

When uninstall WebAdmin feature, execute the WebAdminSetup command to remove WebAdmin setup.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin
# ./WebAdminSetup -d
```

5. Verifying Installation Features

Verify that the feature to be removed is installed by executing the following command.

Feature Name	Package Name
Server	FJSVfsep-SV-<x>
WebAdmin	FJSVfsep-WAD-<x>
Client	FJSVfsep-CL-<x>
Pgpool-II	FJSVfsep-POOL2-<x>

* Where x is a number indicating the version.

Example

```
# rpm -qi FJSVfsep-SV-12
```

6. Run the uninstallation

Run the following command.

Example

```
# rpm -e FJSVfsep-SV-12
```

The installation directory may remain after uninstallation. If it is not required, delete it.

Appendix A Recommended WebAdmin Environments

This appendix describes the recommended WebAdmin environment. The following explanation is based on the assumption that Internet Explorer 11 or later is used unless otherwise stated.

A.1 Recommended Browser Settings

- Use a display resolution of 1280 x 768 or higher, and 256 colors or more.
- Select [View] >> [Text size] >> [Medium].
- Select [View] >> [Zoom] >> [100%].
- Click [Tools] >> [Internet options] >> [General] >> [Fonts], and then:
 - Set [Webpage font] to [Times New Roman].
 - Set [Plain text font] to [Courier New].

A.2 How to Set Up the Pop-up Blocker

If the Pop-up Blocker is enabled, use the procedure below to configure settings to allow pop-ups from the server where FUJITSU Enterprise Postgres is installed.

1. Click [Tools] >> [Internet options], and then select the [Privacy] tab.
If [Turn on Pop-up Blocker] is not selected, the Pop-up Blocker feature will not operate, and therefore steps below are not required.
2. Click [Settings].
3. In the [Pop-up Blocker Settings] window, enter in the [Address of website to allow] the URL of the server where FUJITSU Enterprise Postgres is installed, and then click [Add].
4. Click [Close].
5. In the [Internet Options] window, click [OK].

Appendix B Setting Up and Removing WebAdmin

This appendix describes how to set up and remove WebAdmin.

Note that "<x>" in paths indicates the product version.

B.1 Setting Up WebAdmin

This section explains how to set up WebAdmin.

B.1.1 Setting Up WebAdmin

Follow the procedure below to set up WebAdmin.

1. Change to the superuser

Acquire superuser privileges on the system.

Example

```
$ su -  
Password:*****
```

2. Set the JAVA_HOME environment variable

Set the JAVA_HOME environment variable to the installation destination of Open JRE 8.

Example

```
# export JAVA_HOME="OpenJRE8InstallDir"
```

3. Set up WebAdmin

Set up WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin  
# ./WebAdminSetup
```

4. Specify the port number

Specify the following port numbers to be used in WebAdmin.

Refer to the "/etc/services" file and only change to a different port number if there is overlap with a port number from another service.

Make a note of the port number for the Web server, because it will be required for starting the WebAdmin window.

Item	Value (recommended value)
Web server port number enter port number of Web Server (default: 27515):	27515
WebAdmin internal port number enter Internal port number for WebAdmin (default: 27516):	27516
WebAdmin automatic start Start WebAdmin automatically when system starting? [y,n] (default: y)	y

Web server port number

Specify a numeric value from 1024 to 32767 for the port number to be used for communication between the Web browser and the Web server.

The Web server port number will be registered as a port number with the following service name in the "/etc/services" file.

fsep_120_WA_64_WebAdmin_Port1

WebAdmin internal port number

Specify a numeric value from 1024 to 32767 for the port number to be used for communication between the Web server and the WebAdmin runtime environment.

The WebAdmin internal port number will be registered as a port number with the following service name in the /etc/services file.

fsep_120_WA_64_WebAdmin_Port2

WebAdmin automatic start

Select whether or not to start WebAdmin when the machine is started.



- Unused port numbers
Irrespective of the information specified in the "/etc/services" file, unused port numbers in the OS and other products can sometimes be automatically numbered and then used, or port numbers specified in environment files within products may also be used. Check the port numbers used by the OS and other products, and ensure that these are not duplicated.
- Access restrictions
Prevent unauthorized access and maintain security by using a firewall product, or the packet filtering feature of a router device, to restrict access to the server IP address and the various specified port numbers.
- Port access permissions
If a port is blocked (access permissions have not been granted) by a firewall, enable use of the port by granting access. Refer to the vendor document for information on how to grant port access permissions.
Consider the security risks carefully when opening ports.
- Changing port numbers
When using WebAdmin in multiserver mode, it is recommended not to change WebAdmin ports after creating instances. Otherwise, the created instances may not be accessible through WebAdmin after the port is changed.

B.1.2 Starting the Web Server Feature of WebAdmin

Follow the procedure below to start the Web server feature of WebAdmin.

1. Change to the superuser

Acquire superuser privileges on the system.

Example

```
$ su -  
Password:*****
```

2. Start the Web server feature of WebAdmin

Execute the WebAdminStart command to start the Web server feature of WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin  
# ./WebAdminStart
```

B.1.3 Stopping the Web Server Feature of WebAdmin

Follow the procedure below to stop the Web server feature of WebAdmin.

1. Change to the superuser

Acquire superuser privileges on the system.

Example

```
$ su -  
Password:*****
```

2. Stop the Web server feature of WebAdmin

Execute the WebAdminStop command to stop the Web server feature of WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin  
# ./WebAdminStop
```



- For efficient operation of WebAdmin, it is recommended that the Web server feature be stopped only during a scheduled maintenance period.
- When WebAdmin is used to create and manage instances in a multiserver configuration, the Web server feature must be started and running on all servers at the same time.

B.2 Removing WebAdmin

This section explains how to remove WebAdmin.

This removal procedure stops WebAdmin and ensures that it no longer starts automatically when the machine is restarted.

1. Change to the superuser

Acquire superuser privileges on the system.

Example

```
$ su -  
Password:*****
```

2. Remove WebAdmin setup

Execute the WebAdminSetup command to remove WebAdmin setup.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin  
# ./WebAdminSetup -d
```

B.3 Using an External Repository for WebAdmin

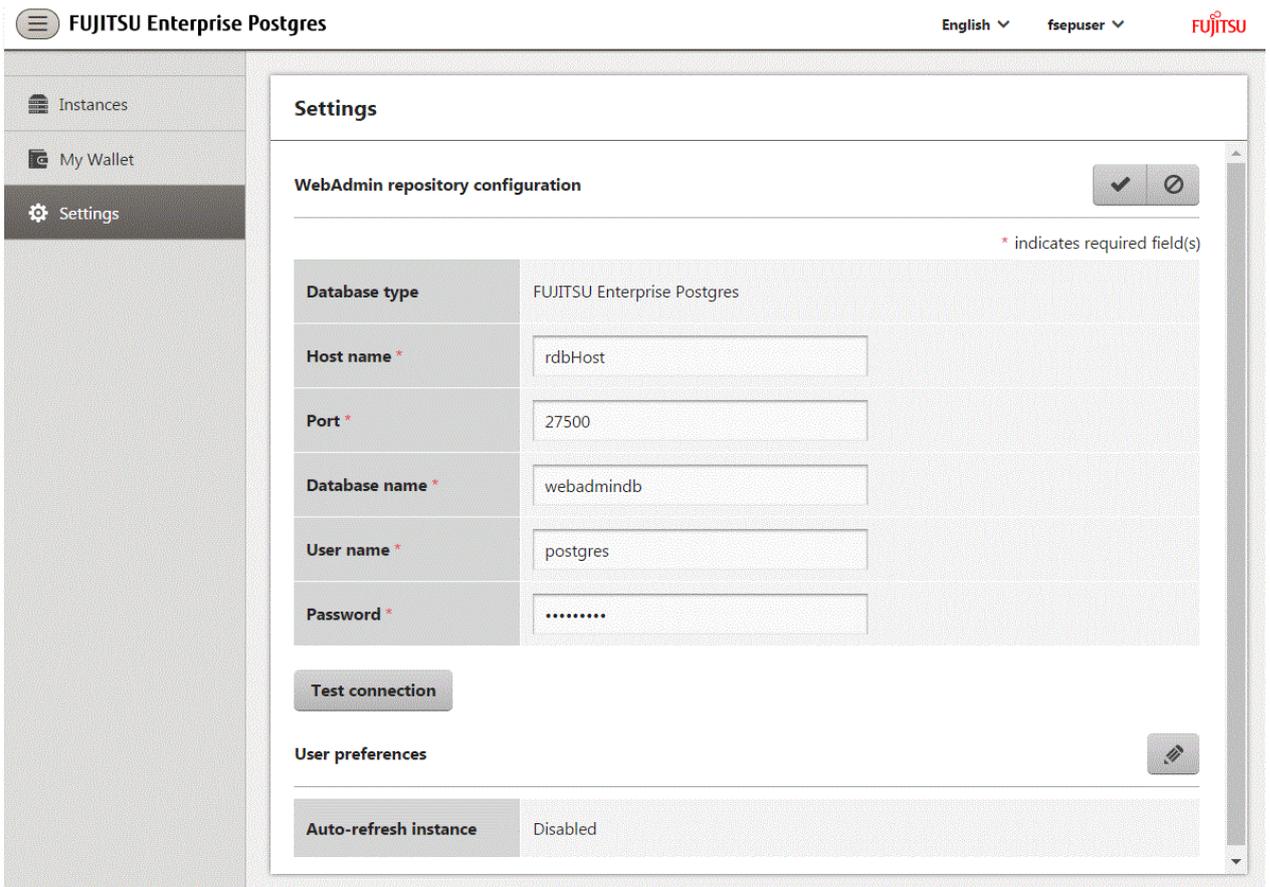
WebAdmin can be configured to use an external database, where it can store the various metadata information it uses. WebAdmin will use this database as a repository to store the information it uses to manage all the created instances. This can be a FUJITSU Enterprise Postgres database or an Open Source PostgreSQL V9.2 or later database.

Using an external database as a WebAdmin repository provides you with more flexibility in managing WebAdmin. This repository can be managed, backed up and restored as needed using command line tools, allowing users to have greater flexibility and control.

Follow the procedure below to set up the repository.

1. Start WebAdmin, and log in to the database server.

2. Click the [Settings] tab, and then click  in the [WebAdmin repository configuration] section.



The screenshot shows the 'Settings' page for 'FUJITSU Enterprise Postgres'. The left sidebar contains 'Instances', 'My Wallet', and 'Settings'. The main content area is titled 'Settings' and has a sub-section 'WebAdmin repository configuration' with a checkmark and a pencil icon. Below this, there is a table of configuration fields:

Field	Value
Database type	FUJITSU Enterprise Postgres
Host name *	rdbHost
Port *	27500
Database name *	webadmindb
User name *	postgres
Password *

Below the fields is a 'Test connection' button. Underneath is the 'User preferences' section with a pencil icon, containing the 'Auto-refresh instance' set to 'Disabled'. A note at the top right of the configuration section states '* indicates required field(s)'.

3. Enter the following items:
 - [Host name]: Host name of the database server
 - [Port]: Port number of the database server
 - [Database name]: Name of the database
 - [User name]: User name to access the database
 - [Password]: Password of the database user

Note

- Database type
It is recommended to use a FUJITSU Enterprise Postgres database as a repository. A compatible PostgreSQL database can also be used as an alternative.
- It is recommended to click [Test connection] to ensure that the details entered are valid and WebAdmin is able to connect to the target database.
- Host name, Database name, User name, Password should not contain hazardous characters. Refer to "[Appendix C WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".

4. Click  to register the repository details.

Note

- Once the repository is set up, it can be changed any number of times by the user logged into WebAdmin. When a repository is changed:
 - It is recommended to preload the backup into this database.
 - If the data is not preloaded, WebAdmin will create a new repository.
- The database repository can be set up even after WebAdmin was already used to create instances. In that scenario, the instances already created are retained and can continue to be operated on.
- If the instance used as a repository is stopped, WebAdmin will be unusable. For this reason, it is recommended to be familiar with starting an instance from the command line. If the instance is stopped for any reason, start it from the command line and WebAdmin will be usable again.

B.4 Using the WebAdmin Auto-Refresh Feature

The WebAdmin auto-refresh feature automatically refreshes the operating status of all instances in the Instance list at the specified interval. It also refreshes the details of the selected instance.

Follow the procedure below to configure the auto-refresh options.

1. Click the [Settings] tab, and then click  in the [User preferences] section.
2. Enter the following items:
 - [Auto-refresh instance]: To use the auto-refresh feature, select "Enabled". The default is "Disabled".
 - [Refresh interval (seconds)]: Number of seconds between each refresh. This is a countdown timer, which is reset every time the instance status is refreshed by any operation. Specify a value from 30 to 3600 (seconds). The default is 30.
3. Click  to save the auto-refresh settings.

Note

- Auto-refresh will run only if the [Instances] page is displayed and no user-initiated operation is in progress.
- A text indicator, which is independent of auto-refresh, is displayed at the top of the Instance list. It is dynamically updated to display when the page was last refreshed.

Appendix C WebAdmin Disallow User Inputs Containing Hazardous Characters

WebAdmin considers the following as hazardous characters, which are not allowed in user inputs.

- | (pipe sign)
- & (ampersand sign)
- ; (semicolon sign)
- \$ (dollar sign)
- % (percent sign)
- @ (at sign)
- ' (single apostrophe)
- " (quotation mark)
- \ ' (backslash-escaped apostrophe)
- \ " (backslash-escaped quotation mark)
- <> (triangular parenthesis)
- () (parenthesis)
- + (plus sign)
- CR (Carriage return, ASCII 0x0d)
- LF (Line feed, ASCII 0x0a)
- , (comma sign)
- \ (backslash)

Appendix D Configuring Parameters

WebAdmin operates and manages databases according to the contents of the following configuration files:

- [postgresql.conf](#)

Contains various items of information that define the operating environment of FUJITSU Enterprise Postgres.

- [pg_hba.conf](#)

Contains various items of information related to client authentication.

These configuration files are deployed to a data storage destination. Data is written to them when the instance is created by WebAdmin and when settings are changed, and data is read from them when the instance is started and when information from the [Setting] menu is displayed.

Direct editing of each configuration file is possible with a text editor.



See

Refer to "Server Configuration" and "Client Authentication" in "Server Administration" in the PostgreSQL Documentation for information on the parameters.



Note

WebAdmin checks for port number and backup storage path anomalies when various operations are performed. An anomaly occurs when the value of [Port number] and/or [Backup storage path] in WebAdmin is different from the value of the corresponding parameter in postgresql.conf. Refer to "Anomaly Detection and Resolution" in the Operation Guide for details.

postgresql.conf

Parameters that can be changed in WebAdmin

The postgresql.conf parameters that can be changed in WebAdmin are shown below:

Section	WebAdmin item	postgresql.conf file parameter
Instance Configuration		
Character encoding	Character set	client_encoding
	Message locale	lc_messages
Communication	Max connections	max_connections
SQL options	Transform NULL format	transform_null_equals
	Date output format	DateStyle (*1)
	Interval output format	IntervalStyle
	Number of digits for floating values	extra_float_digits
	Transaction isolation levels	default_transaction_isolation
	Currency format	lc_monetary
	Date and time format	lc_time
Memory	Sort memory (KB)	work_mem
	Shared buffers (KB)	shared_buffers
Streaming replication	WAL level	wal_level

Section	WebAdmin item	postgresql.conf file parameter
	Maximum WAL senders	max_wal_senders
	WAL keep segments	wal_keep_segments
	Hot standby	hot_standby
	Synchronous standby names	synchronous_standby_names
	WAL receiver timeout (ms)	wal_receiver_timeout
Edit instance		
	Instance name	n/a
	Instance port	port
	Backup storage path	backup_destination

*1: If you specify "Postgres" as the output format, dates will be output in the "12-17-1997" format, not the "Wed Dec 17 1997" format used in the PostgreSQL Documentation.

Information

- Calculate the maximum number of connections using the formula below:

$$\text{maximumNumberOfConnections} = \text{maximumNumberOfConnectionsFromApplications} + 3 (*1)$$

*1: 3 is the default number of connections required by the system.

Calculate the maximum number of connections using the following formula when changing `superuser_reserved_connections` (connections reserved for use by the superuser) in `postgresql.conf`.

$$\text{maximumNumberOfConnections} = \text{maximumNumberOfConnectionsFromApplications} + \text{superuser_reserved_connections}$$

- Also check if the memory used exceeds the memory installed (refer to "[Parameters automatically set by WebAdmin according to the amount of memory](#)").
- When modifying "Shared buffers" or "Max connections", edit the kernel parameter. Refer to "[Appendix H Configuring Kernel Parameters](#)", and "Managing Kernel Resources" in "Server Administration" in the PostgreSQL Documentation for details.

Parameters set by WebAdmin

The following `postgresql.conf` parameters are set by WebAdmin during instance startup (they will be ignored even if specified in `postgresql.conf`):

Parameter	Value
<code>listen_addresses</code>	*
<code>log_destination</code>	'stderr,syslog'
<code>logging_collector</code>	on
<code>log_line_prefix</code>	'%e: %t [%p]: [%l-1] user = %u,db = %d,remote = %r app = %a '
<code>log_filename (*1) (*2)</code>	'logfile-%a.log'
<code>log_file_mode</code>	0600
<code>log_truncate_on_rotation</code>	on
<code>log_rotation_age</code>	1d

*1: The server logs are split into files based on the day of the week, and are rotated after each week.

*2: If the date changes while the instance is stopped, old logs are not deleted and continue to exist. Manually delete old logs that are no longer required to release disk space.

Parameters automatically set by WebAdmin according to the amount of memory

The postgresql.conf parameters automatically set according to the amount of installed memory, during the creation of instances by WebAdmin, are shown below:

Parameter	Value
shared_buffers	30% of the machine's installed memory
work_mem	30% of the machine's installed memory / max_connections / 2
effective_cache_size	75% of the machine's installed memory
maintenance_work_mem	10% of the machine's installed memory / (1 + autovacuum_max_workers) (*1)

*1: The value will be capped at 2097151 KB.

When determining the values to be configured in the above parameters, you must take into account any anticipated increases in access volume or effects on performance during business operations, such as the number of applications and commands that will access the instance, and the content of processes. Also, note that in addition to FUJITSU Enterprise Postgres, other software may be running on the actual database server. You will need to determine the degree of priority for the database and other software, as well as the memory allocation size.

WebAdmin automatically configures complex parameter settings such as those mentioned above, based on the size of the internal memory of the machine. This enables maximum leverage of the machine memory to facilitate resistance against fluctuations during business operations.

Accordingly, the effects of the above-mentioned factors must be estimated and taken into account when determining and configuring parameter values, so that memory resources can be effectively allocated among other software or instances, and so that adverse effects can be mutually avoided. Refer to "Memory" in "Resource Consumption", and "Planner Cost Constants" in "Query Planning", under "Server Administration" in the PostgreSQL Documentation for information on parameter values and required considerations.

Parameter values can be modified using the WebAdmin [Setting] menu, or edited directly using a text editor.

If adding an instance, determine the parameter values, including for existing instances, and make changes accordingly.



Kernel parameters need to be tuned according to the parameters being changed. Refer to "[Appendix H Configuring Kernel Parameters](#)", and "Managing Kernel Resources" in "Server Administration" in the PostgreSQL Documentation for information on tuning kernel parameters.



- Do not directly edit the following postgresql.conf parameters with a text editor, otherwise WebAdmin may not work properly if you make a mistake):
 - archive_mode
 - archive_command (Only allow changing compression settings)
 - wal_level
 - core_directory
 - log_line_prefix
 - log_destination
 - logging_collector
 - log_directory
 - log_file_mode

- log_filename
- log_truncate_on_rotation
- log_rotation_age
- You must take care with the following parameter:
 - superuser_reserved_connections

Set it to a number that includes the 3 connections required in WebAdmin (the default is 3).

pg_hba.conf

Refer to "Client Authentication" in "Server Administration" in the PostgreSQL Documentation for information on content that can be configured in pg_hba.conf.

Note

- Configure the instance administrator permissions in the "local" connection format settings. WebAdmin may not work properly if permissions are not configured.
 - If you specify an item or value that cannot be set by WebAdmin when editing the pg_hba.conf file with a text editor, it will not be possible to reference that line from WebAdmin.
-

Appendix E Estimating Database Disk Space Requirements

This appendix describes how to estimate database disk space requirements.

E.1 Estimating Table Size Requirements

The following tables provide the formulas for estimating table size requirements.

Table E.1 Estimation formula when the record length is 2032 bytes or less

Item	Estimation formula (bytes)
(1) Record length	<p>$27(*1) + \text{NULL map} + \text{OID} + \text{column data}$</p> <p>NULL map: $\text{Number of columns} / 8 (*2)$ OID: 4 Column data: Sum of column lengths</p> <p>*1: Record header section *2: Round the result up to the next integer.</p> <ul style="list-style-type: none"> - Because the column data is placed in boundaries of 8 bytes, you need to make an adjustment so that the sum of the record header section, NULL map and OID is a multiple of 8. For example, if the calculated length is $27 + 1 / 8$ (rounded up) + 0 = 28 bytes, add 4 to make the length 32 bytes. - Because the data of each column is placed in boundaries of the defined data type, take the boundary of each data type into account for the length of the column data. For example, the length of the column data in the table below will not be the sum of the data types, which is 37 bytes, but will instead be 64 bytes following boundary adjustment. Definition: create table tb1(c1 char(1), c2 long, c3 int, c4 box) Estimation: CHAR type 1 byte + boundary adjustment of 7 bytes for LONG type 8 bytes + LONG type 8 bytes + INT type 4 bytes + boundary adjustment of 12 bytes for BOX type 32 bytes + BOX type 32 bytes = 64 bytes - Because each record is placed in boundaries of 8 bytes, you need to make an adjustment so that the length of the column data is a multiple of 8. - If the calculated record length exceeds 2,032 bytes, the variable length data in the record might be compressed automatically. If so, use the estimation formulas in "Table E.2 Estimation formula when the record length exceeds 2032 bytes" to estimate the table size.
(2) Page size requirement	<p>$8192 (*1) \times \text{fillfactor} (*2) - 24 (*3)$</p> <p>*1: Page length (8192) *2: Value of the fillfactor specified in the table definitions (if omitted, 100%) *3: Page header (24)</p> <ul style="list-style-type: none"> - The calculated (2) page size requirement will be rounded down to the nearest integer.
(3) Number of records per page	<p>$(2) \text{ Page size requirement} / ((1) \text{ record length} + 4 (*1))$</p> <p>*1: Pointer length (4)</p> <ul style="list-style-type: none"> - The result will be rounded down to the nearest integer.

Item	Estimation formula (bytes)
(4) Number of pages required for storing records	Total number of records / (3) number of records per page - The result will be rounded up to the next integer.
(5) Amount of space	(4) Number of pages required for storing records x page length x safety factor (*1) *1: Specify 2.0 or higher. - This is the safety factor assumed if vacuuming is performed for garbage collection in tables and indexes.

Table E.2 Estimation formula when the record length exceeds 2032 bytes

Item	Estimation formula (bytes)
(5) Amount of space	Total number of records x (1) record length x safety factor (*1) *1: Specify 2.0 or higher. - This is the safety factor assumed if vacuuming is performed for garbage collection in tables and indexes.

E.2 Estimating Index Size Requirements

This section provides the formulas for estimating index size requirements.

FUJITSU Enterprise Postgres provides six index types: B-tree, Hash, GiST, GIN, SP-GiST, and VCI. If you do not specify the index type in the CREATE INDEX statement, a B-tree index is generated.

The following describes how to estimate a B-tree index. Refer to "[E.7 Estimating VCI Disk Space Requirements](#)" for information on how to estimate VCI.

A B-tree index is saved as a fixed-size page of 8 KB. The page types are meta, root, leaf, internal, deleted, and empty. Since leaf pages usually account for the highest proportion of space required, you need to calculate the requirements for these only.

Table E.3 Estimation formula when the key data length is 512 bytes or less

Item	Estimation formula (bytes)
(1) Entry length	8 (*1) + key data length (*2) *1: Entry header *2: The key data length depends on its data type (refer to " E.3 Sizes of Data Types " for details). Because each entry is placed in boundaries of 8 bytes, you need to make an adjustment so that the length of the key data is a multiple of 8. For example, if the calculated length is 28 bytes, add 4 to make the length 32 bytes. - If the key data length exceeds 512 bytes, key data may be automatically compressed. In this case, use the estimation formula given in " Table E.4 Estimation formula when the key data length exceeds 512 bytes " to estimate the key data length.
(2) Page size requirement	8192 (*1) × fillfactor (*2) - 24 (*3) - 16 (*4) *1: Page length (8192) *2: Value of the fillfactor specified in the index definitions (if omitted, 90%) In the case of indexes of primary key constraints and unique constraints, the value of the fillfactor specified for each constraint in the table definitions (if omitted, 90%) *3: Page header (24) *4: Special data (16)

Item	Estimation formula (bytes)
	- The calculated (2) page size requirement will be rounded down to the nearest integer.
(3) Number of entries per page	(2) Page size requirement / ((1) entry length + 4 (*1)) *1: Pointer length - Result of (3) number of entries per page will be rounded down to the nearest integer.
(4) Number of pages required for storing indexes	Total number of records / (3) number of entries per page - Result of (4) number of pages required for storing indexes will be rounded up to the nearest integer.
(5) Space requirement	(4) Number of pages required for storing indexes x 8192 (*1) / usage rate (*2) *1: Page length *2: Specify 0.7 or lower.

Table E.4 Estimation formula when the key data length exceeds 512 bytes

Item	Estimation formula (bytes)
(5) Space requirement	Total number of records x key data length x compression ratio (*1) / usage rate (*2) *1: The compression ratio depends on the data value, so specify 1. *2: Specify 0.7 or lower as the usage rate.

E.3 Sizes of Data Types

This section lists the sizes of the data types.

E.3.1 Sizes of Fixed-Length Data Types

The following table lists the sizes of fixed-length data types.

Data type	Size (bytes)
SMALLINT (INT2)	2
INTEGER (INT4)	4
BIGINT (INT8)	8
REAL	4
DOUBLE PRECISION	8
SERIAL (SERIAL4)	4
BIGSERIAL (SERIAL8)	8
MONEY	8
FLOAT	8
FLOAT (1-24)	4
FLOAT (25-53)	8
TIMESTAMP WITHOUT TIME ZONE	8
TIMESTAMP WITH TIME ZONE	8
DATE	4
TIME WITHOUT TIME ZONE	8
TIME WITH TIME ZONE	12

Data type	Size (bytes)
INTERVAL	12
BOOLEAN	1
CIDR	IPv4: 7 IPv6: 19
INET	IPv4: 7 IPv6: 19
MACADDR	6
MACADDR8	8
POINT	16
LINE	32
LSEG	32
BOX	32
CIRCLE	24

E.3.2 Sizes of Variable-Length Data Types

The following table lists the sizes of variable-length data types.

Data type	Size (bytes)	Remarks
path	Length of size portion + 12 + 16 x number of vertices	1) When carrying out division, round to the next integer. 2) If the real data length is less than 127, then the length of the size portion is 1 byte, otherwise it is 4 bytes. 3) The number of bytes per character depends on the character set (refer to "E.3.4 Number of Bytes per Character" for details).
polygon	Length of size portion + 36 + 16 x number of vertices	
decimal	Length of size portion + 2 + (integer precision / 4 + decimal precision / 4) x 2	
numeric		
bytea	Length of size portion + real data length	
character varying(<i>n</i>), varchar(<i>n</i>)	Length of size portion + number of characters x number of bytes per character	
character(<i>n</i>), char(<i>n</i>)	Length of size portion + <i>n</i> x number of bytes per character	
text	Length of size portion + number of characters x number of bytes per character	

E.3.3 Sizes of Array Data Types

The following table lists the sizes of array data types.

Data type	Size (bytes)	Remarks
Array	Length of size portion + 12 + 8 x number of dimensions + data size of each item	If the real data length is less than 127, then the length of the size portion is 1 byte, otherwise it is 4 bytes. - Example of estimation when array data is "ARRAY[[1,2,3], [1,2,3]]" Number of dimensions: 2 INTEGER data size: 4 Total size = 1+12+8x2+6x4 = 53

E.3.4 Number of Bytes per Character

The following table lists the number of bytes per character.

The given values relate to the common character sets EUC-JP and UTF8.

Character type	Character set	Number of bytes per character
ASCII	EUC_JP	1
Halfwidth katakana	EUC_JP	2
JIS X 0208 kanji characters	EUC_JP	2
JIS X 0212 kanji characters	EUC_JP	3
ASCII	UTF8	1
Halfwidth katakana	UTF8	3
JIS X 0208 kanji characters	UTF8	3
JIS X 0212 kanji characters	UTF8	3

E.4 Estimating Transaction Log Space Requirements

This section provides the formula for estimating transaction log space requirements.

```
Transaction log space requirements = max_wal_size
```

However, if the update volume is extremely high (for example, due to a large data load and batch processing), disk writing at a checkpoint may not be able to keep up with the load, and a higher number of transaction logs than indicated here may temporarily be accumulated.

E.5 Estimating Archive Log Space Requirements

This section explains how to estimate archive log space requirements.

The archive log is an archive of the transaction logs from the time of a previous backup to the present, so it fluctuates depending on the backup period and the content of update transactions.

The longer the backup period and the more update transactions, the greater the space required for the archive log.

Therefore, measure the actual archive log space by using a test environment to simulate backup scheduling and database update in a real operating environment.

E.6 Estimating Backup Disk Space Requirements

This section provides the formula for estimating backup disk space requirements.

```
Backup disk space requirements = size of the database cluster x 2 x compression ratio  
+ transaction log space requirements + archive log space requirements
```

Note

If the `pgx_dmpall` command performs a backup using a user command, the backup disk size differs according to the database resources targeted for backup and the copy method.

When using compression, the compression ratio depends on the data. Therefore, measure the actual compression ratio by using a test environment to simulate backup scheduling and database update in a real operating environment. Specify 1 to not use compression.

E.7 Estimating VCI Disk Space Requirements

This section provides the formula for estimating VCI disk space requirements.

Disk space = (number of rows in tables) x (number of bytes per row) x (compression ratio) + (WOS size)

Number of bytes per row

Number of bytes per row = (19 + (number of columns specified in CREATE INDEX) / 8
+ (number of bytes per single column value)) x 1.1

Note: Round up the result to the nearest integer.

Compression ratio

Specify a value between 0 and 1. Since compression ratio depends on the data being compressed, use actual data or test data that simulates it, then compare the value with the estimation result. As a guide, the compression ratio measured with the Fujitsu sample data is shown below:

- Data with high degree of randomness (difficult to compress): Up to approximately 0.9 times.
- Data with high degree of similarity (easy to compress): Up to approximately 0.5 times.

WOS size

WOS size = (number of WOS rows) / 185 x 8096

One row is added to the number of WOS rows for each INSERT and DELETE, and two rows are added for UPDATE. On the other hand, the number decreases to 520,000 rows or less during conversion to ROS performed by the ROS control daemon.



Note

VCI does not support retrieval of disk space usage using the database object size function `pg_indexes_size`. To find out the actual total VCI disk space, check the disk space of the storage directory using an OS command or other method.

Appendix F Estimating Memory Requirements

This appendix explains how to estimate the memory.

F.1 FUJITSU Enterprise Postgres Memory Requirements

This section describes the formulas for estimating FUJITSU Enterprise Postgres memory requirements.

Use the following formula to obtain a rough estimate of memory required for FUJITSU Enterprise Postgres:

```
fujitsuEnterprisePostgresRequiredMemory = sharedMemoryAmount + localMemoryAmount
```

Shared memory amount

Refer to "Shared Memory and Semaphores" under "Server Administration" in the PostgreSQL Documentation for information on shared memory. If you enable the Global Meta Cache feature, you must also add the value of `pgx_global_metacache`. Refer to "Parameters" in the Operation Guide for the setting values.

However, note that if instances have been created using WebAdmin, the parameters below will be configured automatically when the instances are created. Take this into account when calculating the shared memory size.

Parameter name	Set value
<code>shared_buffers</code>	30 percent of the internal memory of the machine.
<code>max_connections</code>	100
<code>max_prepared_transactions</code>	100

Local memory amount

```
localMemoryAmount = processStackArea  
+ memoryUsedInDbSessionsThatUseTempTables  
+ memoryUsedInDbSessionsThatPerformSortAndHashTableOperations  
+ memoryUsedInMaintenanceOperations  
+ baseMemoryUsedInEachProcess  
+ memoryUsedPreparingForDataAccess
```

Process stack area

```
processStackArea  
= max_stack_depth x (max_connections + autovacuum_max_workers + 9)
```

This formula evaluates to the maximum value.

Actually it is used according to the growth of the stack.

In the formula above, 9 is the number of processes that perform roles specific to servers.

Memory used in database sessions that use temporary tables

```
memoryUsedInDbSessionsThatUseTempTables  
= temp_buffers x max_connections
```

This formula evaluates to the maximum value.

Memory is gradually used as temporary buffers are used, and is released when the session ends.

Memory used in database sessions that perform sort and hash table operations

```
memoryUsedInDbSessionsThatPerformSortAndHashTableOperations  
= work_mem x max_connections
```

This formula evaluates to the maximum value.

Memory is gradually used as operations such as sort are performed, and is released when the query ends.

Memory used in maintenance operations

```
memoryUsedInMaintenanceOperations
= maintenance_work_mem x (numOfSessionsPerformingMaintenance + autovacuum_max_workers)
```

Note that 'maintenance operations' are operations such as VACUUM, CREATE INDEX, and ALTER TABLE ADD FOREIGN KEY.

Base memory used in each process

```
baseMemoryUsedInEachProcess
= baseMemoryUsedInOneProcess x (max_connections + autovacuum_max_workers + 9)
```

Use the result of the following formula for memory consumed per process. This formula evaluates to the memory used when server processes are running.

In the formula above, 9 is the number of processes that perform roles specific to servers.

The amount of memory consumed per process is determined by the number of tables, indexes, and all columns of all tables that the process accesses. If your system has about 100 tables, you can estimate it to be 3 MB, but otherwise use the following estimate:

```
baseMemoryUsedInOneProcess
= (1.9KB x All user tables + 2.9KB x All user indexes + 1.0KB x All user columns) x 1.5(*1)
```

If you enable the Global Meta Cache feature, use the following formula:

```
baseMemoryUsedInOneProcess
= (All user tables + All user indexes + All user columns) x 1.0KB x 1.5 (*1)
+ (All user tables x 1.4KB + All user indexes x 2.4KB)
```

*1) Safety Factor (1.5)

There are variable length information. This value takes that into account.

Memory used preparing for data access

```
memoryUsedPreparingForDataAccess
= variationAmount x (max_connections + autovacuum_max_workers + 4)
```

```
where variationAmount = shared_buffers / 8KB x 4 bytes
(note that 8KB is the page length, and 4 bytes is the size of page management data)
```

This formula evaluates to the memory required to access the database cache in the shared memory.

In the formula above, among the processes that perform roles specific to servers, 4 is the number of processes that access the database.

F.2 Database Multiplexing Memory Requirements

This section describes the formula for estimating database multiplexing memory requirements for the database server.

Use the following formula to obtain a rough estimate of memory required for database multiplexing:

```
Memory usage of the database multiplexing feature for the database server
= Peak memory usage of the Mirroring Controller processes
+ Peak memory usage of the Mirroring Controller commands
```

```
Peak memory usage of the Mirroring Controller processes=150 MB
```

```
Peak memory usage of the Mirroring Controller commands=50 MB x Number of commands executed
simultaneously
```

F.3 VCI Memory Requirements

This section describes the formula for estimating VCI memory requirements.

Use the following formula to obtain a rough estimate of memory requirements:

```
memUsedByVci = memForData + memForEachProcess
```

Memory required to store data in memory

Secure the space estimated using the formula below on the stable buffer (part of shared_buffers).

```
memForData = (numOfRowsInTables) x (numOfBytesPerRow) + (wosSize)
```

Number of bytes per row

```
numOfBytesPerRow  
= (19 + (numOfColsInCreateIndexStatement) / 8 + (numOfBytesPerSingleColValue)) x 1.1
```

Note: Round up the result to the nearest integer.

WOS size

```
wosSize = (numOfWosRows) / 185 x 8096
```

One row is added to the number of WOS rows for each INSERT and DELETE, and two rows are added for UPDATE. On the other hand, the number decreases to 520,000 rows or less during conversion to ROS performed by the ROS control daemon.

Memory required for each process

```
memForEachProcess  
= memUsedPerScanning  
+ memUsedForVciMaintenace  
+ memUsedByCreateIndexStatement
```

Memory used per scanning

- Parallel scan

```
memUsedPerScanning  
= vci.shared_work_mem + (numOfParallelWorkers + 1) x vci.maintenance_work_mem
```

Note: The number of parallel workers used by VCI simultaneously in the entire instance is equal to or less than vci.max_parallel_degree.

- Non-parallel scan

```
memUsedPerScanning = vci.max_local_ros + vci.maintenance_work_mem
```

Note

- vci.shared_work_mem, and vci.max_local_ros are used to create local ROS. If local ROS exceeds these sizes, execute a query without using VCI according to the conventional plan.
- vci.maintenance_work_mem specifies the memory size to be secured dynamically. If it exceeds the specified value, a disk temporary file is used for operation.

Memory used for VCI maintenance

```
memUsedForVciMaintenace = vci.maintenance_work_mem x vci.control_max_workers
```

Memory used by CREATE INDEX

```
memUsedByCreateIndexStatement = vci.maintenance_work_mem
```



vci.maintenance_work_mem specifies the memory to be secured dynamically. If it exceeds the specified value, a disk temporary file is used for operation.

F.4 High-Speed Data Load Memory Requirements

This section describes the formula for estimating memory requirements for the high-speed data load feature.

Use the following formula to obtain a rough estimate of memory requirements:

```
Memory usage of high speed data load
= (Peak memory usage of pgx_loader processes + Peak memory usage of the pgx_loader commands)
x Number of commands executed simultaneously

Peak memory usage of pgx_loader processes
= Peak memory usage of the backend process    (6 MB)
+ Peak memory usage of parallel workers        (6 MB x number of parallel workers)
+ Peak memory usage of dynamic shared memory  (80 MB x number of parallel workers)

Peak memory usage of the pgx_loader commands=9 MB
```



In addition to the size calculated using the formula above, the database cache on the shared memory estimated using the shared_buffers parameter is consumed according to the size of the data (table and index keys) loaded using this feature. Refer to "E.1 Estimating Table Size Requirements" and "E.2 Estimating Index Size Requirements" for information on estimating an appropriate shared buffers value.

F.5 Global Meta Cache Memory Requirements

This section describes the formula for estimating Global Meta Cache memory requirements.

The memory calculated by "Size of the GMC area" is allocated to the shared memory. The memory calculated by the per-process meta cache management information is allocated to the local memory. Refer to the graphic in "Architecture of Global Meta Cache Feature" in the "Memory usage reduction by Global Meta Cache" in the General Description for more information.

Use the following formula to obtain a rough estimate of memory requirements:

```
Amount of memory used by the Global Meta Cache feature
= Size of GMC area + Per-process meta cache management information

Size of GMC area = (All user tables x 0.4 KB
+ All user indexes x 0.3 KB
+ All user columns x 0.8 KB) x 1.5 (*1)

Per-process meta cache management information
= (All user tables + All user indexes + All user columns) x 0.1KB x max_connections x 1.5 (*1)
```

*1) Safety Factor (1.5)

This value takes into account the case where both GMC before and after the change temporarily exist at the same time in shared memory when the table definition is changed or the row of the system catalog is changed.

Appendix G Quantitative Limits

This appendix lists the quantitative limits of FUJITSU Enterprise Postgres.

Table G.1 Length of identifier

Item	Limit
Database name	Up to 63 bytes (*1) (*2)
Schema name	Up to 63 bytes (*1) (*2)
Table name	Up to 63 bytes (*1) (*2)
View name	Up to 63 bytes (*1) (*2)
Index name	Up to 63 bytes (*1) (*2)
Tablespace name	Up to 63 bytes (*1) (*2)
Cursor name	Up to 63 bytes (*1) (*2)
Function name	Up to 63 bytes (*1) (*2)
Aggregate function name	Up to 63 bytes (*1) (*2)
Trigger name	Up to 63 bytes (*1) (*2)
Constraint name	Up to 63 bytes (*1) (*2)
Conversion name	Up to 63 bytes (*1) (*2)
Role name	Up to 63 bytes (*1) (*2)
Cast name	Up to 63 bytes (*1) (*2)
Collation sequence name	Up to 63 bytes (*1) (*2)
Encoding method conversion name	Up to 63 bytes (*1) (*2)
Domain name	Up to 63 bytes (*1) (*2)
Extension name	Up to 63 bytes (*1) (*2)
Operator name	Up to 63 bytes (*1) (*2)
Operator class name	Up to 63 bytes (*1) (*2)
Operator family name	Up to 63 bytes (*1) (*2)
Rewrite rule name	Up to 63 bytes (*1) (*2)
Sequence name	Up to 63 bytes (*1) (*2)
Text search settings name	Up to 63 bytes (*1) (*2)
Text search dictionary name	Up to 63 bytes (*1) (*2)
Text search parser name	Up to 63 bytes (*1) (*2)
Text search template name	Up to 63 bytes (*1) (*2)
Data type name	Up to 63 bytes (*1) (*2)
Enumerator type label	Up to 63 bytes (*1) (*2)

*1: This is the character string byte length when converted by the server character set character code.

*2: If an identifier that exceeds 63 bytes in length is specified, the excess characters are truncated and it is processed.

Table G.2 Database object

Item	Limit
Number of databases	Less than 4,294,967,296 (*1)

Item	Limit
Number of schemas	Less than 4,294,967,296 (*1)
Number of tables	Less than 4,294,967,296 (*1)
Number of views	Less than 4,294,967,296 (*1)
Number of indexes	Less than 4,294,967,296 (*1)
Number of tablespaces	Less than 4,294,967,296 (*1)
Number of functions	Less than 4,294,967,296 (*1)
Number of aggregate functions	Less than 4,294,967,296 (*1)
Number of triggers	Less than 4,294,967,296 (*1)
Number of constraints	Less than 4,294,967,296 (*1)
Number of conversion	Less than 4,294,967,296 (*1)
Number of roles	Less than 4,294,967,296 (*1)
Number of casts	Less than 4,294,967,296 (*1)
Number of collation sequences	Less than 4,294,967,296 (*1)
Number of encoding method conversions	Less than 4,294,967,296 (*1)
Number of domains	Less than 4,294,967,296 (*1)
Number of extensions	Less than 4,294,967,296 (*1)
Number of operators	Less than 4,294,967,296 (*1)
Number of operator classes	Less than 4,294,967,296 (*1)
Number of operator families	Less than 4,294,967,296 (*1)
Number of rewrite rules	Less than 4,294,967,296 (*1)
Number of sequences	Less than 4,294,967,296 (*1)
Number of text search settings	Less than 4,294,967,296 (*1)
Number of text search dictionaries	Less than 4,294,967,296 (*1)
Number of text search parsers	Less than 4,294,967,296 (*1)
Number of text search templates	Less than 4,294,967,296 (*1)
Number of data types	Less than 4,294,967,296 (*1)
Number of enumerator type labels	Less than 4,294,967,296 (*1)
Number of default access privileges defined in the ALTER DEFAULT PRIVILEGES statement	Less than 4,294,967,296 (*1)
Number of large objects	Less than 4,294,967,296 (*1)
Number of index access methods	Less than 4,294,967,296 (*1)

*1: The total number of all database objects must be less than 4,294,967,296.

Table G.3 Schema element

Item	Limit
Number of columns that can be defined in one table	From 250 to 1600 (according to the data type)
Table row length	Up to 400 gigabytes
Number of columns comprising a unique constraint	Up to 32 columns
Data length comprising a unique constraint	Less than 2,000 bytes (*1) (*2)

Item	Limit
Table size	Up to 32 terabyte
Search condition character string length in a trigger definition statement	Up to 800 megabytes (*1) (*2)
Item size	Up to 1 gigabyte

*1: Operation might proceed correctly even if operations are performed with a quantity outside the limits.

*2: This is the character string byte length when converted by the server character set character code.

Table G.4 Index

Item	Limit
Number of columns comprising a key (including VCI)	Up to 32 columns
Key length (other than VCI)	Less than 2,000 bytes (*1)

*1: This is the character string byte length when converted by the server character set character code.

Table G.5 Data types and attributes that can be handled

Item		Limit	
Character	Data length	Data types and attributes that can be handled (*1)	
	Specification length (n)	Up to 10,485,760 characters (*1)	
Numeric	External decimal expression	Up to 131,072 digits before the decimal point, and up to 16,383 digits after the decimal point	
	Internal binary expression	2 bytes	From -32,768 to 32,767
		4 bytes	From -2,147,483,648 to 2,147,483,647
		8 bytes	From -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
	Internal decimal expression		Up to 13,1072 digits before the decimal point, and up to 16,383 digits after the decimal point
	Floating point expression	4 bytes	From -3.4E+38 to -7.1E-46, 0, or from 7.1E-46 to 3.4E+38
		8 bytes	From -1.7E+308 to -2.5E-324, 0, or from 2.5E-324 to 1.7E+308
bytea		Up to one gigabyte minus 53 bytes	
Large object		Up to 4 terabyte	

*1: This is the character string byte length when converted by the server character set character code.

Table G.6 Function definition

Item	Limit
Number of arguments that can be specified	Up to 100
Number of variable names that can be specified in the declarations section	No limit
Number of SQL statements or control statements that can be specified in a function processing implementation	No limit

Table G.7 Data operation statement

Item	Limit
Maximum number of connections for one process in an application (remote access)	4,000 connections
Number of expressions that can be specified in a selection list	Up to 1,664
Number of tables that can be specified in a FROM clause	No limit
Number of unique expressions that can be specified in a selection list/DISTINCT clause/ORDER BY clause/GROUP BY clause within one SELECT statement	Up to 1,664
Number of expressions that can be specified in a GROUP BY clause	No limit
Number of expressions that can be specified in an ORDER BY clause	No limit
Number of SELECT statements that can be specified in a UNION clause/INTERSECT clause/EXCEPT clause	Up to 4,000 (*1)
Number of nestings in joined tables that can be specified in one view	Up to 4,000 (*1)
Number of functions or operator expressions that can be specified in one expression	Up to 4,000 (*1)
Number of expressions that can be specified in one row constructor	Up to 1,664
Number of expressions that can be specified in an UPDATE statement SET clause	Up to 1,664
Number of expressions that can be specified in one row of a VALUES list	Up to 1,664
Number of expressions that can be specified in a RETURNING clause	Up to 1,664
Total expression length that can be specified in the argument list of one function specification	Up to 800 megabytes (*2)
Number of cursors that can be processed simultaneously by one session	No limit
Character string length of one SQL statement	Up to 800 megabytes (*1) (*3)
Number of input parameter specifications that can be specified in one dynamic SQL statement	No limit
Number of tokens that can be specified in one SQL statement	Up to 10,000
Number of values that can be specified as a list in a WHERE clause IN syntax	No limit
Number of expressions that can be specified in a USING clause	No limit
Number of JOINS that can be specified in a joined table	Up to 4,000 (*1)
Number of expressions that can be specified in COALESCE	No limit
Number of WHEN clauses that can be specified for CASE in a simple format or a searched format	No limit
Data size per record that can be updated or inserted by one SQL statement	Up to one gigabyte minus 53 bytes
Number of objects that can share a lock simultaneously	Up to 256,000 (*1)

*1: Operation might proceed correctly even if operations are performed with a quantity outside the limits.

*2: The total number of all database objects must be less than 4,294,967,296.

*3: This is the character string byte length when converted by the server character set character code.

Table G.8 Data size

Item	Limit
Data size per record for input data files (COPY statement, psql command \copy meta command)	Up to 800 megabytes (*1)
Data size per record for output data files (COPY statement, psql command \copy meta command)	Up to 800 megabytes (*1)

*1: Operation might proceed correctly even if operations are performed with a quantity outside the limits.

Appendix H Configuring Kernel Parameters

Use the "System V IPC Parameters" table in "Managing Kernel Resources" in the PostgreSQL Documentation for the relationship between configuration parameters and kernel parameters, as well as calculation formulas.

Refer to the "Managing Kernel Resources" in the PostgreSQL Documentation to calculate shared memory usage.

For multiple instances, the kernel parameters should be evaluated for all instances. For example, in the case of the maximum number of shared memory segments for the entire system (SHMMNI), the total number of segments obtained by all instances should be added to the kernel parameters. In the case of the maximum number of semaphores for each process (SEMMSL), the largest of all sizes obtained by all instances should be compared to the current value prior to configuring the settings.



Note

If there is insufficient shared memory due to miscalculation of SHMMAX, a message will be output indicating that the shmget system call failed at "errno=22 (EINVAL)". Review the calculation, and reconfigure.

The relationship between System V IPC parameters and kernel parameters in various operating systems is shown below.

System	V IPC parameter	Kernel parameter action
SHMMAX	kernel.shmmax	If <i>currentValue</i> < <i>calculatedValue</i> , configure the calculated value
SHMMIN	No compatible parameter	
SHMALL	kernel.shmall	Specify <i>currentValue</i> + <i>calculatedValue</i>
SHMSEG	No compatible parameter	
SHMMNI	kernel.shmmni	Specify <i>currentValue</i> + <i>calculatedValue</i>
SEMMNI	Fourth parameter of kernel.sem	Specify <i>currentValue</i> + <i>calculatedValue</i>
SEMMNS	Second parameter of kernel.sem	Specify <i>currentValue</i> + <i>calculatedValue</i>
SEMMSL	First parameter of kernel.sem	If <i>currentValue</i> < <i>calculatedValue</i> , configure the calculated value
SEMMAP	No compatible parameter	
SEMVMX	No compatible parameter	

Remark 1: kernel.shmall specifies the number of pages.

Remark 2: Specify all four parameters for kernel.sem. At this time, the value specified in the third parameter should be the same value as before configuration.

Appendix I Determining the Preferred WebAdmin Configuration

This appendix describes the two different configurations in which WebAdmin can be used and how to select the most suitable configuration.

I.1 WebAdmin Configurations

WebAdmin can be installed in two configurations:

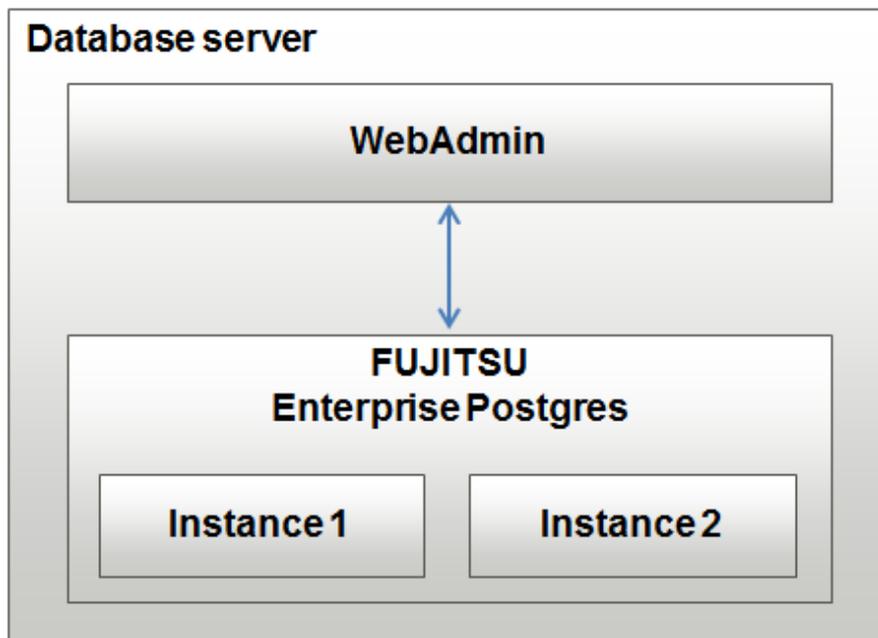
- Single-server
- Multiserver

WebAdmin does not support encrypted communication between browser and server or between servers. Therefore, when using WebAdmin in either configuration, build the communication path with the browser or each server on a network that cannot be accessed externally.

I.1.1 Single-Server Configuration

A single-server configuration enables you to create and operate instances on a single server. In this configuration, WebAdmin must be installed on the same database server as the FUJITSU Enterprise Postgres Server component.

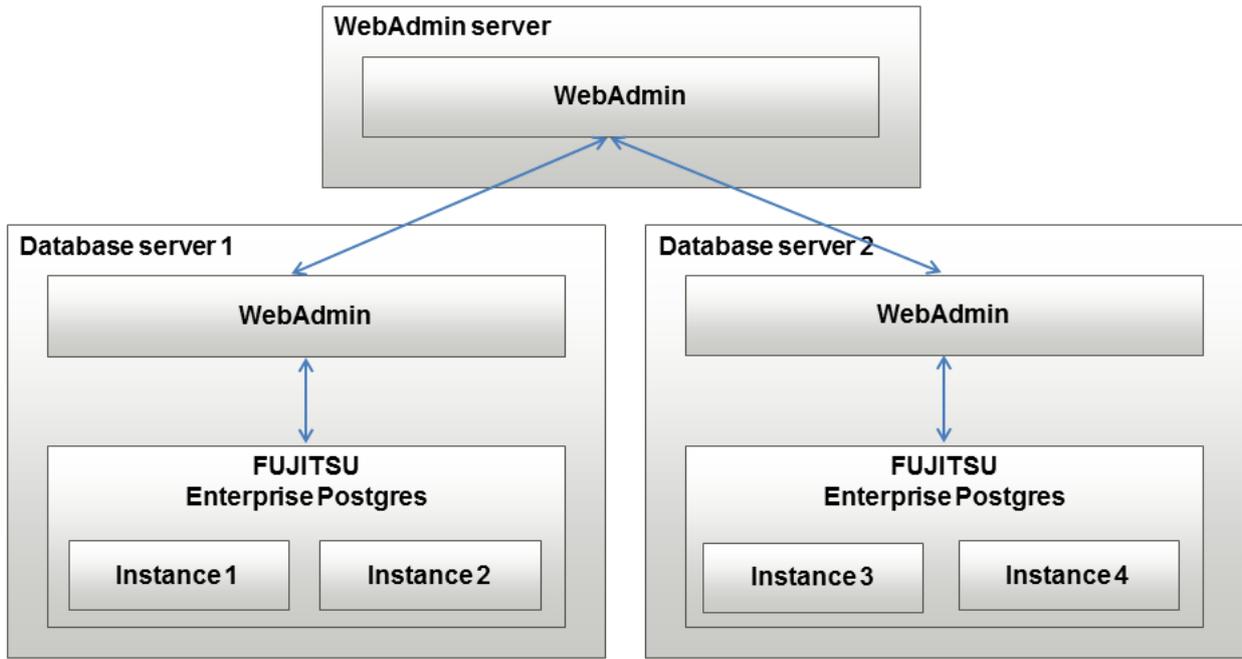
Single-server configuration



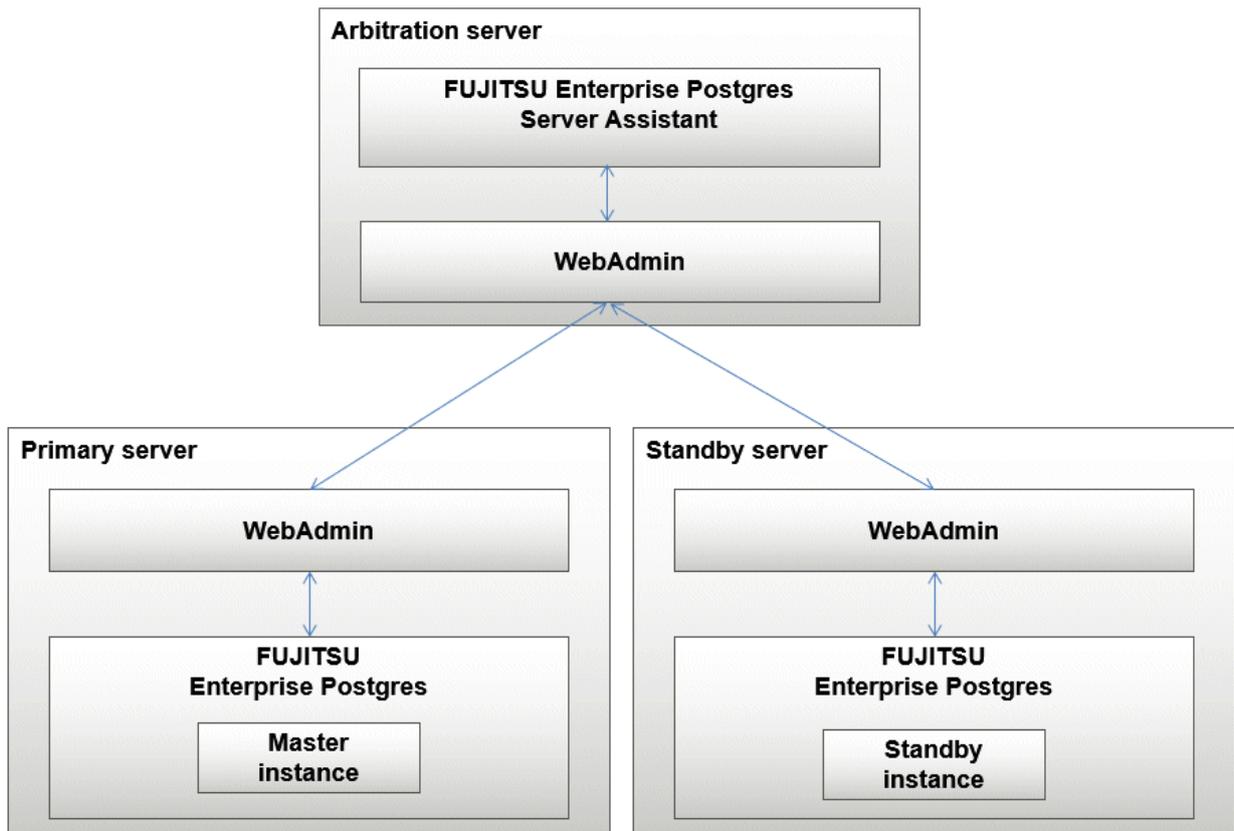
I.1.2 Multiserver Configuration

A multiserver configuration enables you to create and operate instances stored on multiple database servers. As shown in the figure below, WebAdmin can be installed on a dedicated WebAdmin server and used to collectively manage the instances stored on the database servers.

Multiserver configuration



Also, when setting up the arbitration server by WebAdmin during database multiplexing mode, install WebAdmin on the arbitration server.



I.2 Installing WebAdmin in a Single-Server Configuration

To install WebAdmin in a single-server configuration, the FUJITSU Enterprise Postgres Server component and WebAdmin must be installed on the same machine.

Select the following items when installing FUJITSU Enterprise Postgres in a single-server configuration:

- FUJITSU Enterprise Postgres Advanced Edition
- WebAdmin

I.3 Installing WebAdmin in a Multiserver Configuration

In a multiserver configuration, install WebAdmin on one server, and both WebAdmin and the FUJITSU Enterprise Postgres Server component on any number of database servers.

Select the following items when installing FUJITSU Enterprise Postgres in a multiserver configuration:

- WebAdmin server:
 - WebAdmin
- Database server:
 - FUJITSU Enterprise Postgres Advanced Edition
 - WebAdmin

Also, when setting up the arbitration server by WebAdmin during database multiplexing mode, select the following when installing FUJITSU Enterprise Postgres.

- Arbitration server
 - FUJITSU Enterprise Postgres Server Assistant
 - WebAdmin



See

.....
Refer to the Installation and Setup Guide for Server Assistant for details on how to install the Server Assistant.
.....

Appendix J System Configuration when using Pgpool-II

Describes the system configuration when using Pgpool-II.

The system configuration when using Pgpool-II is as follows:

Place on database server

System configuration to coexist the database server with Pgpool-II.

Place on application server

System configuration to coexist the application server with Pgpool-II.

Place on dedicated server

System configuration in which Pgpool-II resides on a dedicated server (Pgpool-II Server) that is separate from the database and application servers.

Select the system configuration that best meets your operational requirements.

J.1 Pgpool-II Configuration

In this example, Pgpool-II is deployed on a different Pgpool-II server than the database and application servers.

There are three configurations of Pgpool-II:

- Single-machine configuration
- Two-machine configuration
- Three-machine configuration

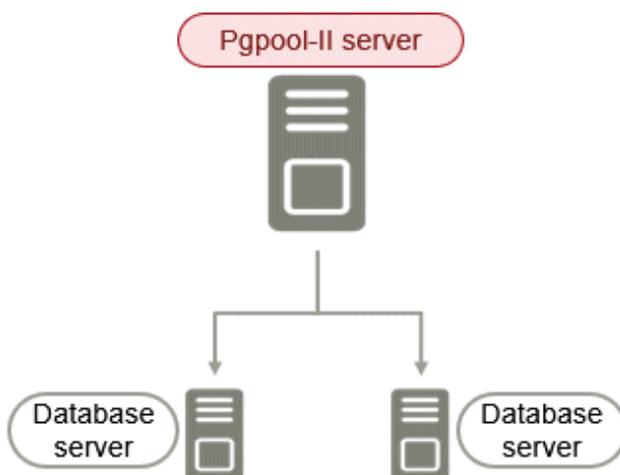
Although the Pgpool-II server can be operated on a single machine, to ensure business continuity, it is recommended to operate the Pgpool-II server using a three-machine configuration in FUJITSU Enterprise Postgres.

If employing a configuration of three or more machines, use an odd number of machines in the configuration.

J.1.1 Single-Machine Configuration

This is the basic configuration when running Pgpool-II.

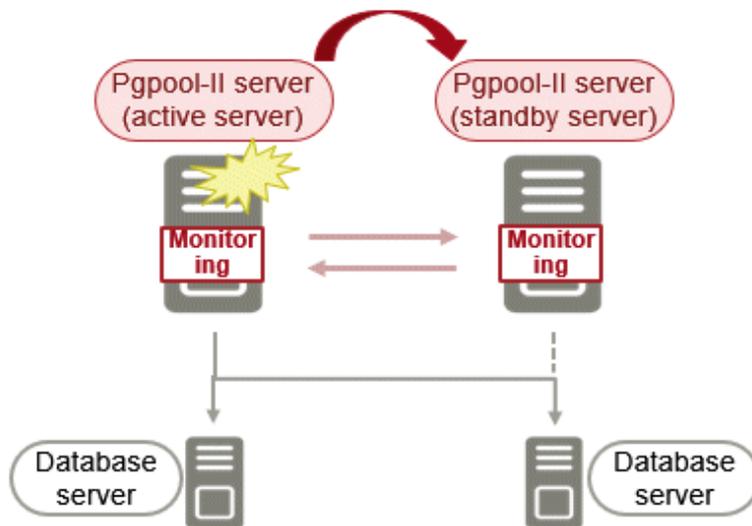
Although the database server has redundancy, if an error occurs on the Pgpool-II server that accesses the database server, the job will stop.



J.1.2 Two-Machine Configuration

When an error occurs on the active server, the Pgpool-II monitoring feature that mutually monitors the status of the Pgpool-II servers enables jobs to continue uninterrupted by switching to the standby server.

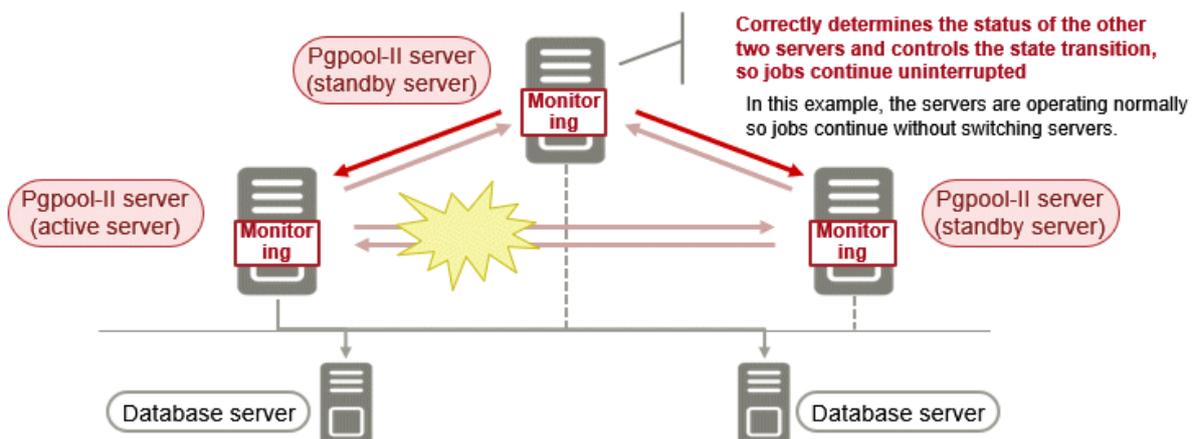
If the network between Pgpool-II servers is disconnected, even if the Pgpool-II servers are running correctly, which may lead to stoppage of jobs.



J.1.3 Three-Machine Configuration

The Pgpool-II monitoring feature enables a Pgpool-II server to monitor the other two Pgpool-II servers.

Even if any of the networks monitoring the Pgpool-II servers are disconnected, the status of servers on a network that is operating normally can be checked correctly, enabling accurate continuation of jobs.



J.2 Installing Pgpool-II

Pgpool-II is bundled with the server program and the client program. To use Pgpool-II, use the server program or the client program to install and set up Pgpool-II.

Depending on where Pgpool-II is installed, select the appropriate DVD for deployment:

Installing on Database Server (coexist)

Install the Pgpool-II program along with the server program from the server program DVD.

Installing on Application Server (coexist)

Install the Pgpool-II program along with the client program from the client program DVD.

Installing on Dedicated server different from the above (Pgpool-II server)

Install the Pgpool-II program along with the client program from the client program DVD.

Appendix K Supported contrib Modules and Extensions Provided by External Projects

FUJITSU Enterprise Postgres supports PostgreSQL contrib modules, and extensions provided by external projects.

Refer to the following for details on the supported contrib modules:

- "Additional Supplied Modules" in the PostgreSQL Documentation
- "Additional Supplied Programs" in the PostgreSQL Documentation



Information

You can also check the list of available extensions using the `pg_available_extensions` view.

Refer to "OSS Supported by FUJITSU Enterprise Postgres" in the General Description for information on supported extensions provided by external projects.

Appendix L Procedure when Modifying the JRE Installation

This appendix describes the procedures to follow when modifying the JRE installation.

The JRE is used by features such as WebAdmin and database multiplexing.

Therefore, when updating or reinstalling JRE after installing FUJITSU Enterprise Postgres, the procedures below must be performed.

L.1 When Using WebAdmin

WebAdmin must be set up again.

Follow the procedure below to modify the JRE installation:

1. Stop the Web server feature of WebAdmin

Refer to "[B.1.3 Stopping the Web Server Feature of WebAdmin](#)" for details.

2. Remove WebAdmin

Refer to "[B.2 Removing WebAdmin](#)" for details.

3. Modify the JRE installation

4. Set the JAVA_HOME environment variable

Set the JAVA_HOME environment variable to the installation destination of Open JRE 8.

Example

```
# export JAVA_HOME="OpenJRE8InstallDir "
```

5. Set up WebAdmin

Refer to "[B.1.1 Setting Up WebAdmin](#)" for details.

6. Start the Web server feature of WebAdmin

Refer to "[B.1.2 Starting the Web Server Feature of WebAdmin](#)" for details.

L.2 When Performing Database Multiplexing

Mirroring Controller must be restarted.

Follow the procedure below to modify the JRE installation:

1. Stop Mirroring Controller

Refer to the Cluster Operation Guide (Database Multiplexing) for details.

2. Modify the JRE installation

3. Change the installation environment to be used by Mirroring Controller

Set the JAVA_HOME environment variable to the installation destination of Open JRE 8, and use the mc_update_jre_env command to change the installation environment to be used by Mirroring Controller.

This procedure must be executed by the superuser.

Example

/opt/fsepv<x>server64/bin is the installation directory where the server product is installed.

```
$ su -  
Password:*****  
# export JAVA_HOME="OpenJRE8InstallDir "  
# /opt/fsepv<x>server64/bin/mc_update_jre_env
```

4. Start Mirroring Controller

Refer to the Cluster Operation Guide (Database Multiplexing) for details.

Note

- If database multiplexing is performed using WebAdmin, perform the procedure described in step 3 "Change the installation environment to be used by Mirroring Controller" after performing step 4 "Set the JAVA_HOME environment variable" in ["L.1 When Using WebAdmin"](#).

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Installation and Setup Guide for Client

Preface

Purpose of this document

This document describes how to install, uninstall and set up the "FUJITSU Enterprise Postgres client feature".

Intended readers

This document is intended for those who install and operate FUJITSU Enterprise Postgres. Readers of this document are assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of Installation](#)

Describes the features that can be installed, and provides an overview of installation methods

[Chapter 2 Installation and Uninstallation of the Linux Client](#)

Describes how to install the FUJITSU Enterprise Postgres client feature (Linux client)

[Chapter 3 Setup](#)

Describes the setup procedures to be performed after installation completes

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Chapter 1 Overview of Installation

This chapter provides an overview of FUJITSU Enterprise Postgres installation.

1.1 Features that can be Installed

FUJITSU Enterprise Postgres provides features to enable access to the database from a variety of platforms and languages, as the connection environment for the client and the database server.

The FUJITSU Enterprise Postgres client package must be installed on the client system to use these features.

The following list shows the features provided by client packages.

- JDBC
- ODBC
- C language (libpq)
- Embedded SQL (ECPG) in C language
- Connection Manager
- High speed data load
- Pgpool-II

1.2 Installation Types

The following installation types are available for FUJITSU Enterprise Postgres:

- New installation
- Reinstallation
- Multi-version installation

1.2.1 New Installation

In initial installation, the FUJITSU Enterprise Postgres client feature is installed for the first time.

1.2.2 Reinstallation

Perform reinstallation to repair installed program files that have become unusable for any reason.

1.2.3 Multi-Version Installation

Perform multi-version installation to install different versions to the installed program files separately.

1.3 Uninstallation

Uninstallation removes the system files of the installed FUJITSU Enterprise Postgres client feature.

Chapter 2 Installation and Uninstallation of the Linux Client

This chapter explains how to install and uninstall the Linux client.

2.1 Operating Environment

This section describes the operating environment required to use the Linux client.

2.1.1 Required Operating System

The following operating systems is required to use the Linux client. Check and use minor version, which is certified and currently supported by Red Hat or SUSE for the target IBM z / Linux One hardware.

- RHEL7.7 or later minor version
- RHEL8.1 or later minor version
- SLES 12 SP5

Information

- The following packages are required for operations on RHEL7.

Package name	Remarks
glibc	-
libgcc	-
libmemcached	Required when using Pgpool-II.
libstdc++	-
libtool-ltdl	-
ncurses-libs	-
nss-softokn-freebl	-
unixODBC	Required when using ODBC drivers.
xz-libs	-
zlib	-

- The following packages are required for operations on RHEL8.

Package name	Remarks
glibc	-
libgcc	-
libmemcached	Required when using Pgpool-II.
libstdc++	-
libtool-ltdl	-
ncurses-libs	-
nss-softokn-freebl	-
unixODBC	Required when using ODBC drivers.
xz-libs	-
zlib	-

- The following packages are required for operations on SLES 12.

Package name	Remarks
glibc	-
libgcc	-
libmemcached	Required when using Pgpool-II.
libstdc++	-
libtool-ltdl	-
ncurses-libs	-
nss-softokn-freebl	-
unixODBC	Required when using ODBC drivers.
xz-libs	-
zlib	-

2.1.2 Related Software

The following table lists the software required to use the Linux client.

Table 2.1 Related software

No.	Software name	Version
1	C compiler (*1)	-
2	JDK or JRE (*2)	Java SE 6 or later

*1: Only operations using the C compiler provided with the operating system are guaranteed.

*2: OpenJDK and IBM Java are supported.

The following table lists servers that can be connected to the Linux client.

Table 2.2 Connectable servers

OS	Software name
Linux	FUJITSU Software Enterprise Postgres Advanced Edition 11 or later

2.1.3 Excluded Software

There are no exclusive products.

2.1.4 Required Patches

There are no required patches.

2.1.5 Hardware Environment

The following hardware is required to use the Linux client.

Memory

At least 160 MB of memory is required.

Mandatory hardware

None.

2.1.6 Disk Space Required for Installation

The following table lists the disk space requirements of the corresponding directories for new installation of the Linux client. If necessary, increase the size of the file system.

Table 2.3 Disk space required for installation

Directory	Required disk space Unit: MB
/etc	1
Installation destination of the client	106

2.1.7 Supported System Environment

This section describes the supported system environment.

TCP/IP protocol

FUJITSU Enterprise Postgres supports version 4 and 6 (IPv4 and IPv6) of TCP/IP protocols.



Do not use link-local addresses if TCP/IP protocol version 6 addresses are used.

2.1.8 Versions of Open-Source Software Used as the Base for FUJITSU Enterprise Postgres Drivers

The following table lists the versions of open-source software used as the base for the various FUJITSU Enterprise Postgres drivers.

Driver	Open-source software version
JDBC	pgjdbc 42.2.8
ODBC	psqlodbc 12.01.0000
libpq	PostgreSQL 12.1

2.2 Installation

This section explains how to install the Linux client.

2.2.1 Pre-installation Tasks

Check the system environment for the following before the Linux client is installed.

Check the disk capacity

Check if sufficient free disk space is available for installing the Linux client.

Refer to "[Table 2.3 Disk space required for installation](#)" for information on disk space requirements.

If sufficient free disk space is unavailable, reconfigure disk partitions.

2.2.2 Run Installation

The installation procedure is described below.



The following characters can be used as input values:

Alphanumeric characters, hyphens, commas and forward slashes

1. Stop applications and programs

If the installation method is the following, all applications and programs that use the product must be stopped:

- Reinstallation

Before starting the installation, stop the following:

- Applications that use the product
- pgBadger
- Pgpool-II

2. Change to the superuser

Run the following command to switch to the superuser on the system.

```
$ su -
Password:*****
```

3. Mount the DVD drive

Insert the client program DVD into the DVD drive, and then execute the following command:

Example

```
# mount -t iso9660 -r -o loop /dev/dvd /media/dvd
```

Here /dev/dvd is the device name for the DVD drive (which may vary depending on your environment), and /media/dvd is the mount point (which may need to be created before calling the command).



If the DVD was mounted automatically using the automatic mount daemon (autofs), "noexec" is set as the mount option, so the installer may fail to start. In this case, use the mount command to remount the DVD correctly, and then run the installation. Note that the mount options of a mounted DVD can be checked by executing the mount command without any arguments.

4. Run the installation

Install the following packages (rpm) with the rpm command.

Feature Name	Operating System	Package (Path)
Client	RHEL7	CLIENT64/Linux/packages/r70s390x/FJSVfsep-CL-*.rpm
	RHEL8	CLIENT64/Linux/packages/r80s390x/FJSVfsep-CL-*.rpm
	SLES 12	CLIENT64/Linux/packages/SUSE12s390x/FJSVfsep-CL-*.rpm
Pgpool-II	RHEL7	PGPOOL2/Linux/packages/r70s390x/FJSVfsep-POOL2-*.rpm
	RHEL8	PGPOOL2/Linux/packages/r80s390x/FJSVfsep-POOL2-*.rpm
	SLES 12	PGPOOL2/Linux/packages/SUSE12s390x/FJSVfsep-POOL2-*.rpm

*is the version, OS, etc.

Example

In the following example, /media/dvd is the name of the mount point where the DVD is mounted.

Below is an example of new installation on RHEL7.

```
# cd /media/dvd/CLIENT64/Linux/packages/r70s390x
# rpm -ivh FJSVfsep-CL-12-1201-0.e17.s390x.rpm
```

Below is an example of new installation on RHEL8.

```
# cd /media/dvd/CLIENT64/Linux/packages/r80s390x
# rpm -ivh FJSVfsep-CL-12-1201-0.e18.s390x.rpm
```

Below is an example of new installation on SLES 12.

```
# cd /media/dvd/CLIENT64/Linux/packages/SUSE12s390x
# rpm -ivh FJSVfsep-CL-12-1201-0.s390x.rpm
```

Below is an example of reinstallation on RHEL7.

```
# cd /media/dvd/CLIENT64/Linux/packages/r70s390x
# rpm -ivh --replacepkgs FJSVfsep-CL-12-1201-0.e17.s390x.rpm
```

Below is an example of reinstallation on RHEL8.

```
# cd /media/dvd/CLIENT64/Linux/packages/r80s390x
# rpm -ivh --replacepkgs FJSVfsep-CL-12-1201-0.e18.s390x.rpm
```

Below is an example of reinstallation on SLES 12.

```
# cd /media/dvd/CLIENT64/Linux/packages/SUSE12s390x
# rpm -ivh --replacepkgs FJSVfsep-CL-12-1201-0.s390x.rpm
```



If you perform reinstallation, and an installation prefix (in the --prefix option of the rpm command) was used for the new installation, you must use the same prefix.

2.3 Uninstallation

This section describes the procedure for uninstalling the Linux client.



- Before uninstalling the product, close the product program and all applications that are using it.

2.3.1 Run Uninstallation

The uninstallation procedure is described below.

1. Stop applications and programs

Before starting the uninstallation, stop the following:

- Applications that use the product
- pgBadger

- Pgpool-II

2. Change to the superuser

Run the following command to switch to the superuser on the system.

```
$ su -  
Password:*****
```

3. Verifying Installation Features

Verify that the feature to be removed is installed by executing the following command.

Feature Name	Package Name
Client	FJSVfsep-CL-< <i>x</i> >

* Where *x* is a number indicating the version.

Example

```
# rpm -qi FJSVfsep-CL-12
```

4. Run the uninstallation

Run the following command.

Example

```
# rpm -e FJSVfsep-CL-12
```

The installation directory may remain after uninstallation. If it is not required, delete it.

Chapter 3 Setup

This chapter describes the setup procedures to be performed after installation completes.

3.1 Configuring Environment Variables

Configure the following environment variables when using client commands.

PATH environment variable

Add "*installationDirectory/bin*".

MANPATH environment variable

Add "*installationDirectory/share/man*".

PGLOCALEDIR environment variable

Add "*installationDirectory/share/locale*".

LD_LIBRARY_PATH environment variable

Add "*installationDirectory/lib*".

Examples of environment variable configurations are shown below.

Example

This example is specific to 64-bit Linux.

Note that "<x>" indicates the product version.

```
$ PATH=/opt/fsepv<x>client64/bin:$PATH ; export PATH
$ MANPATH=/opt/fsepv<x>client64/share/man:$MANPATH ; export MANPATH
$ PGLOCALEDIR=/opt/fsepv<x>client64/share/locale ; export PGLOCALEDIR
$ LD_LIBRARY_PATH=/opt/fsepv<x>client64/lib:$LD_LIBRARY_PATH ; export LD_LIBRARY_PATH
```

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Installation and Setup Guide for Server Assistant

Linux

J2UL-2613-02ZLZ0(00)

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Preface

Purpose of this document

This document describes how to install and uninstall the FUJITSU Enterprise Postgres Server Assistant.

Intended readers

This document is intended for those who install and operate FUJITSU Enterprise Postgres. Readers of this document are assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of Installation](#)

Describes the features that can be installed, and provides an overview of installation methods

[Chapter 2 Installation and Uninstallation of the Linux Server Assistant](#)

Describes how to install and uninstall the Linux Server Assistant

[Chapter 3 Setup of the Server Assistant](#)

Describes the setup to be performed after installation

[Appendix A Estimating Memory Requirements](#)

Describes the formulas for estimating memory requirements

[Appendix B Procedure when Modifying the JRE Installation](#)

Describes the procedure to follow when modifying the JRE installation.

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Chapter 1 Overview of Installation

This chapter provides an overview of FUJITSU Enterprise Postgres Server Assistant installation and uninstallation.

1.1 Features that can be Installed

The Server Assistant can be installed.

The Server Assistant is provided as a Server Assistant package, which is installed on a different server (referred to as the arbitration server) to that of the database server.

1.2 Installation Types

The following installation types are available for FUJITSU Enterprise Postgres:

- New installation
- Reinstallation
- Multi-version installation

1.2.1 New Installation

In initial installation, the FUJITSU Enterprise Postgres Server Assistant is installed for the first time.

1.2.2 Reinstallation

Perform reinstallation to repair installed program files that have become unusable for any reason.

1.2.3 Multi-Version Installation

FUJITSU Enterprise Postgres products can be installed on the same server if the product version (indicated by "x" in "x SPz") is different from that of any version of the product that is already installed.

1.3 Uninstallation

Uninstallation removes the system files of the installed FUJITSU Enterprise Postgres Server Assistant.

Chapter 2 Installation and Uninstallation of the Linux Server Assistant

This chapter explains how to install and uninstall the Linux Server Assistant.

2.1 Operating Environment

This section describes the operating environment required in order to use the Linux Server Assistant.

2.1.1 Required Operating System

One of the following operating systems is required in order to use the Linux Server Assistant. Check and use minor version, which is certified and currently supported by Red Hat or SUSE for the target IBM z / Linux One hardware.

- RHEL7.7 or later minor version
- RHEL8.1 or later minor version
- SLES 12 SP5

Information

- The following packages are required for operations on RHEL7.

Package name	Remarks
glibc	-
libgcc	-
libstdc++	-
ncurses-libs	-
nss-softokn-freebl	-
xz-libs	-
zlib	-
java-1.8.0-openjdk	Use build 1.8.0_212-b04 or later for s390x architecture.

- The following packages are required for operations on RHEL8.

Package name	Remarks
glibc	-
libgcc	-
libstdc++	-
ncurses-libs	-
nss-softokn-freebl	-
xz-libs	-
zlib	-
java-1.8.0-openjdk	Use build 1.8.0_222-b10 or later for s390x architecture.

- The following packages are required for operations on SLES 12.

Package name	Remarks
glibc	-

Package name	Remarks
libgcc	-
libstdc++	-
ncurses-libs	-
nss-softokn-freebl	-
xz-libs	-
zlib	-
java-1.8.0-openjdk	Use build 1.8.0_181-b13 or later for s390x architecture.

2.1.2 Related Software

No other software is required in order to use FUJITSU Enterprise Postgres.

The following table lists servers that can be connected to the Linux Server Assistant.

Table 2.1 Connectable servers

OS	Software name
Linux	FUJITSU Software Enterprise Postgres Advanced Edition 11 or later

2.1.3 Excluded Software

There is no excluded software.

2.1.4 Required Patches

There are no required patches.

2.1.5 Hardware Environment

The following hardware is required in order to use the Linux Server Assistant:

Memory

At least 150 MB of memory is required.

Mandatory hardware

None.

2.1.6 Disk Space Required for Installation

The following table lists the disk space requirements of the corresponding directories for new installation of the Linux Server Assistant. If necessary, increase the size of the file system.

Table 2.2 Disk space required for installation

Directory	Required disk space Unit: MB
/etc	1
<i>serverAssistantInstallDir</i>	2

2.1.7 Supported System Environment

This section describes the supported system environment.

TCP/IP Protocol

FUJITSU Enterprise Postgres supports version 4 and 6 (IPv4 and IPv6) of TCP/IP protocols.



Do not use link-local addresses if TCP/IP protocol version 6 addresses are used.

2.2 Installation

This section describes how to install the Linux Server Assistant.

2.2.1 Pre-installation Tasks

Check the following system environment before installing the Linux Server Assistant.

Check the disk space

Ensure that there is sufficient disk space to install the Linux Server Assistant.

Refer to "[2.1.6 Disk Space Required for Installation](#)" for information on disk space requirements.

If sufficient free disk space is unavailable, reconfigure disk partitions.

Set JAVA_HOME

Ensure that Open JRE 8 is installed, and export the JAVA_HOME environment variable.

```
#export JAVA_HOME="OpenJre8InstallDir"
```

Refer to "[Appendix B Procedure when Modifying the JRE Installation](#)" for information on modifying JRE after installation.

2.2.2 Run Installation

The installation procedure is described below.



The following characters can be used as input values:

Alphanumeric characters, hyphens and forward slashes

1. Stop the program

If the installation method is the following, the program must be stopped:

- Reinstallation

Before starting the installation, stop the following:

- Mirroring Controller arbitration process

Execute the mc_arb command in stop mode to stop the Mirroring Controller arbitration process.

Example

```
$ mc_arb stop -M /mcarb_dir/arbiter1
```

2. Change to the superuser

Run the following command to switch to the superuser on the system.

```
$ su -
Password:*****
```

3. Mount the DVD drive

Insert the Server Assistant program DVD into the DVD drive, and then execute the following command:

Example

```
# mount -t iso9660 -r -o loop /dev/dvd /media/dvd
```

Here /dev/dvd is the device name for the DVD drive (which may vary depending on your environment), and /media/dvd is the mount point (which may need to be created before calling the command).



Note

If the DVD was mounted automatically using the automatic mount daemon (autofs), "noexec" is set as the mount option, so the installer may fail to start. In this case, use the mount command to remount the DVD correctly, and then run the installation. Note that the mount options of a mounted DVD can be checked by executing the mount command without any arguments.

4. Run the installation

Install the following packages (rpm) with the rpm command.

Feature Name	Operating System	Package (Path)
Server Assistant	RHEL7	ARBITER/Linux/packages/r70s390x/FJSVfsep-ARB-*.rpm
	RHEL8	ARBITER/Linux/packages/r80s390x/FJSVfsep-ARB-*.rpm
	SLES 12	ARBITER/Linux/packages/SUSE12s390x/FJSVfsep-ARB-*.rpm

*is the version, OS, etc.

Example

In the following example, /media/dvd is the name of the mount point where the DVD is mounted.

Below is an example of new installation on RHEL7.

```
# cd /media/dvd/ARBITER/Linux/packages/r70s390x
# rpm -ivh FJSVfsep-ARB-12-1201-0.e17.s390x.rpm
```

Below is an example of new installation on RHEL8.

```
# cd /media/dvd/ARBITER/Linux/packages/r80s390x
# rpm -ivh FJSVfsep-ARB-12-1201-0.e18.s390x.rpm
```

Below is an example of new installation on SLES 12.

```
# cd /media/dvd/ARBITER/Linux/packages/SUSE12s390x
# rpm -ivh FJSVfsep-ARB-12-1201-0.s390x.rpm
```

Below is an example of reinstallation on RHEL7.

```
# cd /media/dvd/ARBITER/Linux/packages/r70s390x
# rpm -ivh --replacepks FJSVfsep-ARB-12-1201-0.e17.s390x.rpm
```

Below is an example of reinstallation on RHEL8.

```
# cd /media/dvd/ARBITER/Linux/packages/r80s390x
# rpm -ivh --replacepkgs FJSVfsep-ARB-12-1201-0.el8.s390x.rpm
```

Below is an example of reinstallation on SLES12.

```
# cd /media/dvd/ARBITER/Linux/packages/SUSE12s390x
# rpm -ivh --replacepkgs FJSVfsep-ARB-12-1201-0.s390x.rpm
```



Note

If you perform reinstallation, and an installation prefix (in the `--prefix` option of the `rpm` command) was used for the new installation, you must use the same prefix.

5. Set the installation environment

Use the `mc_update_jre_env` command to set the installation environment to be used by the Server Assistant.

Example

```
# /opt/fsepv<x>assistant/bin/mc_update_jre_env
```

2.3 Uninstallation

This section describes how to uninstall the Linux Server Assistant.



Note

Before uninstalling the product, close the product program.

2.3.1 Run Uninstallation

The uninstallation procedure is described below.

1. Stop the program

Before starting the uninstallation, stop the following:

- Mirroring Controller arbitration process

Execute the `mc_arb` command in stop mode to stop the Mirroring Controller arbitration process.

Example

```
$ mc_arb stop -M /mcarb_dir/arbiter1
```

2. Change to the superuser

Run the following command to switch to the superuser on the system.

```
$ su -
Password:*****
```

3. Verifying Installation Features

Verify that the feature to be removed is installed by executing the following command.

Feature Name	Package Name
Server Assistant	FJSVfsep-ARB-<x>

* Where x is a number indicating the version.

Example

```
# rpm -qi FJSVfsep-ARB-12
```

4. Run the uninstallation

Run the following command.

```
# rpm -e FJSVfsep-ARB-12
```

The installation directory may remain after uninstallation. If it is not required, delete it.

Chapter 3 Setup of the Server Assistant

The Server Assistant is a feature that is installed and used on the arbitration server, so its setup is performed as the arbitration server setup.



See

.....
Refer to "Setting Up Database Multiplexing Mode" in the Cluster Operation Guide (Database Multiplexing) for information on setting up and operating the Mirroring Controller arbitration server.
.....

Appendix A Estimating Memory Requirements

This appendix explains how to estimate the memory.

A.1 Server Assistant Memory Requirements

This section describes the formula for estimating memory requirements for the Server Assistant.

Use the following formula to obtain a rough estimate of memory requirements:

```
Memory usage of the Server Assistant
      = Peak memory usage of the Mirroring Controller arbitration processes
      + Peak memory usage of the Mirroring Controller commands

Peak memory usage of the Mirroring Controller arbitration processes=100 MB

Peak memory usage of the Mirroring Controller commands=50 MB * Number of commands executed
simultaneously
```

Appendix B Procedure when Modifying the JRE Installation

This appendix describes the procedure to follow when modifying the JRE installation.

Therefore, when updating or reinstalling JRE, it is necessary to restart the Mirroring Controller arbitration process, therefore follow the procedure below to modify the JRE installation:

1. Stop the Mirroring Controller arbitration process.

Refer to the Cluster Operation Guide (Database Multiplexing) for details.

2. Modify the JRE installation.

3. Change the installation environment to be used by Mirroring Controller.

Set the JAVA_HOME environment variable to the installation destination of new JRE 8, and use the mc_update_jre_env command to change the installation environment to be used by the Server Assistant.

This procedure must be executed by the superuser.

Example

/opt/fsepv<x>assistant/bin is the installation directory where the Server Assistant is installed.

```
$ su -  
Password:*****  
# export JAVA_HOME="OpenJre8InstallDir "  
# /opt/fsepv<x>assistant/bin/mc_update_jre_env
```

4. Start the Mirroring Controller arbitration process.

Refer to the Cluster Operation Guide (Database Multiplexing) for details.

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



DevSecOps

[Application Development Guide >](#)

[Operation Guide >](#)

[Security Operation Guide >](#)

[Cluster Operation Guide >](#)

[Connection Manager User's Guide >](#)

FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Application Development Guide

Preface

Purpose of this document

This is a guide for the developers of FUJITSU Enterprise Postgres applications.

Intended readers

This document is intended for developers of applications that use FUJITSU Enterprise Postgres. Of the interfaces provided by FUJITSU Enterprise Postgres, this guide describes the PostgreSQL extended interface.

Readers of this document are also assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of the Application Development Function](#)

Provides an overview of FUJITSU Enterprise Postgres application development.

[Chapter 2 JDBC Driver](#)

Explains how to use JDBC drivers.

[Chapter 3 ODBC Driver](#)

Explains how to use ODBC drivers.

[Chapter 4 C Library \(libpq\)](#)

Explains how to use C applications.

[Chapter 5 Embedded SQL in C](#)

Explains how to use embedded SQL in C.

[Chapter 6 SQL References](#)

Explains the SQL statements which were extended in FUJITSU Enterprise Postgres development.

[Chapter 7 Compatibility with Oracle Databases](#)

Explains features that are compatible with Oracle databases.

[Chapter 8 Application Connection Switch Feature](#)

Explains the application connection switch feature.

[Chapter 9 Performance Tuning](#)

Explains how to tune application performance.

[Chapter 10 Scan Using a Vertical Clustered Index \(VCI\)](#)

Explains how to perform scan using a Vertical Clustered Index (VCI).

[Appendix A Precautions when Developing Applications](#)

Provides some points to note about application development.

[Appendix B Conversion Procedures Required due to Differences from Oracle Database](#)

Explains how to convert from an Oracle database to FUJITSU Enterprise Postgres, within the scope noted in "Compatibility with Oracle Databases" from the following perspectives.

[Appendix C Tables Used by the Features Compatible with Oracle Databases](#)

Explains the tables used by the features compatible with Oracle databases.

[Appendix D Quantitative Limits](#)

This appendix explains limitations.

[Appendix E Reference](#)

Provides a reference for each interface.

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Chapter 1 Overview of the Application Development Function

The interface for application development provided by FUJITSU Enterprise Postgres is perfectly compatible with PostgreSQL.

Along with the PostgreSQL interface, FUJITSU Enterprise Postgres also provides the following extended interfaces:

- Support for National Characters

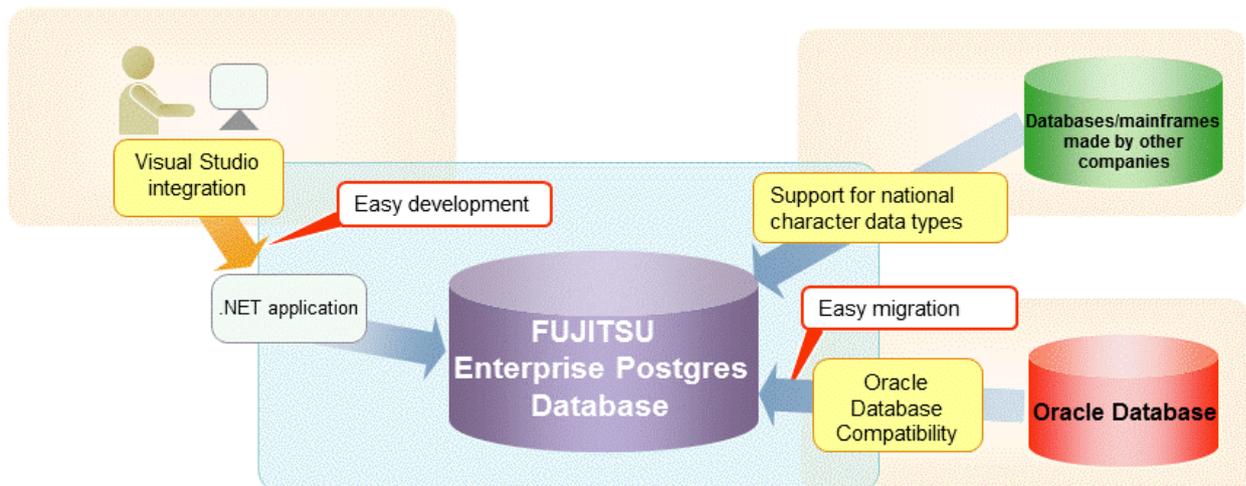
In order to secure portability from mainframes and databases of other companies, FUJITSU Enterprise Postgres provides data types that support national characters. The national characters are usable from the client application languages.

Refer to "[1.1 Support for National Characters](#)" for details.

- Compatibility with Oracle Databases

Compatibility with Oracle databases is offered. Use of the compatible features means that the revisions to existing applications can be isolated, and migration to open interfaces is made simpler.

Refer to "[1.2 Compatibility with Oracle Database](#)" for details.



- Application connection switch feature

The application connection switch feature is provided to enable automatic connection to the target server when there are multiple servers with redundant configurations.

Refer to "[1.3 Application Connection Switch Feature](#)" for details.

- Performance tuning

The following features are provided to control SQL statement query plans:

- Optimizer hints
- Locked statistics

Refer to "[9.1 Enhanced Query Plan Stability](#)" for details.

- Scanning using a Vertical Clustered Index (VCI)

Scans becomes faster during aggregation of many rows by providing the features below:

- Vertical clustered index (VCI)
- In-memory data

Refer to "[Chapter 10 Scan Using a Vertical Clustered Index \(VCI\)](#)" for details.

1.1 Support for National Characters

NCHAR type is provided as the data type to deal with national characters.

Point

- NCHAR can only be used when the character set of the database is UTF-8.
- NCHAR can be used in the places where CHAR can be used (function arguments, etc.).
- For applications handling NCHAR type data in the database, the data format is the same as CHAR type. Therefore, applications handling data in NCHAR type columns can also be used to handle data stored in CHAR type columns.

Note

Note the following in order to cast NCHAR type data as CHAR type.

- When comparing NCHAR type data where the length differs, ASCII spaces are used to fill in the length of the shorter NCHAR type data so that it can be processed as CHAR type data.
- Depending on the character set, the data size may increase by between 1.5 and 2 times.

1.1.1 Literal

Syntax

```
{ N | n } '[national character [ ...]]'
```

General rules

National character string literals consist of an 'N' or 'n', and the national character is enclosed in single quotation marks ('). Example:
N'ABCDEF'

The data type is national character string type.

1.1.2 Data Type

Syntax

```
{ NATIONAL CHARACTER | NATIONAL CHAR | NCHAR } [ VARYING ] [(length) ]
```

The data type of the NCHAR type column is as follows:

Data type specification format	Explanation
NATIONAL CHARACTER(<i>n</i>)	National character string with a fixed length of <i>n</i> characters
NATIONAL CHAR(<i>n</i>)	This will be the same as (1) if (<i>n</i>) is omitted.

Data type specification format	Explanation
NCHAR(<i>n</i>)	<i>n</i> is a whole number larger than 0.
NATIONAL CHARACTER VARYING(<i>n</i>) NATIONAL CHAR VARYING(<i>n</i>) NCHAR VARYING(<i>n</i>)	National character string with a variable length with a maximum of <i>n</i> characters Any length of national character string can be accepted when this is omitted. <i>n</i> is a whole number larger than 0.

General rules

NCHAR is the national character string type data type. The length is the number of characters.

The length of the national character string type is as follows:

- When VARYING is not specified, the length of national character strings is fixed and will be the specified length.
- When VARYING is specified, the length of national character strings will be variable.
In this case, the lower limit will be 0 and the upper limit will be the value specified for length.
- NATIONAL CHARACTER, NATIONAL CHAR, and NCHAR each have the same meaning.

When the national character string to be stored is shorter than the declared upper limit, the NCHAR value is filled with spaces, whereas NCHAR VARYING is stored as is.

The upper limit for character storage is approximately 1GB.

1.1.3 Functions and Operator

Comparison operator

When a NCHAR type or NCHAR VARYING type is specified in a comparison operator, comparison is only possible between NCHAR types or NCHAR VARYING types.

String functions and operators

All of the string functions and operators that can be specified by a CHAR type can also be specified by a NCHAR type. The behavior of these string functions and operators is also the same as with CHAR type.

Pattern matching (LIKE, SIMILAR TO regular expression, POSIX regular expression)

The patterns specified when pattern matching with NCHAR types and NCHAR VARYING types specify the percent sign (%) and the underline (_).

The underline (_) means a match with one national character. The percent sign (%) means a match with any number of national characters 0 or over.

1.2 Compatibility with Oracle Database

The following features have been extended in order to enhance compatibility with Oracle databases:

- Query (external join operator (+), DUAL table)
- Function (DECODE, SUBSTR, NVL)
- Built-in package (DBMS_OUTPUT, UTL_FILE, DBMS_SQL)

Refer to "[Chapter 7 Compatibility with Oracle Databases](#)" for information on the features compatible with Oracle databases.

1.3 Application Connection Switch Feature

The application connection switch feature enables automatic connection to the target server when there are multiple servers with redundant configurations.

Refer to "[Chapter 8 Application Connection Switch Feature](#)" for information on the application connection switch feature.

1.3.1 Integration with Database Multiplexing

The application connection switch feature is provided to enable automatic connection to the appropriate server when there are multiple servers with redundant configurations.



.....
Refer to the Cluster Operation Guide (Database Multiplexing) for information on database multiplexing.
.....

1.4 Notes on Application Compatibility

FUJITSU Enterprise Postgres upgrades contain feature improvements and enhancements that may affect the applications.

Accordingly, note the points below when developing applications, to ensure compatibility after upgrade.

- Checking execution results
- Referencing system catalogs
- Using functions

1.4.1 Checking Execution Results

Refer to SQLSTATE output in messages to check the SQL statements used in applications and the execution results of commands used during development.



.....
Refer to Messages for information on the message content and number.

Refer to "PostgreSQL Error Codes" under "Appendixes" in the PostgreSQL Documentation for information on SQLSTATE.
.....

1.4.2 Referencing System Catalogs

System catalogs can be used to obtain information about the FUJITSU Enterprise Postgres system and database objects.

However, system catalogs may change when the FUJITSU Enterprise Postgres version is upgraded. Also, there are many system catalogs that return information that is inherent to FUJITSU Enterprise Postgres.

Accordingly, reference the information schema defined in standard SQL (`information_schema`) wherever possible. Note also that queries specifying "*" in the selection list must be avoided to prevent columns being added.



.....
Refer to "The Information Schema" under "Client Interfaces" in the PostgreSQL Documentation for details.
.....

The system catalog must be referenced to obtain information not found in the information schema. Instead of directly referencing the system catalog in the application, define a view for that purpose. Note, however, that when defining the view, the column name must be clearly specified after the view name.

An example of defining and using a view is shown below.



```
CREATE VIEW my_tablespace_view(spcname) AS SELECT spcname FROM pg_tablespace;  
SELECT * FROM my_tablespace_view V1, pg_tables T1 WHERE V1.spcname = T1.tablespace;
```

.....

If changes are made to a system catalog, the user will be able to take action by simply making changes to the view, without the need to make changes to the application.

The following shows an example of taking action by redefining a view as if no changes were made.

The `pg_tablespace` system catalog is redefined in response to the column name being changed from `spcname` to `spacename`.



Example

```
DROP VIEW my_tablespace_view;  
CREATE VIEW my_tablespace_view(spacename) AS SELECT spacename FROM pg_tablespace;
```

1.4.3 Using Functions

The default functions provided with FUJITSU Enterprise Postgres enable a variety of operations and manipulations to be performed, and information to be obtained, using SQL statements.

However, it is possible that internal FUJITSU Enterprise Postgres functions, such as those relating to statistical information or for obtaining system-related information, may change as FUJITSU Enterprise Postgres versions are upgraded.

Accordingly, when using these functions, define them as new functions and then use the newly-defined functions in the applications.

An example of defining and using a function is shown below.



Example

```
CREATE FUNCTION my_func(releid regclass) RETURNS bigint LANGUAGE SQL AS 'SELECT  
pg_relation_size(releid)';  
SELECT my_func(2619);
```

If changes are made to a function, the user will be able to take action by simply redefining the function, without the need to make changes to the application.

The following shows an example of taking action by redefining a function as if no changes were made.

The `pg_relation_size` function is redefined after arguments are added.



Example

```
DROP FUNCTION my_func(regclass);  
CREATE FUNCTION my_func(releid regclass) RETURNS bigint LANGUAGE SQL AS 'SELECT pg_relation_size(releid,  
$$main$$)';
```

Chapter 2 JDBC Driver

This section describes how to use JDBC drivers.

2.1 Development Environment

This section describes application development using JDBC drivers and the runtime environment.

2.1.1 Combining with JDK or JRE

Refer to Installation and Setup Guide for Client for information on combining with JDK or JRE where JDBC drivers can operate.

2.2 Setup

This section describes the environment settings required to use JDBC drivers and how to encrypt communication data.

2.2.1 Environment Settings

Configuration of the CLASSPATH environment variable is required as part of the runtime environment for JDBC drivers.

The name of the JDBC driver file is as follows:

- If using JDK 6 or JRE 6

```
postgresql-jdbc4.jar
```

- If using JDK 7 or JRE 7

```
postgresql-jdbc41.jar
```

- If using JDK 8, JRE 8, JDK 11 or JRE 11

```
postgresql-jdbc42.jar
```

The examples below show how to set the CLASSPATH environment variable if JDK 6 or JRE 6 is used.

If JDK 7, JRE 7, JDK 8, JRE 8, JDK 11 or JRE 11 is used, only the name of the JDBC driver file will be different. The method for configuring the CLASSPATH environment variable is the same.

Note that "<x>" indicates the product version.

- Setting example (TC shell)

```
setenv CLASSPATH /opt/fsepv<x>client64/jdbc/lib/postgresql-jdbc4.jar:${CLASSPATH}
```

- Setting example (bash)

```
CLASSPATH=/opt/fsepv<x>client64/jdbc/lib/postgresql-jdbc4.jar:$CLASSPATH;export CLASSPATH
```

2.2.2 Message Language and Encoding System Used by Applications Settings

If the JDBC driver is used, it will automatically set the encoding system on the client to UTF-8, so there is no need to configure this.



See

Refer to "Automatic Character Set Conversion Between Server and Client" in "Server Administration" in the PostgreSQL Documentation for information on encoding systems.

Language settings

You must match the language settings for the application runtime environment with the message locale settings of the database server.

Set language in the "user.language" system property.



Example

Example of running a Java command with system property specified

```
java -Duser.language=en TestClass1
```

2.2.3 Settings for Encrypting Communication Data

When using the communication data encryption feature to connect to the database server, set as follows:

Settings for encrypting communication data for connection to the server

This section describes how to create applications for encrypting communication data.

Set the property of the SSL parameter to "true" to encrypt. The default for the SSL parameter is "false".

If ssl is set to "true", sslmode is internally treated as "verify-full".



Example

- Setting example 1

```
String url = "jdbc:postgresql://sv1/test";
Properties props = new Properties();
props.setProperty("user", "fsepuser");
props.setProperty("password", "secret");
props.setProperty("ssl", "true");
props.setProperty("sslfactory", "org.postgresql.ssl.DefaultJavaSSLFactory");
Connection conn = DriverManager.getConnection(url, props);
```

- Setting example 2

```
String url = "jdbc:postgresql://sv1/test?
user=fsepuser&password=secret&ssl=true&sslfactory=org.postgresql.ssl.DefaultJavaSSLFactory";
Connection conn = DriverManager.getConnection(url);
```

To prevent spoofing of the database server, you need to use the keytool command included with Java to import the CA certificate to the Java keystore. In addition, specify "org.postgresql.ssl.DefaultJavaSSLFactory" for the sslfactory parameter.

Refer to JDK documentation for details.



Note

There is no need to set the ssl parameter if the connection string of the DriverManager class is specified, or if the sslmode parameter is specified in the data source, such as when the application connection switch feature is used. If the ssl parameter is set, the value in the sslmode parameter will be enabled.



See

Refer to "Secure TCP/IP Connections with SSL" in "Server Administration" in the PostgreSQL Documentation for information on encrypting communication data.

2.3 Connecting to the Database

This section explains how to connect to a database.

- [Using the DriverManager Class](#)
- [Using the PGConnectionPoolDataSource Class](#)
- [Using the PGXADataSource Class](#)



Do not specify "V2" for the "*protocolVersion*" of the connection string.

2.3.1 Using the DriverManager Class

To connect to the database using the DriverManager class, first load the JDBC driver, then specify the connection string as a URI in the API of the DriverManager class.

Load the JDBC driver

Specify `org.postgresql.Driver`.

Connection string

URI connection is performed as follows:

```
jdbc:postgresql://host:port/database?  
user=user&password=password1&loginTimeout=loginTimeout&socketTimeout=socketTimeout
```

Argument	Description
host	Specify the host name for the connection destination.
port	Specify the port number for the database server. The default is "27500".
database	Specify the database name.
user	Specify the username that will connect with the database. If this is omitted, the username logged into the operating system that is executing the application will be used.
password	Specify a password when authentication is required.
loginTimeout	Specify the timeout for connections (in units of seconds). Specify a value between 0 and 2147483647. There is no limit set if you set 0 or an invalid value. An error occurs when a connection cannot be established within the specified time.
socketTimeout	Specify the timeout for communication with the server (in units of seconds). Specify a value between 0 and 2147483647. There is no limit set if you set 0 or an invalid value. An error occurs when data is not received from the server within the specified time.



Example

Code examples for applications

```
import java.sql.*;  
...  
Class.forName("org.postgresql.Driver");  
String url = "jdbc:postgresql://sv1:27500/mydb?"
```

```
user=myuser&password=myuser01&loginTimeout=20&socketTimeout=20";
Connection con = DriverManager.getConnection(url);
```

2.3.2 Using the PGConnectionPoolDataSource Class

To connect to databases using data sources, specify the connection information in the properties of the data source.

Method description

Argument	Description
setServerName	Specify the host name for the connection destination.
setPortNumber	Specify the port number for the database server. The default is "27500".
setDatabaseName	Specify the database name.
setUser	Specify the username of the database. By default, the name used will be that of the user on the operating system that is executing the application.
setPassword	Specify a password for server authentication.
setLoginTimeout	Specify the timeout for connections (in units of seconds). Specify a value between 0 and 2147483647. There is no limit set if you set 0 or an invalid value. An error occurs when a connection cannot be established within the specified time.
setSocketTimeout	Specify the timeout for communication with the server (in units of seconds). Specify a value between 0 and 2147483647. There is no limit set if you set 0 or an invalid value. An error occurs when data is not received from the server within the specified time.



Example

Code examples for applications

```
import java.sql.*;
import org.postgresql.ds.PGConnectionPoolDataSource;
...
PGConnectionPoolDataSource source = new PGConnectionPoolDataSource();
source.setServerName("sv1");
source.setPortNumber(27500);
source.setDatabaseName("mydb");
source.setUser("myuser");
source.setPassword("myuser01");
source.setLoginTimeout(20);
source.setSocketTimeout(20);
...
Connection con = source.getConnection();
```

2.3.3 Using the PGXADataSource Class

To connect to databases using data sources, specify the connection information in the properties of the data source.

Method description

Argument	Description
setServerName	Specify the host name for the connection destination.
setPortNumber	Specify the port number for the database server.

Argument	Description
	The default is "27500".
setDatabaseName	Specify the database name.
setUser	Specify the username that will connect with the database. If this is omitted, the name used will be that of the user on the operating system that is executing the application.
setPassword	Specify a password when authentication by a password is required.
setLoginTimeout	Specify the timeout for connections. The units are seconds. Specify a value between 0 and 2147483647. There is no limit set if you set 0 or an invalid value. An error occurs when a connection cannot be established within the specified time.
setSocketTimeout	Specify the timeout for communication with the server. The units are seconds. Specify a value between 0 and 2147483647. There is no limit set if you set 0 or an invalid value. An error occurs when data is not received from the server within the specified time.

Example

Code examples for applications

```
import java.sql.*;
import org.postgresql.xa.PGXADDataSource;
...
PGXADDataSource source = new PGXADDataSource();
source.setServerName("sv1");
source.setPortNumber(27500);
source.setDatabaseName("mydb");
source.setUser("myuser");
source.setPassword("myuser01");
source.setLoginTimeout(20);
source.setSocketTimeout(20);...
Connection con = source.getConnection();
```

2.4 Application Development

This section describes the data types required when developing applications that will be connected with FUJITSU Enterprise Postgres.

2.4.1 Relationship between the Application Data Types and Database Data Types

The following table shows the correspondence between data types in applications and data types in databases.

Data type on the server	Java data type	Data types prescribed by java.sql.Types
character	String	java.sql.Types.CHAR
national character	String	java.sql.Types.NCHAR
character varying	String	java.sql.Types.VARCHAR
national character varying	String	java.sql.Types.NVARCHAR
text	String	java.sql.Types.VARCHAR

Data type on the server	Java data type	Data types prescribed by java.sql.Types
bytea	byte[]	java.sql.Types.BINARY
smallint	short	java.sql.Types.SMALLINT
integer	int	java.sql.Types.INTEGER
bigint	long	java.sql.Types.BIGINT
smallserial	short	java.sql.Types.SMALLINT
serial	int	java.sql.Types.INTEGER
bigserial	long	java.sql.Types.BIGINT
real	float	java.sql.Types.REAL
double precision	double	java.sql.Types.DOUBLE
numeric	java.math.BigDecimal	java.sql.Types.NUMERIC
decimal	java.math.BigDecimal	java.sql.Types.DECIMAL
money	String	java.sql.Types.OTHER
date	java.sql.Date	java.sql.Types.DATE
time with time zone	java.sql.Time	java.sql.Types.TIME
time without time zone	java.sql.Time	java.sql.Types.TIME
timestamp without time zone	java.sql.Timestamp	java.sql.Types.TIMESTAMP
timestamp with time zone	java.sql.Timestamp	java.sql.Types.TIMESTAMP
interval	org.postgresql.util.PGInterval	java.sql.Types.OTHER
boolean	boolean	java.sql.Types.BIT
bit	boolean	java.sql.Types.BIT
bit varying	org.postgresql.util.Pgobject	java.sql.Types.OTHER
oid	long	java.sql.Types.BIGINT
xml	java.sql.SQLXML	java.sql.Types.SQLXML
array	java.sql.Array	java.sql.Types.ARRAY
uuid	java.util.UUID	java.sql.Types.OTHER
point	org.postgresql.geometric.Pgpoint	java.sql.Types.OTHER
box	org.postgresql.geometric.Pgbox	java.sql.Types.OTHER
lseg	org.postgresql.geometric.Pglseg	java.sql.Types.OTHER
path	org.postgresql.geometric.Pgpath	java.sql.Types.OTHER
polygon	org.postgresql.geometric.PGpolygon	java.sql.Types.OTHER
circle	org.postgresql.geometric.PGcircle	java.sql.Types.OTHER
json	org.postgresql.util.PGobject	java.sql.Types.OTHER
Network address type (inet,cidr,macaddr, macaddr8)	org.postgresql.util.PGobject	java.sql.Types.OTHER
Types related to text searches (svector, tsquery)	org.postgresql.util.PGobject	java.sql.Types.OTHER
Enumerated type	org.postgresql.util.PGobject	java.sql.Types.OTHER
Composite type	org.postgresql.util.PGobject	java.sql.Types.OTHER
Range type	org.postgresql.util.PGobject	java.sql.Types.OTHER

Although the `getString()` method of the `ResultSet` object can be used for all server data types, it is not guaranteed that it will always return a string in the same format for the same data type.

Strings in a format compatible with the JDBC specifications can be obtained using the `Java toString()` method of the appropriate data type (for example, `getInt()`, `getTimestamp()`) to conform to the data type on the server.

2.4.2 Statement Caching Feature

The statement caching feature caches SQL statements for each individual connection. This means that when an SQL statement with an identical string is next executed, the analysis and creation of the statement can be skipped. This improves performance in cases such as when an SQL statement with an identical string is executed within a loop or method that is executed repeatedly. Furthermore, the statement caching feature can be combined with the connection pooling feature to further enhance performance.

Cache registration controls

You can configure whether to cache SQL statements using the `setPoolable(boolean)` method of the `PreparedStatement` class when the statement caching feature is enabled.

Values that can be configured are shown below:

`false`

SQL statements will not be cached, even when the statement caching feature is enabled.

`true`

SQL statements will be cached if the statement caching feature is enabled.

2.4.3 Creating Applications while in Database Multiplexing Mode

This section explains points to consider when creating applications while in database multiplexing mode.



See

- Refer to the Cluster Operation Guide (Database Multiplexing) for information on database multiplexing mode.

2.4.3.1 Errors when an Application Connection Switch Occurs and Corresponding Actions

If an application connection switch occurs while in database multiplexing mode, explicitly close the connection and then reestablish the connection or reexecute the application.

The table below shows errors that may occur during a switch, and the corresponding action to take.

State		Error information (*1)	Action
Server failure or FUJITSU Enterprise Postgres system failure	Failure occurs during access	57P01 08006 08007	After the switch is complete, reestablish the connection, or reexecute the application.
	Accessed during system failure	08001	
Switch to the standby server	Switched during access	57P01 08006 08007	
	Accessed during switch	08001	

*1: Return value of the `getSQLState()` method of `SQLException`.

Chapter 3 ODBC Driver

This section describes application development using ODBC drivers.

3.1 Development Environment

Applications using ODBC drivers can be developed using ODBC interface compatible applications.

Refer to the manuals for the programming languages corresponding to the ODBC interface for information about the environment for development.

FUJITSU Enterprise Postgres supports ODBC 3.5.

3.2 Setup

You need to set up PsqLODBC, which is an ODBC driver, in order to use applications that use ODBC drivers with FUJITSU Enterprise Postgres. PsqLODBC is included in the FUJITSU Enterprise Postgres client package.

The following describes how to register the ODBC drivers and the ODBC data source.

3.2.1 Registering ODBC Drivers

When using the ODBC driver on Linux platforms, register the ODBC driver using the following procedure:

1. Install the ODBC driver manager (unixODBC)

Information

- FUJITSU Enterprise Postgres supports unixODBC Version 2.3 or later.

You can download unixODBC from the following site:

<http://www.unixodbc.org/>

- To execute unixODBC, you must first install libtool 2.2.6 or later.

You can download libtool from the following website:

<http://www.gnu.org/software/libtool/>

[Note]

- ODBC driver operation is supported.
- unixODBC operation is not supported.

2. Register the ODBC drivers

Edit the ODBC driver manager (unixODBC) `odbcinst.ini` file.

Information

[location of the `odbcinst.ini` file]

```
unixOdbcInstallDir/etc/odbcinst.ini
```

Set the following content:

Definition name	Description	Setting value
[Driver name]	ODBC driver name	<p>Set the name of the ODBC driver.</p> <p>Select the two strings below that correspond to the application type. Concatenate the strings with no spaces, enclose in "[]", and then specify this as the driver name.</p> <p> Note</p> <p>The placeholders shown below are enclosed in angle brackets '<>' to avoid confusion with literal text. Do not include the angle brackets in the string.</p> <ul style="list-style-type: none"> - Application architecture <ul style="list-style-type: none"> "FUJITSUEnterprisePostgres<<i>fujitsuEnterprisePostgresClientVers</i>>s390x" - Encoding system used by the application <ul style="list-style-type: none"> - In Unicode (only UTF-8 can be used) <ul style="list-style-type: none"> "unicode" - Other than Unicode <ul style="list-style-type: none"> "ansi" <p>Example: The encoding system used by the application is Unicode: "[FUJITSUEnterprisePostgres<<i>fujitsuEnterprisePostgresClientVers</i>>s390xunicode]"</p>
Description	Description of the ODBC driver	Specify a supplementary description for the current data source. Any description may be set.
Driver64	Path of the ODBC driver (64-bit)	<p>Set the path of the ODBC driver (64-bit).</p> <ul style="list-style-type: none"> - If the encoding system is Unicode: <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <i>fujitsuEnterprisePostgresClientInstallDir</i>/odbc/lib/psqlodbcw.so </div> - If the encoding system is other than Unicode: <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <i>fujitsuEnterprisePostgresClientInstallDir</i>/odbc/lib/psqlodbc.a.so </div>
FileUsage	Use of the data source file	Specify 1.
Threading	Level of atomicity secured for connection pooling	Specify 2.

Example

Note that "<x>" indicates the product version.

```
[FUJITSU Enterprise Postgres12s390xunicode]
Description = FUJITSU Enterprise Postgres 12 s390x unicode driver
Driver64    = /opt/fsepv<x>client64/odbc/lib/psqlodbcw.so
FileUsage   = 1
Threading   = 2
```

3.2.2 Registering ODBC Data Sources

This section describes how to register ODBC data sources on Linux.

1. Register the data sources

Edit the `odbc.ini` definition file for the data source.

Information

Edit the file in the installation directory for the ODBC driver manager (unixODBC)

```
unixOdbcInstallDir/etc/odbc.ini
```

Or

Create a new file in the HOME directory

```
~/odbc.ini
```

Point

If `unixOdbcInstallDir` is edited, these will be used as the shared settings for all users that log into the system. If created in the HOME directory (`~`), the settings are used only by the single user.

Set the following content:

Definition name	Setting value
[Data source name]	Set the name for the ODBC data source.
Description	Set a description for the ODBC data source. Any description may be set.
Driver	<p>Set the following as the name of the ODBC driver. Do not change this value.</p> <p>Select the two strings below that correspond to the application type. Concatenate the strings with no spaces and then specify this as the driver name.</p> <p> Note</p> <p>The placeholders shown below are enclosed in angle brackets '<>' to avoid confusion with literal text. Do not include the angle brackets in the string.</p> <ul style="list-style-type: none"> - Application architecture <ul style="list-style-type: none"> "FUJITSU Enterprise Postgres<fujitsuEnterprisePostgresClientVers>s390x" - Encoding system used by the application <ul style="list-style-type: none"> - In Unicode (only UTF-8 can be used) <ul style="list-style-type: none"> "unicode" - Other than Unicode

Definition name	Setting value
	"ansi" Example: The encoding system used by the application is Unicode: "FUJITSU Enterprise Postgres<fujitsuEnterprisePostgresClient Vers>s390xunicode"
Database	Specify the database name to be connected.
Servename	Specify the host name for the database server.
Username	Specify the user ID that will connect with the database.
Password	Specify the password for the user that will connect to the database.
Port	Specify the port number for the database server. The default is "27500".
SSLMode	Specify the communication encryption method. The setting values for SSLMode are as follows: <ul style="list-style-type: none"> - disable: Connect without SSL - allow: Connect without SSL, and if it fails, connect using SSL - prefer: Connect using SSL, and if it fails, connect without SSL - require: Connect always using SSL - verify-ca: Connect using SSL, and use a certificate issued by a trusted CA (*1) - verify-full: Connect using SSL, and use a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
ReadOnly	Specify whether to set the database as read-only. <ul style="list-style-type: none"> - 1: Set read-only - 0: Do not set read-only

*1: If specifying either "verify-ca" or "verify-full", use the environment variable PGSSLROOTCERT to specify the CA certificate file as shown below.

Example

```
export PGSSLROOTCERT=cACertificateFileStorageDir/root.crt
```



Example

```
[MyDataSource]
Description      = FUJITSU Enterprise Postgres
Driver           = FUJITSU Enterprise Postgres12s390xansi
Database        = db01
Servename       = sv1
Port            = 27500
ReadOnly        = 0
```



Note

In consideration of security, specify the UserName and the Password by the application.

2. Configure the environment variable settings

To execute applications that use ODBC drivers, all of the following settings must be configured in the LD_LIBRARY_PATH environment variable:

- *fujitsuEnterprisePostgresClientInstallDir/lib*
- *unixOdbcInstallDir(*1)/lib*
- *libtoolInstallDir(*1)/lib*

*1: If the installation directory is not specified when unixODBC and libtool are installed, they will be installed in /usr/local.

3.2.3 Message Language and Encoding System Used by Applications Settings

This section explains the language settings for the application runtime environment and the encoding settings for the application.

Language settings

You must match the language settings for the application runtime environment with the message locale settings of the database server.

Messages output by an application may include text from messages sent from the database server. In the resulting text, the text of the application message will use the message locale of the application, and the text of the message sent by the database server will use the message locale of the database server. If the message locales do not match, more than one language or encoding system will be used. Moreover, if the encoding systems do not match, characters in the resulting text can be garbled.

Set the locale for messages (LC_MESSAGES category) to match the message locale of the database server. This can be done in a few different ways, such as using environment variables. Refer to the relevant manual of the operating system for information on the setlocale function.



Example

Example of specifying "en_US.UTF-8" with the setlocale function

```
setlocale(LC_ALL, "en_US.UTF-8");
```

Specifying the locale of the LC_ALL category propagates the setting to LC_MESSAGE.

Encoding System Settings

Ensure that the encoding system that is embedded in the application and passed to the database, and the encoding system setting of the runtime environment, are the same. The encoding system cannot be converted correctly on the database server.

Use one of the following methods to set the encoding system for the application:

- Set the PGCLIENTENCODING environment variable in the runtime environment.
- Set the client_encoding keyword in the connection string.
- Use the PQsetClientEncoding function.



See

Refer to "Supported Character Sets" in "Server Administration" in the PostgreSQL Documentation for information on the strings that represent the encoding system that can be set.

For example, when using "Unicode" and "8 bit", set the string "UTF8".



Example

Setting the "PGCLIENTENCODING" environment variable

An example of setting when the encoding of the client is "UTF8" (Bash)

```
> PGCLIENTENCODING=UTF8; export PGCLIENTENCODING
```

Note

Text may be garbled when outputting results to the command prompt. Review the font settings for the command prompt if this occurs.

3.3 Connecting to the Database

Refer to the manual for the programming language corresponding to the ODBC interface.

3.4 Application Development

This section describes how to develop applications using ODBC drivers.

3.4.1 Compiling Applications

Specify the following options when compiling applications.

Table 3.1 Include file and library path

Option	How to specify the option
Path of the include file	<code>-I <i>unixOdbc64bitIncludeFileDir</i></code>
Path of the library	<code>-L <i>unixOdbc64bitLibraryDir</i></code>

Table 3.2 ODBC library

Type of library	Library name
Dynamic library	libodbc.so

Note

Specify `-m64` when creating a 64-bit application.

Example

The following are examples of compiling ODBC applications:

```
gcc -m64 -I/usr/local/include(*1) -L/usr/local/lib(*1) -lodbc testproc.c -o testproc
```

*1: This is an example of building and installing from the source without specifying an installation directory for unixODBC. If you wish to specify a location, set the installation directory.

3.4.2 Creating Applications While in Database Multiplexing Mode

This section explains points to consider when creating applications while in database multiplexing mode.



See

- Refer to the Cluster Operation Guide (Database Multiplexing) for information on database multiplexing mode.

3.4.2.1 Errors when an Application Connection Switch Occurs and Corresponding Actions

If an application connection switch occurs while in database multiplexing mode, explicitly close the connection and then reestablish the connection or reexecute the application.

The table below shows errors that may occur during a switch, and the corresponding action to take.

State		Error information (*1)	Action
Server failure or FUJITSU Enterprise Postgres system failure	Failure occurs during access	57P01 08S01	After the switch is complete, reestablish the connection, or reexecute the application.
	Accessed during system failure	08001	
Switch to the standby server	Switched during access	57P01 08S01	
	Accessed during switch	08001	

*1: Return value of SQLSTATE.

Chapter 4 C Library (libpq)

This chapter describes how to use C libraries.

4.1 Development Environment

Install FUJITSU Enterprise Postgres Client Package for the architecture to be developed and executed.



See

Refer to Installation and Setup Guide for Client for information on the C compiler required for C application development.

4.2 Setup

This section describes the environment settings required to use C libraries and how to encrypt data for communication.

4.2.1 Environment Settings

To execute an application that uses libpq, set the environment variable as shown below.

- Required for compile/link
 - LD_LIBRARY_PATH
fujitsuEnterprisePostgresClientInstallDir/lib
- Required for execution of the application
 - PGLOCALEDIR
fujitsuEnterprisePostgresClientInstallDir/share/locale



Example

Note that "<x>" indicates the product version.

```
> LD_LIBRARY_PATH=/opt/fsepv<x>client64/lib:$LD_LIBRARY_PATH;export LD_LIBRARY_PATH
> PGLOCALEDIR=/opt/fsepv<x>client64/share/locale;export PGLOCALEDIR
```

4.2.2 Message Language and Encoding System Used by Applications Settings

This section explains the language settings for the application runtime environment and the encoding settings for the application.

Language settings

You must match the language settings for the application runtime environment with the message locale settings of the database server.

Messages output by an application may include text from messages sent from the database server. In the resulting text, the text of the application message will use the message locale of the application, and the text of the message sent by the database server will use the message locale of the database server. If the message locales do not match, more than one language or encoding system will be used. Moreover, if the encoding systems do not match, characters in the resulting text can be garbled.

Set the locale for messages (LC_MESSAGES category) to match the message locale of the database server. This can be done in a few different ways, such as using environment variables. Refer to the relevant manual of the operating system for information on the setlocale function.

Example

Example of specifying "en_US.UTF-8" with the setlocale function

```
setlocale(LC_ALL, "en_US.UTF-8");
```

Specifying the locale of the LC_ALL category propagates the setting to LC_MESSAGE.

Encoding System Settings

Ensure that the encoding system that is embedded in the application and passed to the database, and the encoding system setting of the runtime environment, are the same. The encoding system cannot be converted correctly on the database server.

Use one of the following methods to set the encoding system for the application:

- Set the PGCLIENTENCODING environment variable in the runtime environment.
- Set the client_encoding keyword in the connection string.
- Use the PQsetClientEncoding function.

See

Refer to "Supported Character Sets" in "Server Administration" in the PostgreSQL Documentation for information on the strings that represent the encoding system that can be set.

For example, when using "Unicode" and "8 bit", set the string "UTF8".

Note

Text may be garbled when outputting results to the command prompt. Review the font settings for the command prompt if this occurs.

4.2.3 Settings for Encrypting Communication Data

Set in one of the following ways when performing remote access using communication data encryption:

When setting from outside with environment variables

Specify "require", "verify-ca", or "verify-full" in the PGSSLMODE environment variable.

In addition, the parameters for the PGSSLROOTCERT and PGSSLCRL environment variables need to be set to prevent spoofing of the database server.

See

Refer to "Environment Variables" in "Client Interfaces" in the PostgreSQL Documentation for information on environment variables.

When specifying in the connection URI

Specify "require", "verify-ca", or "verify-full" in the "sslmode" parameter of the connection URI.

In addition, the parameters for the sslcert, sslkey, sslrootcert, and sslcrl need to be set to prevent spoofing of the database server.

See

Refer to "Secure TCP/IP Connections with SSL" in "Server Administration" in the PostgreSQL Documentation for information on encrypting communication data.

4.3 Connecting with the Database

Point

Use the connection service file to specify the connection destination. In the connection service file, a name (service name) is defined as a set, comprising information such as connection destination information and various types of tuning information set for connections. By using the service name defined in the connection service file when connecting to databases, it is no longer necessary to modify applications when the connection information changes.

Refer to "Client Interfaces", "The Connection Service File" in the PostgreSQL Documentation for details.

See

Refer to "Database Connection Control Functions" in "Client Interfaces" in the PostgreSQL Documentation.

In addition, refer to "5.3 Connecting with the Database" in "Embedded SQL in C " for information on connection string.

4.4 Application Development

See

Refer to "libpq - C Library" in "Client Interfaces" in the PostgreSQL Documentation for information on developing applications.

However, if you are using the C library, there are the following differences to the PostgreSQL C library (libpq).

4.4.1 Compiling Applications

Specify the following paths when compiling applications.

Refer to your compiler documentation for information on how to specify the path.

Table 4.1 Include file and library path

Type of path	Path name
Path of the include file	<i>fujitsuEnterprisePostgresClientInstallDir/include</i>
Path of the library	<i>fujitsuEnterprisePostgresClientInstallDir/lib</i>

Table 4.2 C Library (libpq library)

Type of library	Library name
Dynamic library	libpq.so
Static library	libpq.a

4.4.2 Creating Applications while in Database Multiplexing Mode

This section explains points to consider when creating applications while in database multiplexing mode.

See

- Refer to the Cluster Operation Guide (Database Multiplexing) for information on database multiplexing mode.

4.4.2.1 Errors when an Application Connection Switch Occurs and Corresponding Actions

If an application connection switch occurs while in database multiplexing mode, explicitly close the connection and then reestablish the connection or reexecute the application.

The table below shows errors that may occur during a switch, and the corresponding action to take.

State		Error information	Action
Server failure or FUJITSU Enterprise Postgres system failure	Failure occurs during access	PGRES_FATAL_ERROR(*1) 57P01(*2) NULL(*2)	After the switch is complete, reestablish the connection, or reexecute the application.
	Accessed during system failure	CONNECTION_BAD(*3)	
Switch to the standby server	Switched during access	PGRES_FATAL_ERROR(*1) 57P01(*2) NULL(*2)	
	Accessed during switch	CONNECTION_BAD(*3)	

*1: Return value of PQresultStatus().

*2: Return value of PQresultErrorField() PG_DIAG_SQLSTATE.

*3: Return value of PQstatus().

Chapter 5 Embedded SQL in C

This chapter describes application development using embedded SQL in C.

5.1 Development Environment

Install FUJITSU Enterprise Postgres Client Package for the architecture to be developed and executed.



See

Refer to Installation and Setup Guide for Client for information on the C compiler required for C application development.



Note

C++ is not supported. Create a library by implementing embedded SQL in C, and call it from C++.

5.2 Setup

5.2.1 Environment Settings

When using embedded SQL in C, the same environment settings as when using the C library (libpq) are required.

Refer to "4.2.1 Environment Settings" in "C Library (libpq)" for information on the environment settings for the library for C.

Additionally, set the following path for the precompiler ecpg in the PATH environment variable:

```
fujitsuEnterprisePostgresClientInstallDir/bin
```

5.2.2 Message Language and Encoding System Used by Applications Settings

The message language and the encoding System Settings Used by Applications settings are the same as when using the library for C.

However, in embedded SQL, the PQsetClientEncoding function cannot be used in the encoding system settings. In embedded SQL, use the SET command to specify the encoding system in client_encoding.

Refer to "4.2.2 Message Language and Encoding System Used by Applications Settings" in "C Library (libpq)" for information on the settings for the library for C.

5.2.3 Settings for Encrypting Communication Data

When encrypting the communication data, the same environment settings as when using the C library (libpq) are required.

Refer to "4.2.3 Settings for Encrypting Communication Data" in "C Library (libpq)" for information on the environment settings for the C library.

5.3 Connecting with the Database



Point

- It is recommended to use a connection service file to specify connection destinations. In the connection service file, a name (service name) is defined as a set, comprising information such as connection destination information and various types of tuning information set for connections. By using the service name defined in the connection service file when connecting to databases, it is no longer

necessary to modify applications when the connection information changes.
 Refer to "The Connection Service File" in "Client Interfaces" in the PostgreSQL Documentation for information.

- If using a connection service file, perform either of the procedures below:

- Set the service name as a string literal or host variable, as follows:

```
tcp:postgresql://?service=my_service
```

- Set the service name in the environment variable PGSERVICE, and use CONNECT TO DEFAULT



Use the CONNECT statement shown below to create a connection to the database server.

Format

```
EXEC SQL CONNECT TO target [AS connection-name] [USER user-name];
```

target

Write in one of the following formats:

- dbname@host:port
- tcp:postgresql://host:port/dbname[?options]
- unix:postgresql://host[:port][/dbname][?options]
 (Definition method when using the UNIX domain socket)
- SQL string literal containing one of the above formats
- Reference to a character variable containing one of the above formats
- DEFAULT

user-name

Write in one of the following formats:

- username
- username/password
- username IDENTIFIED BY password
- username USING password

Description of the arguments

Argument	Description
dbname	Specify the database name.
host	Specify the host name for the connection destination.
port	Specify the port number for the database server. The default is "27500".
connection-name	Specify connection names to identify connections when multiple connections are to be processed within a single program.
username	Specify the user that will connect with the database. If this is omitted, the name used will be that of the user on the operating system that is executing the application.
password	Specify a password when authentication is required.
options	Specify the following parameter when specifying a time for timeout. Connect parameters with & when specifying more than one. The following shows the values specified for each parameter. - connect_timeout

Argument	Description
	<p>Specify the timeout for connections.</p> <p>Specify a value between 0 and 2147483647 (in seconds). There is no limit set if you set 0 or an invalid value. If "1" is specified, the behavior will be the same as when "2" was specified. An error occurs when a connection cannot be established within the specified time.</p> <ul style="list-style-type: none"> - keepalives <p>This enables keepalive.</p> <p>Keepalive is disabled if 0 is specified. Keepalive is enabling when any other value is specified. The default is keepalive enabled. Keepalive causes an error to occur when it is determined that the connection with the database is disabled.</p> - keepalives_idle <p>Specify the time until the system starts sending keepalive messages when communication with the database is not being performed.</p> <p>Specify a value between 1 and 32767 (in seconds). The default value of the system is used if this is not specified.</p> - keepalives_interval <p>Specify the interval between resends when there is no response to keepalive messages.</p> <p>Specify a value between 1 and 32767 (in seconds). The default value of the system is used if this is not specified.</p> - keepalives_count <p>Specify the number of resends for keepalive messages.</p> <p>Specify a value between 1 and 127. The default value of the system is used if this is not specified.</p> - tcp_user_timeout <p>After establishing the connection, when sending from the client to the server, if the TCP resend process operates, specify the time until it is considered to be disconnected.</p> <p>Specify a value between 0 and 2147483647 (in milliseconds). The default value of the system is used if 0. 0 will be set as default if nothing is specified.</p>



Note

If a value other than 0 is specified for the tcp_user_timeout parameter, the waiting time set by the tcp_keepalives_idle parameter and tcp_keepalives_interval parameter will be invalid and the waiting time specified by the tcp_user_timeout parameter will be used.

Code examples for applications

```
EXEC SQL CONNECT TO tcp:postgresql://sv1:27500/mydb?
connect_timeout=20&keepalives_idle=20&keepalives_interval=5&keepalives_count=2&keepalives=1 USER
myuser/myuser01;
```

5.4 Application Development

Refer to "ECPG - Embedded SQL in C" in "Client Interfaces" in the PostgreSQL Documentation for information on developing applications.

However, when using embedded SQL in C, there are the following differences to the embedded SQL (ECPG) in PostgreSQL C.

5.4.1 Support for National Character Data Types

This section describes how to use the national character data types using the SQL embedded C preprocessor.

The following explains the C language variable types corresponding to the NCHAR type:

Specify the number of characters specified for the NCHAR type multiple by 4, plus 1 for the length of the host variable.

Data Type	Host variable type
NATIONAL CHARACTER(<i>n</i>)	NCHAR variable name [nx4+1]
NATIONAL CHARACTER VARYING(<i>n</i>)	NVARCHAR variable name [nx4+1]



See

Refer to "Handling Character Strings" in "Client Interfaces" in the PostgreSQL documentation for information on using character string types.

5.4.2 Compiling Applications

Append the extension "pgc" to the name of the source file for the embedded SQL in C.

When the pgc file is precompiled using the ecpg command, C source files will be created, so use the C compiler for the compile.

Precompiling example

```
ecpg testproc.pgc
```

If an optimizer hint block comment is specified for the SQL statement, specify the following option in the ecpg command:

--enable-hint

Enables the optimizer hint block comment (hereafter, referred to as the "hint clause"). If this option is not specified, the hint clause will be removed as a result of the ecpg precompile and be disabled.

The SQL statements that can be specified in the hint clause are SELECT, INSERT, UPDATE, and DELETE.

The locations in which the hint clause can be specified are immediately after one of the SELECT, INSERT, UPDATE, DELETE, or WITH keywords. A syntax error will occur if any other location is specified.

Example of specifying the hint clause

```
EXEC SQL SELECT /*+ IndexScan(prod ix01) */ name_id INTO :name_id FROM prod WHERE id = 1;
```

Refer to "9.1.1 Optimizer Hints" for information on optimizer hints.



Note

Take the following points into account when using embedded SQL source files:

- Multibyte codes expressed in SJIS or UTF-16 cannot be included in statements or host variable declarations specified in EXEC SQL.
- Do not use UTF-8 with a byte order mark (BOM), because an error may occur during compilation if the BOM character is incorrectly recognized as the source code.
- Multibyte characters cannot be used in host variable names.
- It is not possible to use a TYPE name that contains multibyte characters, even though it can be defined.

Specify the following paths when compiling a C application output with precompiling.

Refer to your compiler documentation for information on how to specify the path.

Table 5.1 Include file and library path

Type of path	Path name
Path of the include file	<i>fujitsuEnterprisePostgresClientInstallDir/include</i>
Path of the library	<i>fujitsuEnterprisePostgresClientInstallDir/lib</i>

Table 5.2 C Library

Type of library	Library name	Note
Dynamic library	libecpg.so	
	libpgtypes.so	When using the pgtypes library
Static library	libecpg.a	
	libpgtypes.a	When using the pgtypes library

5.4.3 Bulk INSERT

This section describes the bulk INSERT.

Synopsis

```
EXEC SQL [ AT conn ] [ FOR { numOfRows | ARRAY_SIZE } ]
INSERT INTO tableName [ ( colName [, ...] ) ]
{ VALUES ( { expr | DEFAULT } [, ...] ) [, ...] | query }
[ RETURNING * | outputExpr [ [ AS ] outputName ] [, ...]
INTO outputHostVar [ [ INDICATOR ] indicatorVar ] [, ...] ];
```

Description

Bulk INSERT is a feature that inserts multiple rows of data in bulk.

By specifying the array host variable that stored the data in the VALUES clause of the INSERT statement, the data for each element in the array can be inserted in bulk. This feature is used by specifying the insertion count in the FOR clause immediately before the INSERT statement.

FOR Clause

Specify the insertion count using *numOfRows* or *ARRAY_SIZE* in the FOR clause. The FOR clause can be specified only in the INSERT statement, not in other update statements.

numOfRows and *ARRAY_SIZE*

Insertion processing will be executed only for the specified count. However, if the count is 1, it will be assumed that the FOR clause was omitted when the application is executed. In this case, proceed according to the INSERT specification in the PostgreSQL Documentation.

Specify the FOR clause as an integer host variable or as a literal.

Specify *ARRAY_SIZE* to insert all elements of the array in the table. When specifying *ARRAY_SIZE*, specify at least one array in *expr*.

If two or more arrays were specified in *expr*, it will be assumed that *ARRAY_SIZE* is the minimum number of elements in the array.

numOfRows or *ARRAY_SIZE* must exceed the minimum number of elements in all arrays specified in *expr*, *outputHostVar*, and *indicatorVal*.

The following example shows how to specify the FOR clause.

```

int number_of_rows = 10;
int id[25];
char name[25][10];

EXEC SQL FOR :number_of_rows      /* will process 10 rows */
INSERT INTO prod (name, id) VALUES (:name, :id);

EXEC SQL FOR ARRAY_SIZE           /* will process 25 rows */
INSERT INTO prod (name, id) VALUES (:name, :id);

```

expr

Specify the value to be inserted in the table. Array host variables, host variable literals, strings, and pointer variables can be specified. Structure type arrays and pointer variable arrays cannot be specified.

Do not use pointer variables and ARRAY_SIZE at the same time. The reason for this is that the number of elements in the area represented by the pointer variable cannot be determined.

query

A query (SELECT statement) that supplies the rows to be inserted. The number of rows returned by *query* must be 1. If two or more rows are returned, an error will occur. This cannot be used at the same time as ARRAY_SIZE.

outputHostVar, indicatorVal

These must be array host variables or pointer variables.

Error Messages

Given below are the error messages that are output when bulk INSERT functionality is not used correctly.

Message

invalid statement name "FOR value should be positive integer"

Cause

The value given for *numOfRows* is less than or equal to 0.

Solution

Specify a value that is more than or equal to 1 for *numOfRows*.

Message

invalid statement name "Host array variable is needed when using FOR ARRAY_SIZE"

Cause

A host array is not specified in the values clause when using the ARRAY_SIZE keyword.

Solution

At least one host array variable should be included in the values clause

Message

SELECT...INTO returns too many rows

Cause

The number of rows returned by the 'SELECT ... INTO' query in the INSERT statement is more than one.

Solution

When the value of *numOfRows* is more than one, the maximum number of rows that can be returned by the 'SELECT ... INTO' query in the INSERT statement is one.

Limitations

The limitations when using bulk INSERT are given below.

- Array of structures should not be used as an input in the 'VALUES' clause. Attempted use will result in junk data being inserted into the table.
- Array of pointers should not be used as an input in the 'VALUES' clause. Attempted use will result in junk data being inserted into the table.
- ECPG supports the use of 'WITH' clause in single INSERT statements. 'WITH' clause cannot be used in bulk INSERT statements.
- ECPG does not calculate the size of the pointer variable. So when a pointer variable is used that includes multiple elements, *numOfRows* should be less than or equal to the number of elements in the pointer. Otherwise, junk data will be inserted into the table.
- If an error occurs, all bulk INSERT actions will be rolled back, therefore, no rows are inserted. However, if the RETURNING clause was used, and the error occurred while obtaining the rows after the insertion was successful, the insertion processing will not be rolled back.

Samples

Given below are some sample usages of the bulk INSERT functionality.

Basic Bulk INSERT

```
int in_f1[4] = {1,2,3,4};
...
EXEC SQL FOR 3 INSERT INTO target (f1) VALUES (:in_f1);
```

The number of rows to insert indicated by the FOR clause is 3, so the data in the first 3 elements of the host array variable are inserted into the table. The contents of the target table will be:

```
f1
----
 1
 2
 3
(3 rows)
```

Also a host integer variable can be used to indicate the number of rows that will be inserted in FOR clause, which will produce the same result as above:

```
int num = 3;
int in_f1[4] = {1,2,3,4};
...
EXEC SQL FOR :num INSERT INTO target (f1) VALUES (:in_f1);
```

Inserting constant values

Constant values can also be bulk INSERTed into the table as follows:

```
EXEC SQL FOR 3 INSERT INTO target (f1,f2) VALUES (DEFAULT,'hello');
```

Assuming the 'DEFAULT' value for the 'f1' column is '0', the contents of the target table will be:

```
f1 | f2
---+-----
 0 | hello
 0 | hello
 0 | hello
(3 rows)
```

Using ARRAY_SIZE

'FOR ARRAY_SIZE' can be used to insert the entire contents of a host array variable, without explicitly specifying the size, into the table.

```

int in_f1[4] = {1,2,3,4};
...
EXEC SQL FOR ARRAY_SIZE INSERT INTO target (f1) VALUES (:in_f1);

```

In the above example, four rows are inserted into the table.

Note

If there are multiple host array variables specified as input values, then the number of rows inserted is same as the smallest array size. The example given below demonstrates this usage.

```

int in_f1[4] = {1,2,3,4};
char in_f3[3][10] = {"one", "two", "three"};
...
EXEC SQL FOR ARRAY_SIZE INSERT INTO target (f1,f3) VALUES (:in_f1,:in_f3);

```

In the above example, the array sizes are 3 and 4. Given that the smallest array size is 3, only three rows are inserted into the table. The table contents are given below.

```

f1 | f3
---+-----
 1 | one
 2 | two
 3 | three
(3 rows)

```

Using Pointers as Input

Pointers that contain multiple elements can be used in bulk INSERT.

```

int *in_pfl = NULL;
in_pfl = (int*)malloc(4*sizeof(int));
in_pfl[0]=1;
in_pfl[1]=2;
in_pfl[2]=3;
in_pfl[3]=4;
...
EXEC SQL FOR 4 INSERT INTO target (f1) values (:in_pfl);

```

The above example will insert four rows into the target table.

Using SELECT query

When using bulk INSERT, the input values can be got from the results of a SELECT statement. For example,

```

EXEC SQL FOR 4 INSERT INTO target(f1) SELECT age FROM source WHERE name LIKE 'foo';

```

Assuming that the 'SELECT' query returns one row, the same row will be inserted into the target table four times.

Note

If the 'SELECT' query returns more than one row, the INSERT statement will throw an error.

```

EXEC SQL FOR 1 INSERT INTO target(f1) SELECT age FROM source;

```

In the above example, all the rows returned by the 'SELECT' statement will be inserted into the table. In this context '1' has the meaning of 'returned row equivalent'.

Using RETURNING clause

Bulk INSERT supports the same RETURNING clause syntax as normal INSERT. An example is given below.

```
int out_f1[4];
int in_f1[4] = {1,2,3,4};
...
EXEC SQL FOR 3 INSERT INTO target (f1) VALUES (:in_f1) RETURNING f1 INTO :out_f1;
```

After the execution of the above INSERT statement, the 'out_f1' array will have 3 elements with the values of '1','2' and '3'.

5.4.4 DECLARE STATEMENT

This section describes the DECLARE STATEMENT.

Synopsis

```
EXEC SQL [ AT connName ] DECLARE statementName STATEMENT;
```

Description

DECLARE STATEMENT is an embedded SQL command that declares an identifier for a prepared statement. The declared identifier can be used as an identifier in a prepared statement for the following SQL commands:

- EXECUTE
- DECLARE
- DESCRIBE
- PREPARE (Embedded SQL commands)
- PREPARE (SQL commands)

You can associate an identifier in a prepared statement with a connection by executing a DECLARE STATEMENT that specifies the connection. If you specify an identifier associated with the connection in a later SQL command, the SQL command is executed using the connection associated with the identifier. The association between the connection and the identifier in the prepared statement is shared throughout the process.

Only one connection can be associated with a prepared statement of the same name. If you make multiple associations across files, subsequent DECLARE STATEMENT are ignored. If you associate the same file more than once, precompiling the file fails.

If you use the identifier associated with a connection in a SQL command, do not use the AT clause. If a connection different from the connection linked to the identifier using the AT clause is selected, a runtime error will occur.

Parameters

connName

A database connection name established by the CONNECT command.

If AT clause is omitted, no association is made between the connection and the identifier. DECLARE STATEMENT is executed, but has no effect.

statementName

Specify the identifier of the prepared statement. You can specify either a SQL identifier or a host variable.

Examples

Dynamic SQL statement

DECLARE STATEMENT is primarily used to execute dynamic SQL statements.

```
EXEC SQL BEGIN DECLARE SECTION;
char dbname[128];
EXEC SQL END DECLARE SECTION;
...
```

```
EXEC SQL CONNECT TO postgres AS con1;
EXEC SQL CONNECT TO another_database AS con2;
EXEC SQL AT con1 DECLARE sql_stmt STATEMENT;
EXEC SQL DECLARE cursor_name CURSOR FOR sql_stmt;
EXEC SQL PREPARE sql_stmt FROM "SELECT current_database()";
EXEC SQL OPEN cursor_name;
EXEC SQL FETCH cursor_name INTO :dbname;
EXEC SQL CLOSE cursor_name;
```

In the example above, the connection 'con1' is associated with the prepared statement identifier 'sql_stmt'. So the current connection is 'con2', but the embedded SQL commands that follow are executed on 'con1'.

PREPARE AS statement

The following is an example using a PREPARE statement in the SQL command:

```
EXEC SQL AT db1 DECLARE stmt STATEMENT;
EXEC SQL PREPARE stmt (int) AS
    SELECT * FROM employee WHERE id = $1;
EXEC SQL EXECUTE stmt USING 1;
```

The above SELECT statement is executed on the connection 'db1'.

Compatibility

DECLARE STATEMENT is not specified in the SQL standard.

See Also

EXECUTE, DECLARE, DESCRIBE, PREPARE (Embedded SQL commands), PREPARE (SQL commands)



See

- Refer to "Embedded SQL Commands" in "Client Interfaces" in the PostgreSQL documentation for information on the embedded SQL commands.
- Refer to "SQL Commands" in "Reference" in the PostgreSQL documentation for information on the SQL commands.

5.4.5 Creating Applications while in Database Multiplexing Mode

This section explains points to consider when creating applications while in database multiplexing mode.



See

- Refer to the Cluster Operation Guide (Database Multiplexing) for information on database multiplexing mode.

5.4.5.1 Errors when an Application Connection Switch Occurs and Corresponding Actions

If an application connection switch occurs while in database multiplexing mode, explicitly close the connection and then reestablish the connection or reexecute the application.

The table below shows errors that may occur during a switch, and the corresponding action to take.

State		Error information (*1)	Action
Server failure or	Failure occurs	57P01	After the switch is complete, reestablish the
	during access	57P02	

State		Error information (*1)	Action
FUJITSU Enterprise Postgres system failure		YE000 26000 40001	connection, or reexecute the application.
	Accessed during node/system failure	08001	
Switch to the standby server	Switched during access	57P01 57P02 YE000 26000 40001	
	Accessed during switch	08001	

*1: Return value of SQLSTATE.

5.4.6 Notes

Notes on creating multithreaded applications

In embedded SQL in C, DISCONNECT ALL disconnects all connections within a process, and therefore it is not thread-safe in all operations that use connections. Do not use it in multithreaded applications.

Chapter 6 SQL References

This chapter explains the SQL statement features expanded by FUJITSU Enterprise Postgres.

6.1 Expanded Trigger Definition Feature

This section explains the expanded trigger definition feature.

6.1.1 CREATE TRIGGER

In addition to features of PostgreSQL, triggers can be created with OR REPLACE option and DO option.

Synopsis

```
CREATE [ OR REPLACE ] [ CONSTRAINT ] TRIGGER name { BEFORE | AFTER | INSTEAD OF } { event [ OR ... ] }
ON table_name
[ FROM referenced_table_name ]
[ NOT DEFERRABLE | [ DEFERRABLE ] [ INITIALLY IMMEDIATE | INITIALLY DEFERRED ] ]
[ REFERENCING { { OLD | NEW } TABLE [ AS ] transition_relation_name } [ ... ] ]
[ FOR [ EACH ] { ROW | STATEMENT } ]
[ WHEN ( condition ) ]
{ EXECUTE { FUNCTION | PROCEDURE } function_name ( arguments )
  | DO [ LANGUAGE lang_name ] code }
```

Description

Refer to the PostgreSQL Documentation for information about CREATE TRIGGER. This section describes OR REPLACE option and DO option.

A trigger which is created with OR REPLACE option and DO option will be associated with the specified table or view and will execute the specified code by the specified procedural language of DO (unnamed code block) when certain events occur.

Parameters

OR REPLACE

If the specified trigger is not defined in the table, it defines a new trigger.

If the specified trigger is already defined in the table, the named trigger replaces existing trigger.

code

When the certain events occur, it executes the code in a specified procedural language. The unnamed code block does not require a prior definition like a function. Syntax is same as procedural language.

lang_name

The name of the language that the function is implemented in. Can be SQL, C, internal, or the name of a user-defined procedural language. The default is 'plpgsql'.

plpgsql is supported in CREATE TRIGGER.



Note

- A normal trigger cannot be replaced by a constraint trigger.
- A constraint trigger cannot be replaced by a normal trigger.
- A trigger defined with DO option cannot be replaced by a trigger defined with EXECUTE PROCEDURE option.
- A trigger defined with EXECUTE PROCEDURE option cannot be replaced by a trigger defined with DO option.

Examples

It executes the code block that is specified by DO before the table is updated.
(Example that LANGUAGE is plpgsql)

```
CREATE TRIGGER check_update
  BEFORE UPDATE ON accounts
  FOR EACH ROW
  DO $$BEGIN RETURN NEW; END;$$ ;
```



Information

When a trigger created with DO option, a new function is created internally. The name of function is "schema name"."on table name"_"trigger name"_TRIGPROC(serial number).

Chapter 7 Compatibility with Oracle Databases

This chapter describes the environment settings and functionality offered for features that are compatible with Oracle databases.

7.1 Overview

Features compatible with Oracle databases are provided. These features enable you to easily migrate to FUJITSU Enterprise Postgres and reduce the costs of reconfiguring applications.

The table below lists features compatible with Oracle databases.

Table 7.1 Features compatible with Oracle databases

Category		Feature	
		Item	Overview
SQL	Queries	Outer join operator (+)	Operator for outer joins
		DUAL table	Table provided by the system
	Functions	DECODE	Compares values, and if they match, returns a corresponding value
		SUBSTR	Extracts part of a string using characters to specify position and length
		NVL	Returns a substitute value when a value is NULL
Package	DBMS_OUTPUT	Sends messages to clients	
	UTL_FILE	Enables text file operations	
	DBMS_SQL	Enables dynamic SQL execution	



See

In addition to the above, refer to the file below for information on the Oracle function.

fujitsuEnterprisePostgresInstallDir/share/doc/extension/README.asciidoc

7.2 Precautions when Using the Features Compatible with Oracle Databases

This section provides notes on using the features compatible with Oracle databases.

7.2.1 Notes on SUBSTR

SUBSTR is implemented in FUJITSU Enterprise Postgres and Oracle databases using different external specifications.

For this reason, when using SUBSTR, define which specification is to take precedence. In the default configuration of FUJITSU Enterprise Postgres, the specifications of FUJITSU Enterprise Postgres take precedence.

When using the SUBSTR function compatible with Oracle databases, set "oracle" and "pg_catalog" in the "search_path" parameter of postgresql.conf. You must specify "oracle" before "pg_catalog" when doing this.

```
search_path = '$user', public, oracle, pg_catalog'
```



Information

- The search_path parameter specifies the order in which schemas are searched. The SUBSTR function in Oracle databases is defined in the oracle schema.

- Refer to "Statement Behavior" in "Client Connection Defaults" in "Server Administration" in the PostgreSQL Documentation for information on `search_path`.

7.2.2 Notes when Integrating with the Interface for Application Development

The SQL noted in "Table 7.1 Features compatible with Oracle databases" can be used in the interface for application development.

Note that both "public" and the schema name in the SQL statement must be specified as the `SearchPath` parameter before "oracle" and "pg_catalog" when using the Oracle database-compatible feature `SUBSTR`.

7.3 Queries

The following queries are supported:

- [Outer Join Operator \(+\)](#)
- [DUAL Table](#)

7.3.1 Outer Join Operator (+)

In the `WHERE` clause conditional expression, by adding the plus sign (+), which is the outer join operator, to the column of the table you want to add as a table join, it is possible to achieve an outer join that is the same as a joined table (`OUTER JOIN`).

Syntax

SELECT statement

```
SELECT ... [WHERE [NOT] joinCond ...] ...  
SELECT ... [WHERE srchCond ]... ] ...
```

Join condition

```
{ colSpec(+) = colSpec | colSpec = colSpec(+) }
```



Note

Here we are dealing only with the `WHERE` clause of the `SELECT` statement. Refer to "SQL Commands" in "Reference" in the PostgreSQL Documentation for information on the overall syntax of the `SELECT` statement.

General rules

`WHERE` clause

- The `WHERE` clause specifies search condition or join conditions for the tables that are derived.
- Search conditions are any expressions that return `BOOLEAN` types as the results of evaluation. Any rows that do not meet these conditions are excluded from the output. When the values of the actual rows are assigned to variables and if the expression returns `TRUE`, those rows are considered to have met the conditions.
- Join conditions are comparison conditions that specify outer join operators. Join conditions in a `WHERE` clause return a table that includes all the rows that meet the join conditions, including rows that do not meet all the join conditions.
- Join conditions take precedence over search conditions. For this reason, all rows returned by the join conditions are subject to the search conditions.
- The following rules and restrictions apply to queries that use outer join operators. It is therefore recommended to use `FROM` clause joined tables (`OUTER JOIN`) rather than outer join operators:
 - Outer join operators can only be specified in the `WHERE` clause.
 - Outer join operators can only be specified for base tables or views.
 - To perform outer joins using multiple join conditions, it is necessary to specify outer join operators for all join conditions.

- When combining join conditions with constants, specify outer join operators in the corresponding column specification. When not specified, they will be treated as search conditions.
- The results column of the outer join of table t1 is not returned if table t1 is joined with table t2 by specifying an outer join operator in the column of t1, then table t1 is joined with table t3 by using search conditions.
- It is not possible to specify columns in the same table as the left/right column specification of a join condition.
- It is not possible to specify an expression other than a column specification for outer join operators, but they may be specified for the columns that compose the expression.

There are the following limitations on the functionality of outer join operators when compared with joined tables (OUTER JOIN). To use functionality that is not available with outer join operators, use joined tables (OUTER JOIN).

Table 7.2 Range of functionality with outer join operators

Functionality available with joined tables (OUTER JOIN)	Outer join operator
Outer joins of two tables	Y
Outer joins of three or more tables	Y (*1)
Used together with joined tables within the same query	N
Use of the OR logical operator to a join condition	N
Use of an IN predicate to a join condition	N
Use of subqueries to a join condition	N

Y: Available

N: Not available

*1: The outer joins by outer join operators can return outer join results only for one other table. For this reason, to combine outer joins of table t1 and table t2 or table t2 and table t3, it is not possible to specify outer join operators simultaneously for table t2.

Example

Table configuration

t1

col1	col2	col3
1001	AAAAA	1000
1002	BBBBB	2000
1003	CCCCC	3000

t2

col1	col2
1001	aaaaa
1002	bbbbb
1004	ddddd

Example 1: Return all rows in table t2, including those that do not exist in table t1.

```
SELECT *
  FROM t1, t2
 WHERE t1.col1(+) = t2.col1;
col1 | col2 | col3 | col1 | col2
-----+-----+-----+-----+-----
```

```

1001 | AAAAA      | 1000 | 1001 | aaaaa
1002 | BBBBB      | 2000 | 1002 | bbbbb
      |            |      | 1004 | ddddd
(3 rows)

```

This is the same syntax as the joined table (OUTER JOIN) of the FROM clause shown next.

```

SELECT *
FROM t1 RIGHT OUTER JOIN t2
      ON t1.col1 = t2.col1;

```

Example 2: In the following example, the results are filtered to records above 2000 in t1.col3 by search conditions, and the records are those in table t2 that include ones that do not exist in table t1. After filtering with the join conditions, there is further filtering with the search conditions, so there will only be one record returned.

```

SELECT *
FROM t1, t2
WHERE t1.col1(+) = t2.col1
      AND t1.col3 >= 2000;
col1 | col2 | col3 | col1 | col2
-----+-----+-----+-----+-----
1002 | BBBBB      | 2000 | 1002 | bbbbb
(1 row)

```

This is the same syntax as the joined table (OUTER JOIN) of the FROM clause shown next.

```

SELECT *
FROM t1 RIGHT OUTER JOIN t2
      ON t1.col1 = t2.col1
WHERE t1.col3 >= 2000;

```

7.3.2 DUAL Table

DUAL table is a virtual table provided by the system. Use when executing SQL where access to a base table is not required, such as when performing tests to get result expressions such as functions and operators.



Example

In the following example, the current system date is returned.

```

SELECT CURRENT_DATE "date" FROM DUAL;
      date
-----
2013-05-14
(1 row)

```

7.4 SQL Function Reference

The following SQL functions are supported:

- [DECODE](#)
- [SUBSTR](#)
- [NVL](#)

7.4.1 DECODE

Description

Compares values and if they match, returns a corresponding value.

Syntax

```
DECODE(expr, srch, result [, srch, result ]... [, default ])
```

General rules

- DECODE compares values of the value expression to be converted and the search values one by one. If the values match, a corresponding result value is returned. If no values match, the default value is returned if it has been specified. A NULL value is returned if a default value has not been specified.
- If the same search value is specified more than once, then the result value returned is the one listed for the first occurrence of the search value.
- The following data types can be used in result values and in the default value:
 - CHAR
 - VARCHAR
 - NCHAR
 - NCHAR VARYING
 - TEXT
 - INTEGER
 - BIGINT
 - NUMERIC
 - DATE
 - TIME WITHOUT TIME ZONE
 - TIMESTAMP WITHOUT TIME ZONE
 - TIMESTAMP WITH TIME ZONE
- The same data type must be specified for the values to be converted and the search values. However, note that different data types may also be specified if a literal is specified in the search value, and the value expression to be converted contains data types that can be converted. When specifying literals, refer to "[Table A.1 Data type combinations that contain literals and can be converted implicitly](#)" in "[A.3 Implicit Data Type Conversions](#)" for information on the data types that can be specified.
- If the result values and default value are all literals, the data types for these values will be as shown below:
 - If all values are string literals, all will become character types.
 - If there is one or more numeric literal, all will become numeric types.
 - If there is one or more literal cast to the datetime/time types, all will become datetime/time types.
- If the result values and default value contain a mixture of literals and non-literals, the literals will be converted to the data types of the non-literals. When specifying literals, refer to "[Table A.1 Data type combinations that contain literals and can be converted implicitly](#)" in "[A.3 Implicit Data Type Conversions](#)" for information on the data types that can be converted.
- The same data type must be specified for all result values and for the default value. However, different data types can be specified if the data type of any of the result values or default value can be converted - these data types are listed below:

Table 7.3 Data type combinations that can be converted by DECODE (summary)

		Other result values or default value		
		Numeric type	Character type	Date/time type
Result value (any)	Numeric type	Y	N	N
	Character type	N	Y	N
	Date/time type	N	N	S (*1)

Y: Can be converted

S: Some data types can be converted

N: Cannot be converted

*1: The data types that can be converted for date/time types are listed below:

Table 7.4 Result value and default value date/time data types that can be converted by DECODE

		Other result values or default value			
		DATE	TIME WITHOUT TIME ZONE	TIMESTAMP WITHOUT TIME ZONE	TIMESTAMP WITH TIME ZONE
Result value (any)	DATE	Y	N	Y	Y
	TIME WITHOUT TIME ZONE	N	Y	N	N
	TIMESTAMP WITHOUT TIME ZONE	Y	N	Y	Y
	TIMESTAMP WITH TIME ZONE	Y	N	Y	Y

Y: Can be converted

N: Cannot be converted

- The data type of the return value will be the data type within the result or default value that is longest and has the highest precision.

Example

In the following example, the value of col3 in table t1 is compared and converted to a different value. If the col3 value matches search value 1, the result value returned is "one". If the col3 value does not match any of search values 1, 2, or 3, the default value "other number" is returned.

```
SELECT col1, DECODE(col3, 1000, 'one',
                    2000, 'two',
                    3000, 'three',
                    'other number') "num-word"
FROM t1;
col1 | num-word
-----+-----
1001 | one
1002 | two
1003 | three
(3 rows)
```

7.4.2 SUBSTR

Description

Extracts part of a string using characters to specify position and length.

Syntax

```
SUBSTR(str, startPos [, len ])
```

General rules

- SUBSTR extracts and returns a substring of string *str*, beginning at position *startPos*, for number of characters *len*.
- When *startPos* is positive, it will be the number of characters from the beginning of the string.
- When *startPos* is 0, it will be treated as 1.
- When *startPos* is negative, it will be the number of characters from the end of the string.
- When *len* is not specified, all characters to the end of the string are returned. NULL is returned when *len* is less than 1.
- For *startPos* and *len*, specify a SMALLINT or INTEGER type. When specifying literals, refer to "[Table A.1 Data type combinations that contain literals and can be converted implicitly](#)" in "[A.3 Implicit Data Type Conversions](#)" for information on the data types that can be specified.
- The data type of the return value is TEXT.

Note

- There are two types of SUBSTR. One that behaves as described above, and one that behaves the same as SUBSTRING. The *search_path* parameter must be modified for it to behave the same as the specification described above.
- It is recommended to set *search_path* in *postgresql.conf*. In this case, it will be effective for each instance. Refer to "[7.2.1 Notes on SUBSTR](#)" for information on how to configure *postgresql.conf*.
- The configuration of *search_path* can be done at the user level or at the database level. Setting examples are shown below.
 - Example of setting at the user level

This can be set by executing an SQL command. In this example, *user1* is used as the username.

```
ALTER USER user1 SET search_path = "$user",public,oracle,pg_catalog;
```

- Example of setting at the database level

This can be set by executing an SQL command. In this example, *db1* will be used as the database name.

```
ALTER DATABASE db1 SET search_path = "$user",public,oracle,pg_catalog;
```

You must specify "oracle" before "pg_catalog".

- If the change has not been implemented, SUBSTR is the same as SUBSTRING.

See

Refer to "SQL Commands" in "Reference" in the PostgreSQL Documentation for information on ALTER USER and ALTER DATABASE.

Information

The general rules for SUBSTRING are as follows:

- The start position will be from the beginning of the string, whether positive, 0, or negative.
- When *len* is not specified, all characters to the end of the string are returned.
- An empty string is returned if no string is extracted or *len* is less than 1.



See

Refer to "String Functions and Operators" under "The SQL Language" in the PostgreSQL Documentation for information on SUBSTRING.



Example

In the following example, part of the string "ABCDEFGH" is extracted:

```
SELECT SUBSTR('ABCDEFGH',3,4) "Substring" FROM DUAL;
```

```
Substring
-----
CDEF
(1 row)
```

```
SELECT SUBSTR('ABCDEFGH',-5,4) "Substring" FROM DUAL;
```

```
Substring
-----
(1 row)
```

7.4.3 NVL

Description

Returns a substitute value when a value is NULL.

Syntax

```
NVL(expr1, expr2)
```

General rules

- NVL returns a substitute value when the specified value is NULL. When *expr1* is NULL, *expr2* is returned. When *expr1* is not NULL, *expr1* is returned.
- Specify the same data types for *expr1* and *expr2*. However, if a constant is specified in *expr2*, and the data type can also be converted by *expr1*, different data types can be specified. When this happens, the conversion by *expr2* is done to suit the data type in *expr1*, so the value of *expr2* returned when *expr1* is a NULL value will be the value converted in the data type of *expr1*.
- When specifying literals, refer to "[Table A.1 Data type combinations that contain literals and can be converted implicitly](#)" in "[A.3 Implicit Data Type Conversions](#)" for information on the data types that can be converted.



Example

In the following example, "IS NULL" is returned if the value of col1 in table t1 is a NULL value.

```
SELECT col2, NVL(col1, 'IS NULL') "nvl" FROM t1;
```

```
col2 | nvl
-----+-----
aaa  | IS NULL
(1 row)
```

7.5 Package Reference

A "package" is a group of features, brought together by schemas, that have a single functionality, and are used by calling from PL/pgSQL.

The following packages are supported:

- [DBMS_OUTPUT](#)
- [UTL_FILE](#)
- [DBMS_SQL](#)

To call the different functionalities from PL/pgSQL, use the PERFORM statement or SELECT statement, using the package name to qualify the name of the functionality. Refer to the explanations for each of the package functionalities for information on the format for calling.

7.5.1 DBMS_OUTPUT

Overview

Sends messages to clients such as psql from PL/pgSQL.

Features

Features	Description
ENABLE	Enables features of this package.
DISABLE	Disables features of this package.
SERVEROUTPUT	Controls whether messages are sent.
PUT	Sends messages.
PUT_LINE	Sends messages with a newline character appended.
NEW_LINE	Sends a newline character.
GET_LINE	Retrieves a line from the message buffer.
GET_LINES	Retrieves multiple lines from the message buffer.

Syntax

```
{ ENABLE( [buffSize ]
| DISABLE( )
| SERVEROUTPUT( sendMsgs )
| PUT( str )
| PUT_LINE( str )
| NEW_LINE( )
| GET_LINE( )
| GET_LINES( maxLineNum )
}
```

7.5.1.1 Description

This section explains each feature of DBMS_OUTPUT.

ENABLE

- ENABLE enables the use of PUT, PUT_LINE, NEW_LINE, GET_LINE, and GET_LINES.
- With multiple executions of ENABLE, the value specified last is the buffer size (in bytes). Specify a buffer size from 2000 to 1000000.
- The default value of the buffer size is 20000. If NULL is specified as the buffer size, 1000000 will be used.
- If ENABLE has not been executed, PUT, PUT_LINE, NEW_LINE, GET_LINE, and GET_LINES are ignored even if they are executed.



Example

```
PERFORM DBMS_OUTPUT.ENABLE(20000);
```

DISABLE

- DISABLE disables the use of PUT, PUT_LINE, NEW_LINE, GET_LINE, and GET_LINES.
- Remaining buffer information is discarded.



Example

```
PERFORM DBMS_OUTPUT.DISABLE( );
```

SERVEROUTPUT

- SERVEROUTPUT controls whether messages are sent.
- Specify TRUE or FALSE for *sendMsgs*.
- If TRUE is specified, when PUT, PUT_LINE, or NEW_LINE is executed, the message is sent to a client such as psql and not stored in the buffer.
- If FALSE is specified, when PUT, PUT_LINE, or NEW_LINE is executed, the message is stored in the buffer and not sent to a client such as psql.



See

Refer to "Boolean Type" in "Data Types" in "The SQL Language" in the PostgreSQL Documentation for information on boolean type (TRUE/FALSE) values.



Example

```
PERFORM DBMS_OUTPUT.SERVEROUTPUT( TRUE );
```

PUT

- PUT sets the message to be sent.
- The string is the message to be sent.
- When TRUE is specified for SERVEROUTPUT, the messages are sent to clients such as psql.
- When FALSE is specified for SERVEROUTPUT, the messages are retained in the buffer.
- PUT does not append a newline character. To append a newline character, execute NEW_LINE.
- If a string longer than the buffer size specified in ENABLE is sent, an error occurs.



Example

```
PERFORM DBMS_OUTPUT.PUT( 'abc' );
```

PUT_LINE

- PUT_LINE sets the message to be sent appended with a newline character.
- The string is the message that is sent.

- When TRUE is specified for SERVEROUTPUT, the messages are sent to clients such as psql.
- When FALSE is specified for SERVEROUTPUT, the messages are retained in the buffer.
- PUT_LINE appends a newline character to the end of messages.
- If a string longer than the buffer size specified in ENABLE is sent, an error occurs.

Example

```
PERFORM DBMS_OUTPUT.PUT_LINE('abc');
```

NEW_LINE

- NEW_LINE appends a newline character to the message created with PUT.
- When TRUE is specified for SERVEROUTPUT, the messages are sent to clients such as psql.
- When FALSE is specified for SERVEROUTPUT, the messages are retained in the buffer.

Example

```
PERFORM DBMS_OUTPUT.NEW_LINE();
```

GET_LINE

- GET_LINE retrieves a line from the message buffer.
- Use a SELECT statement to obtain the retrieved line and status code returned by the operation, which are stored in the line and status columns.
- The line column stores the line retrieved from the buffer. The data type of line is TEXT.
- The status column stores the status code returned by the operation: 0-completed successfully; 1-failed because there are no more lines in the buffer. The data type of status is INTEGER.
- If GET_LINE or GET_LINES is executed and then PUT, PUT_LINE, or NEW_LINE is while messages that have not been retrieved from the buffer still exist, the messages not retrieved from the buffer will be discarded.

Example

```
DECLARE
    buff1    VARCHAR(20);
    stts1    INTEGER;
BEGIN
    SELECT line,status INTO buff1,stts1 FROM DBMS_OUTPUT.GET_LINE();
```

GET_LINES

- GET_LINES retrieves multiple lines from the message buffer.
- Use a SELECT statement to obtain the retrieved lines and the number of lines retrieved, which are stored in the lines and numlines columns.
- The lines column stores the lines retrieved from the buffer. The data type of lines is TEXT.
- The numlines column stores the number of lines retrieved from the buffer. The data type of numlines is INTEGER.

- *maxLineNum* is the maximum number of lines to retrieve from the buffer. The data type is INTEGER.
- If GET_LINE or GET_LINES is executed and then PUT, PUT_LINE, or NEW_LINE is executed while messages that have not been retrieved from the buffer still exist, the messages not retrieved from the buffer will be discarded.

Example

```
DECLARE
    buff    VARCHAR(20)[10];
    stts    INTEGER := 10;
BEGIN
    SELECT lines, numlines INTO buff,stts FROM DBMS_OUTPUT.GET_LINES(stts);
```

7.5.1.2 Example

A usage example of DBMS_OUTPUT is shown below.

```
CREATE FUNCTION dbms_output_exe() RETURNS VOID AS $$
DECLARE
    buff1    VARCHAR(20);
    buff2    VARCHAR(20);
    stts1    INTEGER;
    stts2    INTEGER;
BEGIN
    PERFORM DBMS_OUTPUT.DISABLE();
    PERFORM DBMS_OUTPUT.ENABLE();
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(FALSE);
    PERFORM DBMS_OUTPUT.PUT('DBMS_OUTPUT TEST 1');
    PERFORM DBMS_OUTPUT.NEW_LINE();
    PERFORM DBMS_OUTPUT.PUT_LINE('DBMS_OUTPUT TEST 2');
    SELECT line,status INTO buff1,stts1 FROM DBMS_OUTPUT.GET_LINE();
    SELECT line,status INTO buff2,stts2 FROM DBMS_OUTPUT.GET_LINE();
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);
    PERFORM DBMS_OUTPUT.PUT_LINE(buff1);
    PERFORM DBMS_OUTPUT.PUT_LINE(buff2);
END;
$$ LANGUAGE plpgsql;
SELECT dbms_output_exe();
DROP FUNCTION dbms_output_exe();
```

7.5.2 UTL_FILE

Overview

Text files can be written and read using PL/pgSQL.

To perform these file operations, the directory for the operation target must be registered in the UTL_FILE.UTL_FILE_DIR table beforehand. Use the INSERT statement as the database administrator or a user who has INSERT privileges to register the directory. Also, if the directory is no longer necessary, delete it from the same table. Refer to "[7.5.2.1 Registering and Deleting Directories](#)" for information on the how to register and delete the directory.

Note

- When performing file operations, access privileges for the UTL_FILE.UTL_FILE_DIR table are required according to the operation. However, because the user performing file operations can access any file regardless of the operating system access privileges for the target file, set the access privileges for the table appropriately so that important files are not accessed by any user.

Refer to "C.1 UTL_FILE.UTL_FILE_DIR" for information on the UTL_FILE.UTL_FILE_DIR table.

Declare the file handler explained hereafter as follows in PL/pgSQL:

```
DECLARE
f UTL_FILE.FILE_TYPE;
```

Features

Feature	Description
FCLOSE	Closes a file.
FCLOSE_ALL	Closes all files open in a session.
FCOPY	Copies a whole file or a contiguous portion thereof.
FFLUSH	Flushes the buffer.
FGETATTR	Retrieves the attributes of a file.
FOPEN	Opens a file.
FRENAME	Renames a file.
GET_LINE	Reads one line from a text file.
IS_OPEN	Checks if a file is open.
NEW_LINE	Writes newline characters.
PUT	Writes a string.
PUT_LINE	Appends a newline character to a string and writes the string.
PUTF	Writes a formatted string.

Syntax

```
{ FCLOSE(fileHandle)
| FCLOSE_ALL()
| FCOPY(srcDir, srcFileName, destDir, destFileName
  [ {,startLine | ,startLine ,endLine } ])
| FFLUSH(fileHandle)
| FGETATTR(dir, filename)
| FOPEN(dir, fileName, openMode [, maxLineSize ])
| FRENAME(srcDir, srcFileName, destDir, destFileName [ ,overwrite ])
| GET_LINES(fileHandle [,len ])
| IS_OPEN(fileHandle)
| NEW_LINE(fileHandle [, numOfNewLines ])
| PUT(fileHandle, str)
| PUT_LINE(fileHandle, str [, writeToFile ])
| PUTF(fileHandle, fmt [, args ]... )
}
```

7.5.2.1 Registering and Deleting Directories

Registering the directory

1. Check if the directory is already registered (if it is, then step 2 is not necessary).

```
SELECT * FROM UTL_FILE.UTL_FILE_DIR WHERE dir='/home/fsep';
```

2. Register the directory.

```
INSERT INTO UTL_FILE.UTL_FILE_DIR VALUES('/home/fsep');
```

Deleting the directory

```
DELETE FROM UTL_FILE.UTL_FILE_DIR WHERE dir='/home/fsep';
```

7.5.2.2 Description

This section explains each feature of UTL_FILE.

FCLOSE

- FCLOSE closes a file that is open.
- Specify an open file handle.
- The value returned is a NULL value.



Example

```
f := UTL_FILE.FCLOSE(f);
```

FCLOSE_ALL

- FCLOSE_ALL closes all files open in a session.
- Files closed with FCLOSE_ALL can no longer be read or written.



Example

```
PERFORM UTL_FILE.FCLOSE_ALL();
```

FCOPY

- FCOPY copies a whole file or a contiguous portion thereof. The whole file is copied if *startLine* and *endLine* are not specified.
- Specify the directory location of the source file.
- Specify the source file.
- Specify the directory where the destination file will be created.
- Specify the file name of the destination file.
- Specify the line number at which to begin copying. Specify a value greater than 0. If not specified, 1 is used.
- Specify the line number at which to stop copying. If not specified, the last line number of the file is used.



Example

```
PERFORM UTL_FILE.FCOPY('/home/fsep', 'regress_fsep.txt', '/home/fsep', 'regress_fsep2.txt');
```

FFLUSH

- FFLUSH forcibly writes the buffer data to a file.
- Specify an open file handle.



Example

```
PERFORM UTL_FILE.FFLUSH(f);
```

FGETATTR

- FGETATTR retrieves file attributes: file existence, file size, and information about the block size of the file.
- Specify the directory where the file exists.
- Specify the file name.
- Use a SELECT statement to obtain the file attributes, which are stored in the fexists, file_length, and blocksize columns.
- The fexists column stores a boolean (TRUE/FALSE) value. If the file exists, fexists is set to TRUE. If the file does not exist, fexists is set to FALSE. The data type of fexists is BOOLEAN.
- The file_length column stores the length of the file in bytes. If the file does not exist, file_length is NULL. The data type of file_length is INTEGER.
- The blocksize column stores the block size of the file in bytes. If the file does not exist, blocksize is NULL. The data type of blocksize is INTEGER.



Example

```
SELECT fexists, file_length, blocksize INTO file_flag, file_len, size FROM UTL_FILE.FGETATTR('/home/fsep', 'regress_fsep.txt');
```

FOPEN

- FOPEN opens a file.
- Specify the directory where the file exists.
- Specify the file name.
- Specify the mode for opening the file:
 - r: Read
 - w: Write
 - a: Add
- Specify the maximum string length (in bytes) that can be processed with one operation. If omitted, the default is 1024. Specify a value from 1 to 32767.
- Up to 50 files per session can be open at the same time.



Example

```
f := UTL_FILE.FOPEN('/home/fsep', 'regress_fsep.txt', 'r', 1024);
```

FRENAME

- FRENAME renames a file.
- Specify the directory location of the source file.
- Specify the source file to be renamed.

- Specify the directory where the renamed file will be created.
- Specify the new name of the file.
- Specify whether to overwrite a file if one exists with the same name and in the same location as the renamed file. If TRUE is specified, the existing file will be overwritten. If FALSE is specified, an error occurs. If omitted, FALSE is set.



Refer to "Boolean Type" in "Data Types" in "The SQL Language" in the PostgreSQL Documentation for information on boolean type (TRUE/FALSE) values.



```
PERFORM UTL_FILE.FRENAME('/home/fsep', 'regress_fsep.txt', '/home/fsep',
'regress_fsep2.txt', TRUE);
```

GET_LINE

- GET_LINE reads one line from a file.
- Specify the file handle returned by FOPEN using the r (read) mode.
- Specify the number of bytes to read from the file. If not specified, the maximum string length specified at FOPEN will be used.
- The return value is the buffer that receives the line read from the file.
- Newline characters are not loaded to the buffer.
- An empty string is returned if a blank line is loaded.
- Specify the maximum length (in bytes) of the data to be read. Specify a value from 1 to 32767. If not specified, the maximum string length specified at FOPEN is set. If no maximum string length is specified at FOPEN. 1024 is set.
- If the line length is greater than the specified number of bytes to read, the remainder of the line is read on the next call.
- A NO_DATA_FOUND exception will occur when trying to read past the last line.



```
buff := UTL_FILE.GET_LINE(f);
```

IS_OPEN

- IS_OPEN checks if a file is open.
- Specify the file handle.
- The return value is a BOOLEAN type. TRUE represents an open state and FALSE represents a closed state.



Refer to "Boolean Type" in "Data Types" in "The SQL Language" in the PostgreSQL Documentation for information on boolean type (TRUE/FALSE) values.



Example

```
IF UTL_FILE.IS_OPEN(f) THEN
  PERFORM UTL_FILE.FCLOSE(f);
END IF;
```

NEW_LINE

- NEW_LINE writes one or more newline characters.
- Specify an open file handle.
- Specify the number of newline characters to be written to the file. If omitted, "1" is used.



Example

```
PERFORM UTL_FILE.NEW_LINE(f, 2);
```

PUT

- PUT writes a string to a file.
- Specify the file handle that was opened with FOPEN using w (write) or a (append).
- Specify the string to be written to the file.
- The maximum length (in bytes) of the string to be written is the maximum string length specified at FOPEN.
- The return value is a TEXT type and is the buffer that receives the line loaded from the file.



Example

```
PERFORM UTL_FILE.PUT(f, 'ABC');
```

PUT_LINE

- PUT_LINE appends a newline character to a string and writes the string.
- Specify the file handle that was opened with FOPEN w (write) or a (append).
- Specify whether to forcibly write to the file. If TRUE is specified, file writing is forced. If FALSE is specified, file writing is asynchronous. If omitted, FALSE will be set.
- The maximum length of the string (in bytes) is the maximum string length specified at FOPEN.



Example

```
PERFORM UTL_FILE.PUT_LINE(f, 'ABC', TRUE);
```

PUTF

- PUTF writes a formatted string.
- Specify the file handle that was opened with FOPEN w (write) or a (append).

- Specify the format, which is a string that includes the formatting characters \n and %s.
- The \n in the format is code for a newline character.
- Specify the same number of input values as there are %s in the format. Up to a maximum of five input values can be specified. The %s in the format are replaced with the corresponding input characters. If an input value corresponding to %s is not specified, it is replaced with an empty string.



Example

```
PERFORM UTL_FILE.PUTF(f, '[1=%s, 2=%s, 3=%s, 4=%s, 5=%s]\n', '1', '2', '3', '4', '5');
```

7.5.2.3 Example

The procedure when using UTL_FILE, and a usage example, are shown below.

1. Preparation

Before starting a new job that uses UTL_FILE, register the directory in the UTL_FILE.UTL_FILE_DIR table.

Refer to "[7.5.2.1 Registering and Deleting Directories](#)" for information on how to register the directory.

2. Performing a job

Perform a job that uses UTL_FILE. The example is shown below.

```
CREATE OR REPLACE FUNCTION gen_file(mydir TEXT, infile TEXT, outfile TEXT, copyfile TEXT) RETURNS
void AS $$
DECLARE
  v1 VARCHAR(32767);
  inf UTL_FILE.FILE_TYPE;
  otf UTL_FILE.FILE_TYPE;
BEGIN
  inf := UTL_FILE.FOPEN(mydir, infile,'r',256);
  otf := UTL_FILE.FOPEN(mydir, outfile,'w');
  v1 := UTL_FILE.GET_LINE(inf,256);
  PERFORM UTL_FILE.PUT_LINE(otf,v1,TRUE);
  v1 := UTL_FILE.GET_LINE(inf,256);
  PERFORM UTL_FILE.PUTF(otf,'%s\n',v1);
  v1 := UTL_FILE.GET_LINE(inf, 256);
  PERFORM UTL_FILE.PUT(otf,v1);
  PERFORM UTL_FILE.NEW_LINE(otf);
  PERFORM UTL_FILE.FFLUSH(otf);

  inf := UTL_FILE.FCLOSE(inf);
  otf := UTL_FILE.FCLOSE(otf);

  PERFORM UTL_FILE.FCOPY(mydir, outfile, mydir, copyfile, 2, 3);
  PERFORM UTL_FILE.FRENAME(mydir, outfile, mydir, 'rename.txt');

END;
$$ LANGUAGE plpgsql;

SELECT gen_file('/home/fsep', 'input.txt', 'output.txt', 'copyfile.txt');
```

3. Post-processing

If you remove a job that uses UTL_FILE, delete the directory information from the UTL_FILE.UTL_FILE_DIR table. Ensure that the directory information is not being used by another job before deleting it.

Refer to "[7.5.2.1 Registering and Deleting Directories](#)" for information on how to delete the directory.

7.5.3 DBMS_SQL

Overview

Dynamic SQL can be executed from PL/pgSQL.

Features

Feature	Description
BIND_VARIABLE	Sets values in the host variable within the SQL statement.
CLOSE_CURSOR	Closes the cursor.
COLUMN_VALUE	Retrieves the value of the column in the select list extracted with FETCH_ROWS.
DEFINE_COLUMN	Defines the column from which values are extracted and the storage destination.
EXECUTE	Executes SQL statements.
FETCH_ROWS	Positions the specified cursor at the next row and extracts values from the row.
OPEN_CURSOR	Opens a new cursor.
PARSE	Parses SQL statements.

Note

- In DBMS_SQL, the data types supported in dynamic SQL are limited, and therefore the user must consider this. The supported data types are:

- INTEGER
- DECIMAL
- NUMERIC
- REAL
- DOUBLE PRECISION
- CHAR(*1)
- VARCHAR(*1)
- NCHAR(*1)
- NCHAR VARYING(*1)
- TEXT
- DATE
- TIMESTAMP WITHOUT TIME ZONE
- TIMESTAMP WITH TIME ZONE
- INTERVAL(*2)
- SMALLINT
- BIGINT

*1:

The host variables with CHAR, VARCHAR, NCHAR, and NCHAR VARYING data types are treated as TEXT, to match the string function arguments and return values. Refer to "String Functions and Operators" in "Functions and Operators" in "The SQL Language" in the PostgreSQL Documentation for information on string functions.

When specifying the arguments of the features compatible with Oracle databases NVL and/or DECODE, use CAST to convert the data types of the host variables to ensure that data types between arguments are the same.

*2:

When using COLUMN_VALUE to obtain an INTERVAL type value specified in the select list, use an INTERVAL type variable with a wide range such as when no interval qualifier is specified, or with a range that matches that of the variable in the select list. If an interval qualifier variable with a narrow range is specified, then the value within the interval qualifier range will be obtained, but an error that the values outside the range have been truncated will not occur.



Example

This example illustrates where a value expression that returns an INTERVAL value is set in the select list and the result is received with COLUMN_VALUE. Note that the SQL statement operation result returns a value within the INTERVAL DAY TO SECOND range.

[Bad example]

Values of MINUTE, and those after MINUTE, are truncated, because the variable(v_interval) is INTERVAL DAY TO HOUR.

```
v_interval      INTERVAL DAY TO HOUR;
...
PERFORM DBMS_SQL.PARSE(cursor, 'SELECT CURRENT_TIMESTAMP - ''2010-01-01'' FROM DUAL', 1);
...
SELECT value INTO v_interval FROM DBMS_SQL.COLUMN_VALUE(cursor, 1, v_interval);
result:1324 days 09:00:00
```

[Good example]

By ensuring that the variable(v_interval) is INTERVAL, the values are received correctly.

```
v_interval      INTERVAL;
...
PERFORM DBMS_SQL.PARSE(cursor, 'SELECT CURRENT_TIMESTAMP - ''2010-01-01'' FROM DUAL', 1);
...
SELECT value INTO v_interval FROM DBMS_SQL.COLUMN_VALUE(cursor, 1, v_interval);
result:1324 days 09:04:37.530623
```

Syntax

```
{ BIND_VARIABLE(cursor, varName, val [, len ])
| CLOSE_CURSOR(cursor)
| COLUMN_VALUE(cursor, colPos, varName)
| DEFINE_COLUMN(cursor, colPos, varName [, len ])
| EXECUTE(cursor)
| FETCH_ROWS(cursor)
| OPEN_CURSOR([parm1 ])
| PARSE(cursor, sqlStmt, parm1 [, parm2, parm3, parm4 ])
}
```

7.5.3.1 Description

This section explains each feature of DBMS_SQL.

BIND_VARIABLE

- BIND_VARIABLE sets values in the host variable within the SQL statement.
- Specify the cursor number to be processed.
- Specify the name of the host variable within the SQL statement using a string for the host variable name.
- Specify the value set in the host variable. The data type of the host variable is the same as that of the value expression - it is implicitly converted in accordance with its position within the SQL statement. Refer to "[A.3 Implicit Data Type Conversions](#)" for information on implicit conversions.

- If the value is a character type, the string length is the number of characters. If the string length is not specified, the size is the total length of the string.
- It is necessary to place a colon at the beginning of the host variable in SQL statements to identify the host variable. The colon does not have to be added to the host variable names specified at BIND_VARIABLE. The following shows examples of host variable names specified with SQL statements and host variable names specified with BIND_VARIABLE:

```
PERFORM DBMS_SQL.PARSE(cursor, 'SELECT emp_name FROM emp WHERE sal > :x', 1);
```

In this example, BIND_VARIABLE will be as follows:

```
PERFORM DBMS_SQL.BIND_VARIABLE(cursor, ':x', 3500);
```

Or,

```
PERFORM DBMS_SQL.BIND_VARIABLE(cursor, 'x', 3500);
```

- The length of the host variable name can be up to 30 bytes (excluding colons).
- If the data type of the set value is string, specify the effective size of the column value as the fourth argument.

Example

If the data type of the value to be set is not a string:

```
PERFORM DBMS_SQL.BIND_VARIABLE(cursor, ':NO', 1);
```

If the data type of the value to be set is a string:

```
PERFORM DBMS_SQL.BIND_VARIABLE(cursor, ':NAME', h_memid, 5);
```

CLOSE_CURSOR

- CLOSE_CURSOR closes the cursor.
- Specify the cursor number to be processed.
- The value returned is a NULL value.

Example

```
cursor := DBMS_SQL.CLOSE_CURSOR(cursor);
```

COLUMN_VALUE

- COLUMN_VALUE retrieves the value of the column in the select list extracted with FETCH_ROWS.
- Specify the cursor number to be processed.
- Specify the position of the column of the select list in the SELECT statement. The position of the first column is 1.
- Specify the destination variable name.
- Use a SELECT statement to obtain the values of the value, column_error, and actual_length columns.
- The value column returns the value of the column specified at the column position. The data type of the variable name must match that of the column. If the data type of the column in the SELECT statement specified in PARSE is not compatible with DBMS_SQL, use CAST to convert to a compatible data type.
- The data type of the column_error column is NUMERIC. If the column value could not be set correctly in the value column, a value other than 0 will be returned:

22001: The extracted string has been truncated
22002: The extracted value contains a NULL value

- The data type of the actual_length column is INTEGER. If the extracted value is a character type, the number of characters will be returned (if the value was truncated, the number of characters prior to the truncation will be returned), otherwise, the number of bytes will be returned.

Example

When retrieving the value of the column, the error code, and the actual length of the column value:

```
SELECT value, column_error, actual_length INTO v_memid, v_col_err, v_act_len FROM  
DBMS_SQL.COLUMN_VALUE(cursor, 1, v_memid);
```

When retrieving just the value of the column:

```
SELECT value INTO v_memid FROM DBMS_SQL.COLUMN_VALUE(cursor, 1, v_memid);
```

DEFINE_COLUMN

- DEFINE_COLUMN defines the column from which values are extracted and the storage destination.
- Specify the cursor number to be processed.
- Specify the position of the column in the select list in the SELECT statement. The position of the first column is 1.
- Specify the destination variable name. The data type should be match with the data type of the column from which the value is to be extracted. If the data type of the column in the SELECT statement specified in PARSE is not compatible with DBMS_SQL, use CAST to convert to a compatible data type.
- Specify the maximum number of characters of character type column values.
- If the data type of the column value is string, specify the effective size of the column value as the fourth argument.

Example

When the data type of the column value is not a string:

```
PERFORM DBMS_SQL.DEFINE_COLUMN(cursor, 1, v_memid);
```

When the data type of the column value is a string:

```
PERFORM DBMS_SQL.DEFINE_COLUMN(cursor, 1, v_memid, 10);
```

EXECUTE

- EXECUTE executes SQL statements.
- Specify the cursor number to be processed.
- The return value is an INTEGER type, is valid only with INSERT statement, UPDATE statement, and DELETE statement, and is the number of rows processed. Anything else is invalid.

Example

```
ret := DBMS_SQL.EXECUTE(cursor);
```

FETCH_ROWS

- FETCH_ROWS positions at the next row and extracts values from the row.
- Specify the cursor number to be processed.
- The return value is an INTEGER type and is the number of rows extracted. 0 is returned if all are extracted.
- The extracted information is retrieved with COLUMN_VALUE.



Example

```
LOOP
  IF DBMS_SQL.FETCH_ROWS(cursor) = 0 THEN
    EXIT;
  END IF;
  ...
END LOOP;
```

OPEN_CURSOR

- OPEN_CURSOR opens a new cursor.
- The parameter is used for compatibility with Oracle databases only, and is ignored by FUJITSU Enterprise Postgres. An INTEGER type can be specified, but it will be ignored. If migrating from an Oracle database, specify 1.
- Close unnecessary cursors by executing CLOSE_CURSOR.
- The return value is an INTEGER type and is the cursor number.



Example

```
cursor := DBMS_SQL.OPEN_CURSOR( );
```

PARSE

- PARSE analyzes dynamic SQL statements.
- Specify the cursor number to be processed.
- Specify the SQL statement to be parsed.
- Parameters 1, 2, 3, and 4 are used for compatibility with Oracle databases only, and are ignored by FUJITSU Enterprise Postgres. If you are specifying values anyway, specify the following:
 - Parameter 1 is an INTEGER type. Specify 1.
 - Parameters 2 and 3 are TEXT types. Specify NULL.
 - Parameter 4 is a BOOLEAN type. Specify TRUE.If migrating from an Oracle database, the specified values for parameters 2, 3, and 4 do not need to be changed.
- Add a colon to the beginning of host variables in SQL statements.
- The DDL statement is executed when PARSE is issued. EXECUTE is not required for the DDL statement.
- If PARSE is called again for opened cursors, the content in the data regions within the cursors is reset, and the SQL statement is parsed anew.



Example

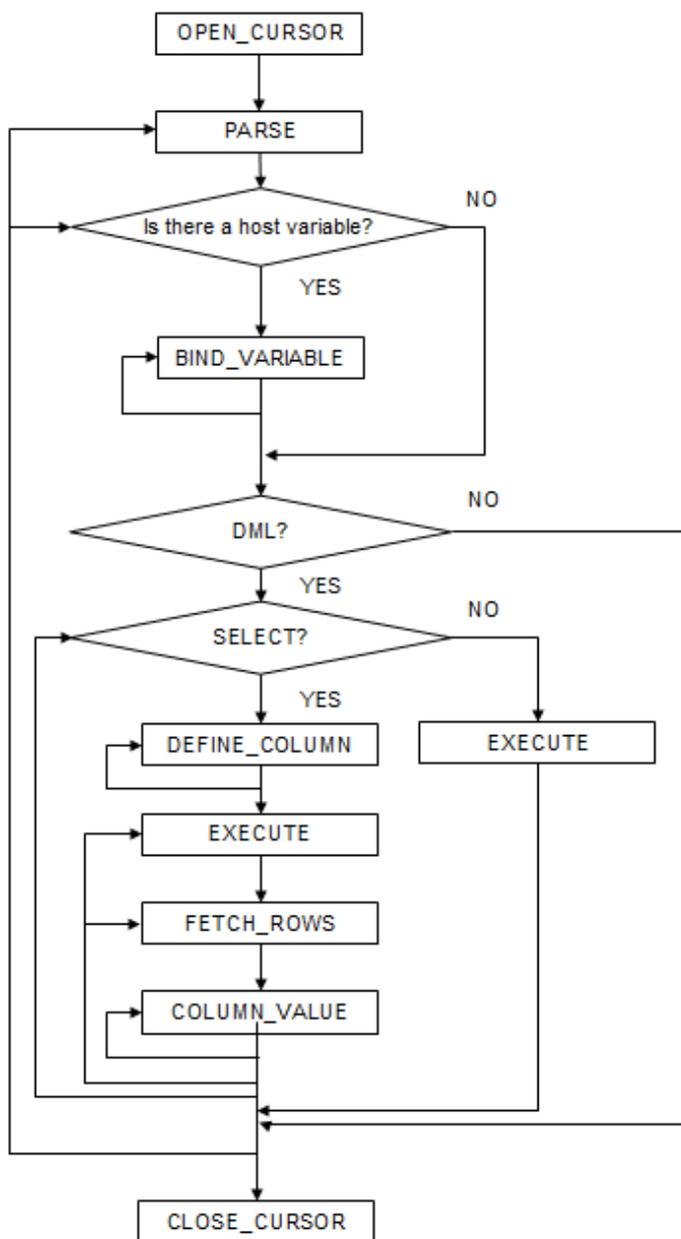
```
PERFORM DBMS_SQL.PARSE(cursor, 'SELECT memid, memnm FROM member WHERE memid = :NO', 1);
```

7.5.3.2 Example

This section explains the flow of DBMS_SQL and provides an example.

Flow of DBMS_SQL

Flow of DBMS_SQL



Example

```
CREATE FUNCTION smp_00()
RETURNS INTEGER
AS $$
DECLARE
    str_sql      VARCHAR(255);
    cursor       INTEGER;
    h_smpid      INTEGER;
    v_smpid      INTEGER;
    v_smpnm      VARCHAR(20);
    v_smpage     INTEGER;
    errcd        INTEGER;
    length       INTEGER;
    ret          INTEGER;
BEGIN
    str_sql      := 'SELECT smpid, smpnm, smpage FROM smp_tbl WHERE smpid < :H_SMPID ORDER BY smpid';
    h_smpid      := 3;
    v_smpid      := 0;
    v_smpnm      := '';
    v_smpage     := 0;

    cursor := DBMS_SQL.OPEN_CURSOR();

    PERFORM DBMS_SQL.PARSE(cursor, str_sql, 1);

    PERFORM DBMS_SQL.BIND_VARIABLE(cursor, ':H_SMPID', h_smpid);

    PERFORM DBMS_SQL.DEFINE_COLUMN(cursor, 1, v_smpid);
    PERFORM DBMS_SQL.DEFINE_COLUMN(cursor, 2, v_smpnm, 10);
    PERFORM DBMS_SQL.DEFINE_COLUMN(cursor, 3, v_smpage);

    ret := DBMS_SQL.EXECUTE(cursor);
    loop
        if DBMS_SQL.FETCH_ROWS(cursor) = 0 then
            EXIT;
        end if;

        SELECT value,column_error,actual_length INTO v_smpid,errcd,length FROM
DBMS_SQL.COLUMN_VALUE(cursor, 1, v_smpid);
        RAISE NOTICE '-----';
        RAISE NOTICE '-----';
        RAISE NOTICE 'smpid          = %', v_smpid;
        RAISE NOTICE 'errcd           = %', errcd;
        RAISE NOTICE 'length          = %', length;

        SELECT value,column_error,actual_length INTO v_smpnm,errcd,length FROM
DBMS_SQL.COLUMN_VALUE(cursor, 2, v_smpnm);
        RAISE NOTICE '-----';
        RAISE NOTICE 'smpnm           = %', v_smpnm;
        RAISE NOTICE 'errcd           = %', errcd;
        RAISE NOTICE 'length          = %', length;

        select value,column_error,actual_length INTO v_smpage,errcd,length FROM
DBMS_SQL.COLUMN_VALUE(cursor, 3, v_smpage);
        RAISE NOTICE '-----';
        RAISE NOTICE 'smpage          = %', v_smpage;
        RAISE NOTICE 'errcd           = %', errcd;
        RAISE NOTICE 'length          = %', length;
        RAISE NOTICE '';
    end loop;

    cursor := DBMS_SQL.CLOSE_CURSOR(cursor);
```

```
    RETURN 0;  
END;  
$$ LANGUAGE plpgsql;
```

Chapter 8 Application Connection Switch Feature

The application connection switch feature enables automatic connection to the target server when there are multiple servers with redundant configurations.

When using this feature, specify the primary server and secondary server as the connected servers in the application connection information. A standby server can optionally be prioritized over the primary server as the target server.

If an application connection switch occurs, explicitly close the connection and then reestablish the connection or reexecute the application. Refer to "Errors when an Application Connection Switch Occurs and Corresponding Actions" of the relevant client interface for information on how to confirm the switch.

8.1 Connection Information for the Application Connection Switch Feature

To use the application connection switch feature, set the information shown below when connecting the database.

IP address or host name

Specify the IP address or host name that will be used to configure the database multiplexing system.

Port number

A port number used by each database server to listen for connections from applications.

In each client interface, multiple port numbers can be specified, however in the format shown below, for example:

host1,host2:port2

JDBC

If only one port number is specified, it will be assumed that host1: 27500 (the default value) and host2:port2 were specified. Omit all port numbers, or specify only one per server.

Others

If only one port number is specified, it will be assumed that the same port is used for all the hosts.

Target server

From the specified connection destination server information, specify the selection sequence of the servers to which the application will connect. The values specified for the target server have the meanings shown below. If a value is omitted, "any" will be assumed.

Primary server

The primary server is selected as the connection target from the specified "IP addresses or host names". Specify this to perform tasks that can be performed only on the primary server, such as applications in line with updates, or management tasks such as REINDEX and VACUUM.

Standby server (this value can be used only when the JDBC driver is used)

The standby server is selected as the connection target from the specified "IP addresses or host names". On standby server, the update will always fail. If the target server is not standby, the JDBC driver will throw an error stating that it is unable to find a server with the specified targetServerType.

Priority given to a standby server

The standby server is selected preferentially as the connection target from the specified "IP addresses or host names". If there is no standby server, the application will connect to the primary server.

Any

This method is not recommended in database multiplexing systems. This is because, although the connection destination server is selected in the specified sequence from the specified "IP addresses or host names", if the server that was successfully connected to first is the standby server, the write operations will always fail.

The table below shows the server selection order values to set for each driver:

Server selection order	JDBC drivers	Other drivers
Primary server	"master"	"read-write"
Standby server	"slave"	-
Priority given to a standby server	"preferSlave"	"prefer-read"
Any	"any"	"any"

SSL server certificate Common Name (CN)

To perform SSL authentication by creating the same server certificate for each server in a multiplexing system, specify the SSL server certificate Common Name (CN) in this parameter. Accordingly, SSL authentication using the CN can be performed without having to consider the names of the multiple servers contained in the multiplexing system.

8.2 Using the Application Connection Switch Feature

This section explains how to set the connection destination server using the application connection switch feature.

Of the parameters used as connection information for each client interface, only the parameters specific to the application connection switch feature are explained here. Refer to "Setup" and "Connecting to the Database" for information on the other parameters of each client interface.

8.2.1 Using the JDBC Driver

Set the following information in the connection string of the DriverManager class, or in the data source.

Table 8.1 Information to be set

Argument	Explanation
host1 host2	Specify the IP address or host name.
port1 port2	Specify the port number for the connection. The port number can be omitted. If omitted, the default is 27500.
database_name	Specify the database name.
targetServerType	Specify the selection sequence of the servers to which the application will connect. Refer to " Target server " for details.
sslmode	Specify this to encrypt communications. By default, this is disabled. The setting values for sslmode are as follows: disable: Connect without SSL require: Connect always with SSL verify-ca: Connect with SSL, using a certificate issued by a trusted CA (*1) verify-full: Connect with SSL, using a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
sslservercertcn	This parameter is enabled only to perform SSL authentication (sslmode=verify-full). Specify the server certificate CN. If this is omitted, the value will be null, and the server certificate CN will be authenticated using the host name specified in host.

*1: If specifying either "verify-ca" or "verify-full", the CA certificate file can be specified using connection string sslrootcert.

When using Driver Manager

Specify the following URL in the API of the DriverManager class:

```
jdbc:postgresql://host1[:port1],host2[:port2]/dbName[?targetServerType={master | slave |
preferSlave | any}][&sslmode=verify-
full&sslrootcert=cACertificateFile&sslservercertcn=targetServerCertificateCN]
```

- If the target server is omitted, the default value "any" is used.
- When using IPV6, specify the host in the "[host]" (with square brackets) format.

[Example]

```
jdbc:postgresql://[2001:Db8::1234]:27500,192.168.1.1:27500/dbName
```

When using the data source

Specify the properties of the data source in the following format:

```
source.setServerName("host1[:port1],host2[:port2]");
source.setTargetServerType("master");
source.setSslmode("verify-full");
source.setSslrootcert("cACertificateFile");
source.setSslservercertcn("targetServerCertificateCN");
```

- If the port number is omitted, the value specified in the portNumber property will be used. Also, if the portNumber property is omitted, the default is 27500.
- If the target server is omitted, the value will be "any".
- When using IPV6, specify the host in the "[host]" (with square brackets) format.

[Example]

```
source.setServerName("[2001:Db8::1234]:27500,192.168.1.1:27500");
```



Note

If using the connection parameter loginTimeout, the value will be applied for the time taken attempting to connect to all of the specified hosts.

8.2.2 Using the ODBC Driver

Set the following information in the connection string or data source.

Table 8.2 Information to be set

Parameter	Explanation
Servername	Specify IP address 1 and IP address 2, or the host name, using a comma as the delimiter. Based on ODBC rules, it is recommended to enclose the whole string containing comma delimiters with {}. Format: {host1,host2}
Port	Specify the connection destination port numbers, using a comma as the delimiter. Based on ODBC rules, it is recommended to enclose the whole string containing comma delimiters with {}. Format: {port1,port2} Specify the port number corresponding to the IP address or host specified for the nth Servername as the nth Port. The port number can be omitted. If omitted, the default is 27500.

Parameter	Explanation
	If <i>n</i> server names are specified, and <i>m</i> ports are specified then there will be error reported. The only exceptions are where <i>m</i> = <i>n</i> or <i>m</i> =1. In case only one port is specified, then the same is applied for all the hosts.
target_session_attrs	Specify the selection sequence of the servers to which the application will connect. Refer to " Target server " for details.
SSLMode	Specify this to encrypt communications. By default, this is disabled. The setting values for SSLMode are as follows: disable: Connect without SSL allow: Connect without SSL, and if it fails, connect with SSL prefer: Connect with SSL, and if it fails, connect without SSL require: Connect always with SSL verify-ca: Connect with SSL, using a certificate issued by a trusted CA (*1) verify-full: Connect with SSL, using a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
SSLServerCertCN	This parameter is enabled only to perform SSL authentication (SSLMode=verify-full). Specify the server certificate CN. If this is omitted, the value will be null, and the server certificate CN will be authenticated using the host name specified in Servername.

*1: If specifying either "verify-ca" or "verify-full", use the system environment variable PGSSLROOTCERT of your operating system to specify the CA certificate file as shown below.

Example)

Variable name: PGSSLROOTCERT

Variable value: *cACertificateFile*

When specifying a connection string

Specify the following connection string:

```
...;Servername={host1,host2};Port={port1,port2};[target_session_attrs={read-write | prefer-read | any}];[ SSLMode=verify-full;SSLServerCertCN=targetServerCertificateCN]...
```

- When using IPV6, specify the host in the "*host*" format.

[Example]

```
Servername={2001:Db8::1234,192.168.1.1};Port={27500,27500};
```

When using the data source

Specify the properties of the data source in the following format:

```
Servername={host1,host2}
Port={port1,port2}
target_session_attrs={read-write | prefer-read | any }
SSLMode=verify-full
SSLServerCertCN=targetServerCertificateCN
```

- When using IPV6, specify the host in the "*host*" format.

[Example]

```
Servername={2001:Db8::1234,192.168.1.1}
```

Note

If using the connection parameter `login_timeout`, this value is applied for connections to each of the specified hosts. If both multiplexed database servers have failed, the connection will time out when a time equal to double the `login_timeout` value elapses.

8.2.3 Using a Connection Service File

Set the connection parameters as follows.

Table 8.3 Information to be set

Parameter	Explanation
<code>host</code>	Specify the host names, using a comma as the delimiter.
<code>hostaddr</code>	Specify IP address 1 and IP address 2, using a comma as the delimiter.
<code>port</code>	Specify the connection destination port numbers, using a comma as the delimiter. Specify the port number for the server specified for the <i>n</i> th host or <code>hostaddr</code> as the <i>n</i> th port. The port number can be omitted. If omitted, the default is 27500. If <i>n</i> server names are specified, and <i>m</i> ports are specified then there will be error reported. The only exceptions are where <i>m</i> = <i>n</i> or <i>m</i> =1. In case only one port is specified, then the same is applied for all the hosts.
<code>target_session_attrs</code>	Specify the selection sequence of the servers to which the application will connect. Refer to " Target server " for details.
<code>sslmode</code>	Specify this to encrypt communications. By default, this is disabled. The setting values for <code>sslmode</code> are as follows: disable: Connect without SSL allow: Connect without SSL, and if it fails, connect with SSL prefer: Connect with SSL, and if it fails, connect without SSL require: Connect always with SSL verify-ca: Connect with SSL, using a certificate issued by a trusted CA (*1) verify-full: Connect with SSL, using a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
<code>sslservercertcn</code>	This parameter is enabled only to perform SSL authentication (<code>sslmode=verify-full</code>). Specify the server certificate CN. If this is omitted, the value will be null, and the server certificate CN will be authenticated using the host name specified in <code>host</code> .

*1: If specifying either "verify-ca" or "verify-full", use the system environment variable `PGSSLROOTCERT` (connection parameter `sslrootcert`) of your operating system to specify the CA certificate file as shown below.

Example)

Variable name: `PGSSLROOTCERT`

Variable value: `cACertificateFile`

Note

If using the connection parameter `connect_timeout`, this value is applied for connections to each of the specified hosts. If both multiplexed database servers have failed, the connection will time out when a time equal to double the `connect_timeout` value elapses.

If using the C Library, embedded SQL or psql commands (including other client commands that specify connection destinations), it is recommended to use a connection service file to specify connection destinations.

In the connection service file, a name (service name) is defined as a set, comprising information such as connection destination information and various types of tuning information set for connections. By using the service name defined in the connection service file when connecting to databases, it is no longer necessary to modify applications when the connection information changes.

8.2.4 Using the C Library (libpq)

It is recommended that you use a connection service file. Refer to "8.2.3 Using a Connection Service File" for details.

If a connection service file will not be used, set the following information for the database connection control functions (PQconnectdbParams, PQconnectdb, and so on) or environment variables.

Table 8.4 Information to be set

Parameter (environment variable name)	Explanation
host(PGHOST)	Specify the host names, using a comma as the delimiter.
hostaddr(PGHOSTADDR)	Specify IP address 1 and IP address 2, using a comma as the delimiter.
port(PGPORT)	Specify the connection destination port numbers, using a comma as the delimiter. Specify the port number for the server specified for the nth host or hostaddr as the nth port. The port number can be omitted. If omitted, the default is 27500. If <i>n</i> server names are specified, and <i>m</i> ports are specified then there will be error reported. The only exceptions are where <i>m=n</i> or <i>m=1</i> . In case only one port is specified, then the same is applied for all the hosts.
target_session_attrs(PGTARGETSESSIONATTRS)	Specify the selection sequence of the servers to which the application will connect. Refer to "Target server" for details.
sslmode(PGSSLMODE)	Specify this to encrypt communications. By default, this is disabled. The setting values for sslmode are as follows: disable: Connect without SSL allow: Connect without SSL, and if it fails, connect with SSL prefer: Connect with SSL, and if it fails, connect without SSL require: Connect always with SSL verify-ca: Connect with SSL, using a certificate issued by a trusted CA (*1) verify-full: Connect with SSL, using a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
sslservercertcn(PGXSSLSERVERCERTCN)	This parameter is enabled only to perform SSL authentication (sslmode=verify-full). Specify the server certificate CN. If this is omitted, the value will be null, and the server certificate CN will be authenticated using the host name specified in host.

*1: If specifying either "verify-ca" or "verify-full", use the system environment variable PGSSLROOTCERT (connection parameter sslrootcert) of your operating system to specify the CA certificate file as shown below.

Example)

Variable name: PGSSLROOTCERT

Variable value: *cACertificateFile*

When using URI

```
postgresql://host1[:port1],host2[:port2][,...]/database_name  
[?target_session_attrs={read-write | prefer-read | any }]
```

- When using IPV6, specify the host in the "[*host*]" (with square brackets) format.

[Example]

```
postgresql://postgres@[2001:Db8::1234]:27500,192.168.1.1:27500/database_name
```

When using key-value

```
host=host1[,host2] port=port1[,port2] user=user1 password=pwd1 dbname=mydb  
[target_session_attrs={read-write| prefer-read | any }]
```

- When using IPV6, specify the host in the "*host*" format.

[Example]

```
host=2001:Db8::1234,192.168.1.1 port=27500,27500
```



Note

If using the connection parameter `connect_timeout`, this value is applied for connections to each of the specified hosts. If both multiplexed database servers have failed, the connection will time out when a time equal to double the `connect_timeout` value elapses.



Information

If using a password file (`.pgpass`), describe the entries matching each server.

- Example 1:

```
host1:port1:dbname:user:password  
host2:port2:dbname:user:password
```

- Example 2:

```
*:port:dbname:user:password
```

8.2.5 Using Embedded SQL

It is recommended that you use a connection service file. Refer to "[8.2.3 Using a Connection Service File](#)" for details.



Point

If using a connection service file, either of the following methods is available:

- Set the service name as a string literal or host variable, as follows:

```
tcp:postgresql://?service=my_service
```

- Set the service name in the environment variable `PGSERVICE`, and use `CONNECT TO DEFAULT`

If a connection service file will not be used, use a literal or variable to specify the connection destination server information for target in the SQL statement below:

```
EXEC SQL CONNECT TO target [AS connection-name] [USER user-name];
```

Method used

```
dbname@host1,host2[:[port1][,port2]]
tcp:postgresql://host1,host2[:[port1][,port2]] [/dbname] [?target_session_attrs={read-write |
prefer-read | any}][&sslmode=verify-full&sslservercertcn=targetServerCertificateCN]
```

- The above format cannot be specified directly without using a literal or variable.

Table 8.5 Information to be set

Argument	Explanation
host1 host2	Specify the IP address or host name. IPv6 format addresses cannot be specified.
port1 port2	Specify the connection destination port numbers, using a comma as the delimiter. The port number can be omitted. If omitted, the default is 27500.
dbname	Specify the database name.
target_session_attrs	Specify the selection sequence of the servers to which the application will connect. Refer to "Target server" for details.
sslmode	Specify this to encrypt communications. By default, this is disabled. The setting values for sslmode are as follows: disable: Connect without SSL allow: Connect without SSL, and if it fails, connect with SSL prefer: Connect with SSL, and if it fails, connect without SSL require: Connect always with SSL verify-ca: Connect with SSL, using a certificate issued by a trusted CA (*1) verify-full: Connect with SSL, using a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
sslservercertcn	This parameter is enabled only to perform SSL authentication (sslmode=verify-full). Specify the server certificate CN. If this is omitted, the value will be null, and the server certificate CN will be authenticated using the host name specified in host.

*1: If specifying either "verify-ca" or "verify-full", use the system environment variable PGSSLROOTCERT (connection parameter sslrootcert) of your operating system to specify the CA certificate file as shown below.

Example)

Variable name: PGSSLROOTCERT

Variable value: *cACertificateFile*



Point

Environment variables can also be used. Refer to "8.2.4 Using the C Library (libpq)" for information on environment variables.



If using the connection parameter `connect_timeout`, this value is applied for connections to each of the specified hosts. If both multiplexed database servers have failed, the connection will time out when a time equal to double the `connect_timeout` value elapses.

8.2.6 Using the psql Command

It is recommended that you use a connection service file. Refer to "8.2.3 Using a Connection Service File" for details.

If a connection service file will not be used, specify the following information in the psql command option/environment variable.

Table 8.6 Information to be set

Option (environment variable)	Explanation
-h/--host(PGHOST/ PGHOSTADDR)	Specify IP address 1 and IP address 2, or the host name, using a comma as the delimiter. This can also be specified for the environment variable PGHOST or PGHOSTADDR.
-p/--port(PGPORT)	Specify the connection destination port numbers, using a comma as the delimiter. This can also be specified for the environment variable PGPORT. Specify the port number corresponding to the IP address specified for the nth -h option as the nth -p option. The port number can be omitted. If omitted, the default is 27500. If <i>n</i> -h options are specified, and <i>m</i> -p options are specified then there will be error reported. The only exception is where <i>m</i> = <i>n</i> or <i>m</i> =1. In case only one port is specified, then the same is applied for all the hosts.
(PGTARGETSESSIONATTR S)	Specify the selection sequence of the servers to which the application will connect. Refer to "Target server" for details.
(PGSSLMODE)	Specify this to encrypt communications. By default, this is disabled. The setting values for PGSSLMODE are as follows: disable: Connect without SSL allow: Connect without SSL, and if it fails, connect with SSL prefer: Connect with SSL, and if it fails, connect without SSL require: Connect always with SSL verify-ca: Connect with SSL, using a certificate issued by a trusted CA (*1) verify-full: Connect with SSL, using a certificate issued by a trusted CA to verify if the server host name matches the certificate (*1)
(PGXSSLSERVERCERTCN)	This environment variable is enabled only to perform SSL authentication (PGSSLMODE=verify-full). Specify the server certificate CN. If this is omitted, the value will be null, and the server certificate CN will be authenticated using the host name specified in host.

*1: If specifying either "verify-ca" or "verify-full", use the system environment variable PGSSLROOTCERT (connection parameter `sslrootcert`) of your operating system to specify the CA certificate file as shown below.

Example)

Variable name: PGSSLROOTCERT

Variable value: *cACertificateFile*

Note

.....

If using the connection parameter `connect_timeout`, this value is applied for connections to each of the specified hosts. If both multiplexed database servers have failed, the connection will time out when a time equal to double the `connect_timeout` value elapses.

.....

Information

.....

Use the same method as for `psql` commands to specify connection destination server information for other client commands used to specify connection destinations.

.....

Chapter 9 Performance Tuning

This chapter explains how to tune application performance.

9.1 Enhanced Query Plan Stability

FUJITSU Enterprise Postgres estimates the cost of query plans based on SQL statements and database statistical information, and selects the least expensive query plan. However, like other databases, FUJITSU Enterprise Postgres does not necessarily select the most suitable query plan. For example, it may suddenly select unsuitable query plan due to changes in the data conditions.

In mission-critical systems, stable performance is more important than improved performance, and changes in query plans case to be avoided. In this situation, by stabilizing the SQL statement query plan so that it does not change, deterioration of the application performance is suppressed.

9.1.1 Optimizer Hints

This section explains the basic feature content of the optimizer hint (`pg_hint_plan`).

Refer to the open-source software webpage for information on `pg_hint_plan`.

In FUJITSU Enterprise Postgres, the optimizer hints can be specified in all application interfaces.

Description

You can specify a query plan in each SQL statement.

List of Features

The main query plans that can be specified using this feature are as follows:

- Query methods
- Join methods
- Join sequences

Query methods

Specify which method to use to query the specified table.

The main features are as follows:

- SeqScan (*tableName*)
- BitMapScan (*tableName* [*indexName* ...])
- IndexScan (*tableName* [*indexName* ...])
- IndexOnlyScan (*tableName* [*indexName* ...])

Note

- If the specified index does not exist, or is not related to the search condition column specified in the WHERE clause, for example, SeqScan will be used.
- Even if IndexOnlyScan is specified, IndexScan may be used if it is necessary to access the table because a row was updated, for example.
- If multiple query methods were specified for the same table, the method specified last will be used.

Join methods

Specify the join method.

The main features are as follows:

- NestLoop (*tableName tableName [tableName ...]*)
- MergeJoin (*tableName tableName [tableName ...]*)
- HashJoin (*tableName tableName [tableName ...]*)

Note

- These cannot be specified for view tables and subqueries.
- If multiple methods were specified for the same table combination, the method specified last will be used.

Join sequences

The tables will be joined in the specified table sequence.

Specify the information using the following method:

- Leading (*(table table)*)

The method used to specify [*table*] is as follows:

table = tableName or (*table table*)

Note

If multiple sequences were specified for the same table combination, the sequence specified last will be used.

Usage method

The use of this feature is explained below.

Method used to define this feature

Define this feature by specifying the format (block comment) `"/**+ ... */"`.

- To specify hint clauses in each SELECT statement, for example when there are multiple SELECT statements in the SQL statement, define all hint clauses in the first block comment.

Example

Specifying hint clauses for the emp table and the dept table

```
WITH /**+ IndexScan(emp emp_age_index) IndexScan(dept dept_deptno_index) */ age30
AS (SELECT * FROM emp WHERE age BETWEEN 30 AND 39)
SELECT * FROM age30, dept WHERE age30.deptno = dept.deptno;
```

- To specify separate hint clauses for the same object in the SQL statement, define aliases in each object, and then specify hint clauses for those aliases.

Example

Specifying separate hint clauses for the emp table

```
WITH /*+ SeqScan(ta) IndexScan(tb) */ over100
AS (SELECT empno FROM emp ta WHERE salary > 1000000)
SELECT * FROM emp tb, over100 WHERE tb.empno = over100.empno AND tb.age < 30
```

- When using embedded SQL in C, the locations in which the hint clause block comment is specified are restricted. Refer to "5.4.2 Compiling Applications" for details.

Usage notes

- If a hint clause was specified in multiple block comments in the SQL statement, the hint clause specified in the second block comment and thereafter will be ignored.
- If characters other than those listed below appear before the hint clause in the SQL statement, they will be invalid even for hint clause block comments.
 - Space, tab, line feed
 - Letter (uppercase and lowercase), number
 - Underscore, comma
 - Brackets ()

9.1.2 Locked Statistics

This section explains the basic feature content for locked statistics (pg_dbms_stats).

Refer to the open-source software webpage for information on pg_dbms_stats.

Description

Locks the statistics.

By using this feature to lock the statistics for performance obtained in job load testing in an environment that simulates a production environment, performance degradation caused by changes to the query plan after go-live can be suppressed.

Additionally, by using the export and import features, statistics that were checked in the test environment can also be reproduced in the production environment.

List of Features

The main features that can be specified using this feature are as follows.

[Features]

Feature	Details	Description
Lock/unlock of the statistics	Lock	Locks the statistics so that the currently selected query plan remains selected.
	Unlock	Unlocks the statistics.
Backup/restore of the statistics	Backup	Backs up the current statistics.
	Restore	Restores the statistics to the point when they were backed up, and then locks them.
	Purge	Deletes backups that are no longer necessary.
Backup/restore using external files	Export	Outputs the current statistics to an external file (binary format).
	Import	Reads the statistics from an external file created by the export feature, and then locks them.

[Target object]

Target resource	Range of feature
Database	In the database
Schema	In the schema
Table	In the table
Column	ID column

Usage method

The use of this feature is explained below.

Method used to specify this feature

Specify this feature as an SQL function.

The methods used to specify the main features are shown in the table below.

Feature	Object	Function specified
Lock	Database	dbms_stats.lock_database_stats()
	Schema	dbms_stats.lock_schema_stats('schemaName')
	Table	dbms_stats.lock_table_stats('schemaName.tableName')
Unlock	Database	dbms_stats.unlock_database_stats()
	Schema	dbms_stats.unlock_schema_stats('schemaName')
	Table	dbms_stats.unlock_table_stats('schemaName.tableName')
Import	Database	dbms_stats.import_database_stats('fullPathOfExportedFile')
Backup	Database	dbms_stats.backup_database_stats('commentUsedForIdentification')
Restore	Database	[Format 1] dbms_stats.restore_database_stats('timestamp')
		[Timestamp] Specify in the same format as the time column of the backup_history table. Backups earlier than the specified time will be restored.
Purge	Backup	[Format 2] dbms_stats.restore_stats(backupId)
		[Backup ID] Specify a value in the id column of the backup_history table. The specified backup will be restored.
Purge	Backup	dbms_stats.purge_stats(backupId,flagUsedForDeletion)
		[Backup ID] Specify a value in the id column of the backup_history table.
		[Flag used for deletion] true: The target backup is forcibly deleted. false: The target backup is deleted only when there are also backups for the entire database.

Remark 1: The export feature is executed using the COPY statement, not the SQL function.



Example

Example 1: Locking the statistics of the entire database

```

userdb=# SELECT dbms_stats.lock_database_stats();
lock_database_stats
-----
tbl1
tbl1_pkey

```

Note that the locked information can be referenced as follows:

```

userdb=# select relname from dbms_stats.relation_stats_locked;
relname
-----
tbl1
tbl1_pkey

```

Example 2: Unlocking the statistics of the entire database

```

userdb=# SELECT dbms_stats.unlock_database_stats();
unlock_database_stats
-----
tbl1
tbl1_pkey

```

Example 3: Backing up the statistics of the entire database

```

userdb=# SELECT dbms_stats.backup_database_stats('backup1');
backup_database_stats
-----
1

```

Note that the backed up statistics can be referenced as follows:

```

userdb=# select id,comment,time,unit from dbms_stats.backup_history;
 id | comment |           time           | unit
-----+-----+-----+-----
  1 | backup1 | 2014-03-04 11:08:40.315948+09 | d

```

The ID:1 backup "backup1" is obtained for each database at "2014-03-04 11:08:40.315948+09".
[Meaning of unit] d: database s: schema t: table c: column

Example 4: Exporting the statistics of the entire database

```

$ psql -d userdb -f export.sql
BEGIN
COMMIT

```

export.sql is the file in which the COPY statement is defined.

Refer to "export_effective_stats-<x>.sql_sample" for information on the content of the COPY statement. "<x>" indicates the product version.

"export_effective_stats-<x>.sql_sample" is stored as follows:

fujitsuEnterprisePostgresInstallDir/share/doc/extension

Example 5: Importing the statistics of the entire database

```

$ psql -d userdb -c "SELECT dbms_stats.import_database_stats ('$PWD/export_stats.dmp')"
import_database_stats
-----

```

(1 row)

Usage notes

- You must run the ANALYZE command once for the target tables of this feature. If the ANALYZE command is not run, the statistics cannot be locked.
Refer to "SQL Commands" in "Reference" in the PostgreSQL Documentation for information on the ANALYZE command.
- To use this feature to delete an object that has locked the statistics, use the unlock feature to delete the object lock information first.
- This feature does not specify the statistics value directly. It reproduces the status that has actually occurred. For this reason, if the text format is specified in the COPY statement when the export occurs, restore will not be possible. Always use the binary format when performing the export.

Chapter 10 Scan Using a Vertical Clustered Index (VCI)

This chapter describes scanning using a VCI.

10.1 Operating Conditions

Faster aggregation can be achieved by using a VCI defined for all columns to be referenced.

This section describes the conditions under which a scan can use a VCI.

Whether to use VCI is determined based on cost estimation in the same way as normal indexes. Therefore, another execution plan will be selected if it is cheaper than a VCI even if a VCI is available.

SQL statements that can use VCIs

In addition to general SELECT statements, VCIs can be used for the SQL statements below (as long as they do not specify any of the elements listed in "SQL statements that cannot use VCIs" below):

- SELECT INTO
- CREATE TABLE AS SELECT
- CREATE MATERIALIZED VIEW ... AS SELECT
- CREATE VIEW ... AS SELECT
- COPY (SELECT ...) TO

SQL statements that cannot use VCIs

VCIs cannot be used for SQL statements that specify any of the following:

- Subquery to reference the column in which the parent query is referencing is specified
- Lock clause (such as FOR UPDATE)
- Cursor declared with WITH HOLD or scrollable
- SERIALIZABLE transaction isolation level
- Function or operator listed in "Functions and operators that do not use a VCI"
- User-defined function

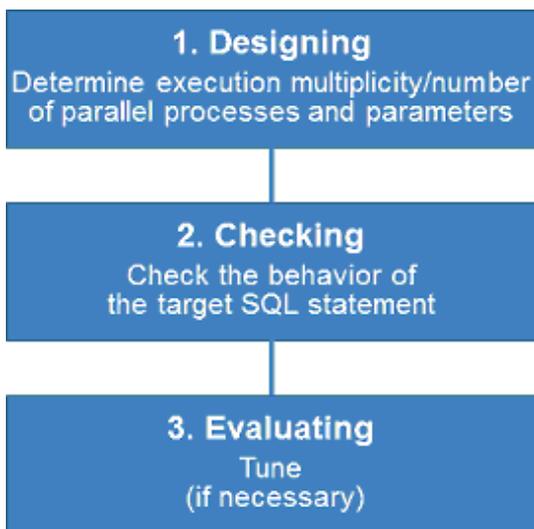
Table 10.1 Functions and operators that cannot use VCIs

Classification		Function/operator
Mathematical functions and operators	Random functions	random and setseed
String functions and operators	String functions	format (if the <i>format</i> argument is specified), regexp_matches, regexp_split_to_array and regexp_split_to_table
Date/time functions and operators	Date/time functions	age(timestamp), current_date, current_time, current_timestamp, localtime, localtimestamp, statement_timestamp and transaction_timestamp
	Delaying execution functions	pg_sleep, pg_sleep_for, and pg_sleep_until
Enum support functions		All functions and operators
Geometric functions and operators		All functions and operators
Network address functions and operators		All functions and operators
Text search functions and operators		All functions and operators
XML functions		All functions

Classification		Function/operator
JSON functions and operators		All functions and operators
Sequence manipulation functions		All functions
Array functions and operators		All functions and operators
Range functions and operators		All functions and operators
Aggregate functions	General-purpose aggregate functions	array_agg, json_agg, json_object_agg, string_agg and xmlagg
	Aggregate functions for statistics	corr, covar_pop, covar_samp, regr_avgx, regr_avgy, regr_count, regr_intercept, regr_r2, regr_slope, regr_sxx, regr_sxy and regr_syy
	Ordered-set aggregate functions	All functions
	Hypothetical-set aggregate functions	All functions
Window functions		All functions
Subquery expressions		Subquery expressions with its row constructor specified on the left side
Row and array comparisons		Row constructor and composite type comparisons
Set returning functions		All functions
System information functions		All functions
System administration functions		All functions
Trigger functions		All functions
Session information functions		current_role and current_user

10.2 Usage

This section describes how to use a VCI in line with the following steps:



10.2.1 Designing

Design as follows before using a VCI.

- Execution multiplicity and number of parallel processes

- Parameters

Execution multiplicity and number of parallel processes

Determine the maximum number of SQL statements that can be executed simultaneously and the number of parallel processes based on the number of CPU cores that can be allocated for scans that use VCI to perform aggregate processing. Design in advance the multiplicity of SQL statements for executing scans that use VCI and the number of parallel processes for scans that use VCI.

For example, if the number of CPUs that can be allocated is 32 cores, then the maximum number of SQL statements that can be executed simultaneously is 8 and the number of parallel processes is 4.

Note

A temporary file is created in /dev/shm or in a directory specified for the vci.smc_directory parameter as the dynamic shared memory for each SQL statement during a scan using a VCI.

Ensure that this directory has sufficient space to meet the memory requirements estimated for the execution multiplicity and number of parallel processes of SQL statements (refer to "Memory used per scanning" in "VCI Memory Requirements" in the Installation and Setup Guide for Server for details). If it does not have sufficient space when a scan is performed, SQL statements will return errors due to the insufficient memory.

Parameters

The VCI parallel scan feature cannot be used for setting parameters immediately after creating an instance.

Therefore, set the parameters below based on the values determined in "Execution multiplicity and number of parallel processes of SQL statements" above.

Parameter name	Description	Default	Value index
vci.max_parallel_degree	Maximum number of VCI parallel processes (background processes) to be used per SQL statement.	0	Specify the number of parallel processes.
vci.smc_directory	Directory name in which a temporary file is created as the dynamic shared memory during a scan using a VCI.	/dev/shm	Specify a directory that has enough free space for the memory used for each query during the scan.
max_worker_processes	Maximum number of background processes that the system supports.	8	Add the value of the maximum number of SQL statements that can be executed simultaneously for scans that use VCI multiplied by vci.max_parallel_degree.

See

Refer to "Parameters" in the Operation Guide for information on the details of and how to set the parameters.

10.2.2 Checking

Execute the SQL statement with "EXPLAIN ANALYZE" to check the following:

- If a VCI was used
"Custom Scan (VCI...)" is displayed in the plan if a VCI was used.
- Number of parallel processes
The number of parallel processes when the SQL statement is executed is displayed in "Allocated Workers". Check that it is running the designed number of parallel processes.

- Response
Check if the execution time displayed in "Execution time" is as estimated.

The following shows an example of the output result of EXPLAIN ANALYZE:

```
EXPLAIN ANALYZE SELECT COUNT(*) FROM test WHERE x > 10000;
                                QUERY PLAN
-----
Custom Scan (VCI Aggregate) (cost=19403.15..19403.16 rows=1 width=0) (actual time=58.505..58.506
rows=1 loops=1)
    Allocated Workers: 4
    -> Custom Scan (VCI Scan) using test_x_idx on test (cost=0.00..16925.00 rows=991261 width=0)
    (never executed)
        Filter: (x > 10000)
Planning time: 0.151 ms
Execution time: 86.910 ms
(6 rows)
```



Note

A cost output by the execution plan that uses a VCI may be inaccurate. A VCI works if all or part of the best execution plan when the SQL statement was executed is replaced with an execution plan that uses a VCI. If the cost of the execution plan to be replaced is lower than a certain value (vci.cost_threshold parameter), it will not be replaced or recalculated. Therefore, the cost of the original execution plan is output as is.

10.2.3 Evaluating

If the results in "10.2.2 Checking" is any of the following, tune accordingly:

If a VCI is not used

- Check if the "10.1 Operating Conditions" are met.
- Check if vci.enable is set to "on".
- A VCI may not be appropriately used when statistics are outdated, such as immediately after inserting a large amount of data. In such cases, execute the VACUUM ANALYZE statement or the ANALYZE statement.
- A VCI is not used if there is insufficient memory for VCI scan. This may occur during time-consuming transactions involving tables for which VCIs were defined. Set vci.log_query to "on", and check if either "could not use VCI: local ROS size (%zu) exceeds limit (%zu)" or "out of memory during local ROS generation" is output. If it is, then increase the value of the vci.max_local_ros.

Response is not as expected

Tuning may improve response. Check the following:

- If vci.max_parallel_degree is not set or is set to 0, set an appropriate value according to "10.2.1 Designing".
- If there is a margin in the CPU usage, increase the value of vci.max_parallel_degree and check again. In addition, if the value that of max_worker_processes is lower than the maximum number of SQL statements that can be executed simultaneously for parallel scan multiplied by vci.max_parallel_degree, increase it and check again.

10.3 Usage Notes

This section provides notes on using VCI.

- Regardless of whether VCI is used, the content of the result does not change. However, records may be returned in a different order if the ORDER BY clause is not specified.
- To reduce resource consumption, edit postgresql.conf or use the SET statement to enable/disable vci.enable when you use this feature only for specific times or jobs (SQL applications).

- The optimizer hint (`pg_hint_plan`) cannot be specified for a VCI. The hint clause is ignored if it is specified.
- If a plan other than VCI is specified for the optimizer hint (`pg_hint_plan`), a VCI may be used. Therefore, if you specify a query plan with the hint clause, use the SET statement to set `vci.enable` to "off".
- The message below may be output when a scan that uses VCI is performed on the streaming replication standby server:

```
"LOG: recovery has paused"
"HINT: Execute pg_wal_replay_resume() to continue."
```

This message is output because application of the WAL to the VCI temporarily pauses due to the scan being performed.

- Even if a scan is performed using a VCI, information in the `idx_scan`, `idx_tup_read`, and `idx_tup_fetch` columns of the collected statistics views, `pg_stat_all_indexes` and `pg_stat_user_indexes`, will not be updated.
- Currently, it is not possible to replace the query plan for parallel aggregation with the query plan using VCI. Therefore, if you create a VCI on a column of a partition table and aggregate (`sum ()` etc.) on that column, one of the following plans will be selected. Use different setting parameters according to the situation of the target table.
 - Plan of the parallel aggregations using scan methods other than VCI scan

It is selected when `max_parallel_workers_per_gather` is 1 or more.

```
explain select sum(value) from test;
                                QUERY PLAN
-----
Finalize Aggregate (cost=99906.30..99906.31 rows=1 width=8)
-> Gather (cost=99906.08..99906.29 rows=2 width=8)
    Workers Planned: 2
    -> Partial Aggregate (cost=98906.08..98906.09 rows=1 width=8)
        -> Parallel Append (cost=0.00..94739.83 rows=1666500 width=4)
            -> Parallel Seq Scan on test_1 (cost=0.00..43203.67 rows=833250 width=4)
            -> Parallel Seq Scan on test_2 (cost=0.00..43203.67 rows=833250 width=4)
```

This plan is fast when the number of records to be aggregated (number of records that hit the search conditions) is very large. This is because the benefit of parallelizing aggregation is important, not the performance of scanning. For example, each parallel worker will perform a sequential scan and aggregate most of the scanned records.

- Plan that aggregates VCI scan results by a single aggregator node

It is selected by setting `max_parallel_workers_per_gather` to 0 and not creating a query plan of parallel aggregate.

```
explain select sum(value) from test;
                                QUERY PLAN
-----
Aggregate (cost=145571.00..145571.01 rows=1 width=8)
-> Append (cost=0.00..135572.00 rows=3999600 width=4)
    -> Custom Scan (VCI Scan) using test_1_id_value_idx on test_1 (cost=0.00..57787.00
rows=1999800 width=4)
        Allocated Workers: 2
    -> Custom Scan (VCI Scan) using test_2_id_value_idx on test_2 (cost=0.00..57787.00
rows=1999800 width=4)
        Allocated Workers: 2
```

This plan is fast when the number of aggregated items is not large or when the size of the aggregated column is smaller than the record size. This is because the scan performance is more important, so it is faster to aggregate the results of VCI scans of each partition.

- Originally, if there is only one partition to be accessed, the following VCI aggregation plan can be used. Below is an example of scanning only one partition with partition pruning.

```
explain select sum(value) from test where id < 1000001;
                                QUERY PLAN
-----
Custom Scan (VCI Aggregate) (cost=62786.50..62786.51 rows=1 width=8)
  Allocated Workers: 2
```

```
-> Custom Scan (VCI Scan) using test_1_id_value_idx on test_1 (cost=0.00..57787.00
rows=1999800 width=4)
  Filter: (id < 1000001)
```

However, the current planner does not try to choose VCI aggregation because it creates a plan for parallel aggregation if the table is partitioned. So in this case, set `max_parallel_workers_per_gather` to 0 to force the planner to choose VCI aggregation.

Appendix A Precautions when Developing Applications

This appendix describes precautions when developing applications with FUJITSU Enterprise Postgres.

A.1 Precautions when Using Functions and Operators

This section describes notes for using functions and operators.

A.1.1 General rules of Functions and Operators

This section describes general rules for using functions and operators. Ensure the general rules are followed when using functions and operators to develop applications.

General rules

- Specify the stated numbers for arguments when specifying numbers for arguments in functions.
- Specify the stated data types when specifying data types for functions. If you use a data type other than the stated data types, use CAST to explicitly convert the data type.
- Specify data types that can be compared when specifying data types for operators. If you use a data type that cannot be compared, use CAST to explicitly convert the data type.



See

Refer to "Functions and Operators" under "The SQL Language" in the PostgreSQL Documentation for information on the functions and operators available with FUJITSU Enterprise Postgres.

A.1.2 Errors when Developing Applications that Use Functions and/or Operators

This section provides examples of problems that may occur when developing applications that use functions and/or operators, and describes how to deal with them.

The error "Function ***** does not exist" occurs when executing SQL

The following error will occur when executing an SQL statement that does not abide by the general rules for functions:

```
ERROR: Function ***** does not exist
```

Note: "*****" denotes the function for which the error occurred, and the data type of its arguments.

The cause of the error will be one of the following:

- The specified function does not exist.
- The wrong number of arguments or wrong argument data type was specified

Corrective action

Check the following points and correct any errors:

- Check if there are any errors in the specified function name, number of arguments, or argument data type, and revise accordingly.
- Check the argument data type of the function displayed in the message. If an unintended data type is displayed, use a function such as CAST to convert it.

The error "Operator does not exist" occurs when executing SQL

The following error will occur when executing an SQL statement that specifies a data type in the operator that cannot be compared:

```
ERROR: Operator does not exist: *****
```

Note: "*****" denotes the operator for which the error occurred, and the data type of the specified value.

Corrective action

Ensure the data type of the expressions specified on the left and right sides of the operator can be compared. If required, revise to ensure these data types can be compared by using a function such as CAST to explicitly convert them.

A.2 Notes when Using Temporary Tables

In standard SQL, a temporary table can be defined in advance to enable an empty temporary table to be created automatically when the application connects to the database. However, in FUJITSU Enterprise Postgres, a temporary table must be created when the application connects to the database by explicitly using the CREATE TABLE statement.

If the same temporary table is repeatedly created and deleted during the same session, the system table might expand, and memory usage might increase. To prevent this, specify the CREATE TABLE statement to ensure the temporary table is reused.

For example, in cases where a temporary table would be created and deleted for repeatedly executed transactions, specify the CREATE TABLE statement as shown below:

- Specify "IF NOT EXISTS" to create a temporary table only if none exists when the transaction starts.
- Specify "ON COMMIT DELETE ROWS" to ensure all rows are deleted when the transaction ends.



See

Refer to "SQL Commands" under "Reference" in the PostgreSQL Documentation for information on the CREATE TABLE statement.

Examples of SQL using a temporary table are shown below:

Example of bad use (creating and deleting a temporary table)

```
BEGIN;  
CREATE TEMPORARY TABLE mytable(col1 CHAR(4), col2 INTEGER) ON COMMIT DROP;  
    (mytable processes)  
COMMIT;
```

Example of good use (reusing a temporary table)

```
BEGIN;  
CREATE TEMPORARY TABLE IF NOT EXISTS mytable(col1 CHAR(4), col2 INTEGER) ON COMMIT DELETE ROWS;  
    (mytable processes)  
COMMIT;
```

A.3 Implicit Data Type Conversions

An implicit data type conversion refers to a data type conversion performed automatically by FUJITSU Enterprise Postgres, without the need to explicitly specify the data type to convert to.

The combination of possible data type conversions differs, depending on whether the expression in the conversion source is a literal.

For non-literals, data types can only be converted to other types within the same range.

For literals, character string literal types can be converted to the target data type. Numeric literals are implicitly converted to specific numeric types. These implicitly converted numeric literals can then have their types converted to match the conversion target data type within the numeric type range. For bit character string literals, only the bit column data type can be specified. The following shows the range of type conversions for literals.

Table A.1 Data type combinations that contain literals and can be converted implicitly

Conversion target		Conversion source		
		Character literal (*1)	Numeric literal(*2)	Bit character string literal
Numeric type	SMALLINT	Y	N	N
	INTEGER	Y	Y (*3)	N
	BIGINT	Y	Y (*4)	N
	DECIMAL	Y	Y (*5)	N
	NUMERIC	Y	Y (*5)	N
	REAL	Y	N	N
	DOUBLE PRECISION	Y	N	N
	SMALLSERIAL	Y	N	N
	SERIAL	Y	Y (*3)	N
	BIGSERIAL	Y	Y (*4)	N
Currency type	MONEY	Y	N	N
Character type	CHAR	Y	N	N
	VARCHAR	Y	N	N
	NCHAR	Y	N	N
	NCHAR VARYING	Y	N	N
	TEXT	Y	N	N
Binary data type	BYTEA	Y	N	N
Date/time type	TIMESTAMP WITHOUT TIME ZONE	Y	N	N
	TIMESTAMP WITH TIME ZONE	Y	N	N
	DATE	Y	N	N
	TIME WITHOUT TIME ZONE	Y	N	N
	TIME WITH TIME ZONE	Y	N	N
	INTERVAL	Y	N	N
Boolean type	BOOLEAN	Y	N	N
Geometric type	POINT	Y	N	N
	LSEG	Y	N	N
	BOX	Y	N	N
	PATH	Y	N	N
	POLYGON	Y	N	N
	CIRCLE	Y	N	N
Network address type	CIDR	Y	N	N
	INET	Y	N	N
	MACADDR	Y	N	N
	MACADDR8	Y	N	N
Bit string type	BIT	Y	N	Y

Conversion target		Conversion source		
		Character literal (*1)	Numeric literal(*2)	Bit character string literal
	BIT VARYING	Y	N	Y
Text search type	TSVECTOR	Y	N	N
	TSQUERY	Y	N	N
UUID type	UUID	Y	N	N
XML type	XML	Y	N	N
JSON type	JSON	Y	N	N

Y: Can be converted

N: Cannot be converted

*1: Only strings that can be converted to the data type of the conversion target can be specified (such as "1" if the conversion target is a numeric type)

*2: "Y" indicates specific numeric types that are converted first.

*3: Integers that can be expressed as INTEGER types can be specified

*4: Integers that cannot be expressed as INTEGER types, but can be expressed as BIGINT types, can be specified

*5: Integers that cannot be expressed as INTEGER or BIGINT types, but that can be expressed as NUMERIC types, or numeric literals that contain a decimal point or the exponent symbol (e), can be specified

Implicit data type conversions can be used when comparing or storing data.

The conversion rules differ, depending on the reason for converting. Purpose-specific explanations are provided below.

A.3.1 Function Argument

Value expressions specified in a function argument will be converted to the data type of that function argument.



See

Refer to "Functions and Operators" under "The SQL Language" in the PostgreSQL Documentation for information on data types that can be specified in function arguments.

A.3.2 Operators

Comparison operators, BETWEEN, IN

Combinations of data types that can be compared using comparison operators, BETWEEN, or IN are shown below.

Table A.2 Combinations of comparable data type

Left side	Right side		
	Numeric type	Character string type	Date/time type
Numeric type	Y	N	N
Character type	N	Y	N
Date/time type	N	N	Y

Y: Can be compared
N: Cannot be compared

When strings with different lengths are compared, the shorter one is padded with spaces to make the lengths match.

When numeric values with different precisions are compared, data will be converted to the type with the higher precision.

Set operation and CASE also follow the same rules.

Other operators

Value expressions specified in operators will be converted to data types that are valid for that operator.



.....
Refer to "Functions and Operators" under "The SQL Language" in the PostgreSQL Documentation for information on data types that can be specified in operators.
.....

A.3.3 Storing Values

Value expressions specified in the VALUES clause of the INSERT statement or the SET clause of the UPDATE statement will be converted to the data type of the column in which they will be stored.

A.4 Notes on Using Index

This section explains the notes on using the following indexes:

- SP-GiST index

A.4.1 SP-GiST Index

If more than 2 concurrent updates are performed on a table in which the SP-GiST index is defined, applications may stop responding. When this occur, all system processes including the Check Pointer process will also be in the state of no response. For these reasons, use of the SP-GiST index is not recommended.

A.5 Notes on Using Multibyte Characters in Definition Names

Multibyte characters must not be used in database names or user names, because certain conditions may apply or it may not be possible to connect to some clients.

Related notes and constraints are described below.

1) Configuring the client encoding system

The client encoding system must be configured when the names are created.



.....
Refer to "Character Set Support" in "Server Administration" in the PostgreSQL Documentation for information on how to configure the client encoding system.
.....

2) Encoding system of names used for connection

Ensure that the encoding system of names used for connection is the same as that of the database that was connected when these names were created.

The reasons for this are as follows:

- Storage system for names in FUJITSU Enterprise Postgres

The system catalog saves encoded names by using the encoding system of the database at the time the names were created.

- Encoding conversion policy when connected

When connected, names sent from the client are matched with names in the system catalog without performing encoding conversion.

Accordingly, if the database that was connected when the names were defined uses the EUC_JP encoding system, but the database name is specified using UTF-8 encoding, then the database will be considered to be non-existent.

3) Connection constraints

The table below shows the connection constraints for each client type, based on the following assumptions:

- The conditions described in 1) and 2) above are satisfied.
- The database name and user names use the same encoding system.

Client type	Client operating system
JDBC driver	Cannot be connected
ODBC driver	No connection constraints
SQLEmbedded SQL in C	No connection constraints
psql command	No connection constraints

Appendix B Conversion Procedures Required due to Differences from Oracle Database

This appendix explains how to convert from an Oracle database to FUJITSU Enterprise Postgres, within the scope noted in "[Chapter 7 Compatibility with Oracle Databases](#)" from the following perspectives:

- Feature differences
- Specification differences

This document assumes that the version of the Oracle database to be converted is 7-10.2g.

B.1 Outer Join Operator (Perform Outer Join)

Features

In the WHERE clause conditional expression, by adding the plus sign (+), which is the outer join operator, to the column of the table you want to add as a table join, it is possible to achieve an outer join that is the same as a joined table (OUTER JOIN).

B.1.1 Comparing with the ^= Comparison Operator

Oracle database

```
SELECT *
FROM t1, t2
WHERE t1.col1(+) ^= t2.col1;
```

* col1 is assumed to be CHAR(4) type

FUJITSU Enterprise Postgres

```
SELECT *
FROM t1, t2
WHERE t1.col1(+) != t2.col1;
```

* col1 is assumed to be CHAR(4) type

Feature differences

Oracle database

The ^= comparison operator can be specified.

FUJITSU Enterprise Postgres

The ^= comparison operator cannot be specified.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "^=" is used.
2. Ensure that the keyword, "(+)", is either on the right or left-hand side.
3. Change "^=" to "!=".

B.2 DECODE (Compare Values and Return Corresponding Results)

Features

DECODE compares values of the conversion target value expression and the search values one by one, and if the values of the conversion target value expression and the search values match, a corresponding result value is returned.

B.2.1 Comparing Numeric Data of Character String Types and Numeric Characters

Oracle database

```
SELECT DECODE( col1,
              1000, 'ITEM-A',
              2000, 'ITEM-B',
              'ITEM-C')
FROM t1;
```

* col1 is assumed to be CHAR(4) type

FUJITSU Enterprise Postgres

```
SELECT DECODE( CAST(col1 AS INTEGER),
              1000, 'ITEM-A',
              2000, 'ITEM-B',
              'ITEM-C')
FROM t1;
```

* col1 is assumed to be CHAR(4) type

Feature differences

Oracle database

When the value expression is a string and the search value is a numeric, the string value will be converted to the data type of the comparison target numeric, so that they can be compared.

FUJITSU Enterprise Postgres

If the conversion target value expression is a string value, then no search value can be specified with numbers.

Conversion procedure

Since the data type that can be specified for the conversion target value expression is unknown, use CAST to explicitly convert the conversion target value expression (col1 in the example) to a numeric (INTEGER type in the example).

B.2.2 Obtaining Comparison Result from more than 50 Conditional Expressions

Oracle database

```
SELECT DECODE(col1,
              1, 'A',
              2, 'B',
              ...
              78, 'BZ',
              NULL, 'UNKNOWN',
              'OTHER')
FROM t1;
```

* col1 is assumed to be INTEGER type

FUJITSU Enterprise Postgres

```
SELECT CASE
    WHEN col1 = 1 THEN 'A'
    WHEN col1 = 2 THEN 'B'
    ...
    WHEN col1 = 78 THEN 'BZ'
    WHEN col1 IS NULL THEN 'UNKNOWN'
    ELSE 'OTHER'
END
FROM t1;
```

* col1 is assumed to be INTEGER type

Feature differences

Oracle database

Search value with a maximum of 127 items (up to 255 arguments in total) can be specified.

FUJITSU Enterprise Postgres

Search value with a maximum of 49 items (up to 100 arguments in total) only can be specified.

Conversion procedure

Convert to the CASE expression using the following procedure:

1. Specify the DECODE conversion target value expression (col1 in the first argument, in the example) and the search value (1 in the second argument, in the example) for the CASE expression search condition. Specify the DECODE result value ('A' in the third argument, in the example) for the CASE expression THEN (WHEN col1 = 1 THEN 'A', in the example). Note that if the search value is NULL, specify "IS NULL" for the search condition for the CASE expression.
2. If the DECODE default value ('OTHER' in the last argument, in the example) is specified, specify the default value for the CASE expression ELSE (ELSE 'OTHER', in the example).

B.2.3 Obtaining Comparison Result from Values with Different Data Types

Oracle database

```
SELECT DECODE( col1,
    '1000', 'A',
    '2000', 1,
    'OTHER' )
FROM t1;
```

* col1 is assumed to be CHAR(4) type

FUJITSU Enterprise Postgres

```
SELECT DECODE( col1,
    '1000', 'A',
    '2000', '1',
    'OTHER' )
FROM t1;
```

* col1 is assumed to be CHAR(4) type

Feature differences

Oracle database

The data types of all result values are converted to the data type of the first result value.

FUJITSU Enterprise Postgres

Results in an error.

Conversion procedure

Convert using the following procedure:

1. Check the literal data type for the first result value specified.
2. Change the literals specified for each result value to the literal data type checked in the step 1.

B.3 SUBSTR (Extract a String of the Specified Length from Another String)

Features

SUBSTR returns the number of characters specified in the third argument (starting from the position specified in the second argument) from the string specified in the first argument.

Refer to "[7.2.1 Notes on SUBSTR](#)" for details on precautions when using SUBSTR.

B.3.1 Specifying a Value Expression with a Data Type Different from the One that can be Specified for Function Arguments

Oracle database

```
SELECT SUBSTR( col1,  
              1,  
              col2)  
FROM DUAL;
```

* col1 and col2 are assumed to be CHAR type

FUJITSU Enterprise Postgres

```
CREATE CAST (CHAR AS INTEGER) WITH INOUT AS IMPLICIT;  
  
SELECT SUBSTR( col1,  
              1,  
              col2)  
FROM DUAL;  
# No changes to SELECT statement;
```

* col1 and col2 are assumed to be CHAR type

Feature differences

Oracle database

If the type can be converted to a data type that can be specified for function arguments, conversion is performed implicitly.

FUJITSU Enterprise Postgres

If the data types are different from each other, or if loss of significance occurs, implicit conversion is not performed.

Conversion procedure

Since the data type of the string length is clear, first execute the following CREATE CAST only once so that the CHAR type value (col2 in the example) specified for the string length is implicitly converted to INTEGER type.

```
CREATE CAST (CHAR AS INTEGER) WITH INOUT AS IMPLICIT;
```

B.3.2 Extracting a String with the Specified Format from a Datetime Type Value

Oracle database

```
SELECT SUBSTR( CURRENT_TIMESTAMP ,
              1,
              8)
FROM DUAL;
```

FUJITSU Enterprise Postgres

```
SELECT SUBSTR( TO_CHAR(CURRENT_TIMESTAMP ,
                      'DD-MON-YY HH.MI.SS.US PM' )
              1,
              8)
FROM DUAL;
```

Feature differences

Oracle database

A datetime value such as CURRENT_TIMESTAMP can be specified for character value expressions.

FUJITSU Enterprise Postgres

A datetime value such as CURRENT_TIMESTAMP cannot be specified for character value expressions.

Conversion procedure

First, specify TO_CHAR for the SUBSTR character value expression.

Specify datetime type (CURRENT_TIMESTAMP, in the example) in firstArg of TO_CHAR, and specify the format template pattern ('DD-MON-YY HH.MI.SS.US PM', in the example) for secondArg to match with the result of SUBSTR before conversion.

TO_CHAR specification format: TO_CHAR(*firstArg*, *secondArg*)



Information

Refer to "Data Type Formatting Functions" in the PostgreSQL Documentation for information on format template patterns that can be specified for TO_CHAR in FUJITSU Enterprise Postgres.

B.3.3 Concatenating a String Value with a NULL value

Oracle database

```
SELECT SUBSTR( col1 || col2 ,
              2,
              5)
FROM t1;
```

* col1 and col2 are assumed to be character string type, and col2 may contain NULL

FUJITSU Enterprise Postgres

```
SELECT SUBSTR( col1 || NVL(col2, '')
              2,
              5)
FROM t1;
```

* col1 and col2 are assumed to be character string type, and col2 may contain NULL

Feature differences

Oracle database

NULL is handled as an empty string, and strings are joined.

FUJITSU Enterprise Postgres

NULL is not handled as an empty string, and the result of joining the strings becomes NULL.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "||" is used.
2. Check if any of the value expressions can contain NULL - if they can, then execute step 3.
3. Modify to NVL(*valExpr*,").

B.4 NVL (Replace NULL)

Features

NVL converts NULL values.

B.4.1 Obtaining Result from Arguments with Different Data Types

Oracle database

```
SELECT NVL( col1,
           col2)
FROM t1;
```

* col1 is assumed to be VARCHAR(100) type, and col2 is assumed to be CHAR(100) type

FUJITSU Enterprise Postgres

```
SELECT NVL( col1,
           CAST(col2 AS VARCHAR(100)))
FROM t1;
```

* col1 is assumed to be VARCHAR(100) type, and col2 is assumed to be CHAR(100) type

Feature differences

Oracle database

Value expressions with different data types can be specified. If the first argument is a string value, then VARCHAR2 is returned, and if it is a numeric, then a numeric type with greater range is returned.

FUJITSU Enterprise Postgres

Value expressions with different data types cannot be specified.

Conversion procedure

Since the data types that can be specified for the expressions in the two arguments are unknown, use the following steps to convert:

1. Check the data types specified for each of the two expressions.
2. Using the data type that is to be received as a result, explicitly convert the other argument with CAST.

B.4.2 Operating on Datetime/Numeric, Including Adding Number of Days to a Particular Day

Oracle database

```
SELECT NVL( col1 + 10, CURRENT_DATE )
FROM t1;
```

* col1 is assumed to be TIMESTAMP WITHOUT TIME ZONE type or TIMESTAMP WITH TIME ZONE type

FUJITSU Enterprise Postgres

```
SELECT NVL( CAST(col1 AS DATE) + 10, CURRENT_DATE )
FROM t1;
```

* col1 is assumed to be TIMESTAMP WITHOUT TIME ZONE type or TIMESTAMP WITH TIME ZONE type

Feature differences

Oracle database

Numbers can be operated (added to or subtracted from) with either TIMESTAMP WITHOUT TIME ZONE type or TIMESTAMP WITH TIME ZONE type. Operation result will be DATE type.

FUJITSU Enterprise Postgres

Numbers cannot be operated (added to or subtracted from) with neither TIMESTAMP WITHOUT TIME ZONE type nor TIMESTAMP WITH TIME ZONE type. However, numbers can be operated (added to or subtracted from) with DATE type.

Conversion procedure

Convert using the following procedure:

1. Search locations where the keyword "+" or "-" is used in addition or subtraction, and check if these operations are between numbers and TIMESTAMP WITHOUT TIME ZONE type or TIMESTAMP WITH TIME ZONE type.
2. If they are, use CAST to explicitly convert TIMESTAMP WITHOUT TIME ZONE type or TIMESTAMP WITH TIME ZONE type to DATE type.

B.4.3 Calculating INTERVAL Values, Including Adding Periods to a Date

Oracle database

```
SELECT NVL( CURRENT_DATE + (col1 * 1.5), col2 )
FROM t1;
```

* col1 and col2 are assumed to be INTERVAL YEAR TO MONTH types

FUJITSU Enterprise Postgres

```
SELECT NVL( CURRENT_DATE +
          CAST(col1 * 1.5 AS
            INTERVAL YEAR TO MONTH), col2 )
FROM t1;
```

* col1 and col2 are assumed to be INTERVAL YEAR TO MONTH types

Feature differences

Oracle database

INTERVAL YEAR TO MONTH type multiplication and division result in INTERVAL YEAR TO MONTH type and any fraction (number of days) will be truncated.

FUJITSU Enterprise Postgres

INTERVAL YEAR TO MONTH type multiplication and division result in INTERVAL type and fractions (number of days) will not be truncated.

Conversion procedure

Convert using the following procedure:

1. Search locations where the keywords "*" or "/" are used in multiplication or division, and check if the specified value is INTERVAL YEAR TO MONTH type.
2. If the value is INTERVAL YEAR TO MONTH type, use CAST to explicitly convert the operation result to INTERVAL YEAR TO MONTH type.

B.5 DBMS_OUTPUT (Output Messages)

Features

DBMS_OUTPUT sends messages to clients such as psql from PL/pgSQL.

B.5.1 Outputting Messages Such As Process Progress Status

Oracle database

```
set serveroutput on;...(1)

DECLARE
  v_col1      CHAR(20);
  v_col2      INTEGER;
  CURSOR c1 IS
    SELECT col1, col2 FROM t1;
BEGIN
  DBMS_OUTPUT.PUT_LINE('-- BATCH_001 Start --');
  OPEN c1;
  DBMS_OUTPUT.PUT_LINE('-- LOOP Start --');
  LOOP
    FETCH c1 INTO v_col1, v_col2;
    EXIT WHEN c1%NOTFOUND;
    DBMS_OUTPUT.PUT('.');
  END LOOP;
  DBMS_OUTPUT.NEW_LINE; ...(2)
  DBMS_OUTPUT.PUT_LINE('-- LOOP End --');
  CLOSE c1;

  DBMS_OUTPUT.PUT_LINE('-- BATCH_001 End --');

EXCEPTION
  WHEN OTHERS THEN
    DBMS_OUTPUT.PUT_LINE('-- SQL Error --');
    DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
END;
/
```

FUJITSU Enterprise Postgres

```
DO $$
DECLARE
    v_col1      CHAR(20);
    v_col2      INTEGER;
    c1 CURSOR FOR
        SELECT col1, col2 FROM t1;
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE); ... (1)
    PERFORM DBMS_OUTPUT.ENABLE(NULL); ... (1)

    PERFORM DBMS_OUTPUT.PUT_LINE('-- BATCH_001 Start --');

    OPEN c1;
    PERFORM DBMS_OUTPUT.PUT_LINE('-- LOOP Start --');
    LOOP
        FETCH c1 INTO v_col1, v_col2;
        EXIT WHEN FOUND = false;
        PERFORM DBMS_OUTPUT.PUT('.');
    END LOOP;
    PERFORM DBMS_OUTPUT.NEW_LINE(); ... (2)

    PERFORM DBMS_OUTPUT.PUT_LINE('-- LOOP End --');
    CLOSE c1;

    PERFORM DBMS_OUTPUT.PUT_LINE('-- BATCH_001 End --');

EXCEPTION
    WHEN OTHERS THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- SQL Error --');
        PERFORM DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
END;
$$
;
```

(1) SERVEROUTPUT/ENABLE

Specification differences

Oracle database

Use SET statement and specify SERVEROUTPUT ON.

FUJITSU Enterprise Postgres

Specify DBMS_SQL.SERVEROUTPUT(TRUE).

Conversion procedure

Convert using the following procedure:

1. Check if a SET SERVEROUTPUT statement is specified before the PL/SQL block of a stored procedure.
2. If a SET SERVEROUTPUT statement is specified, specify DBMS_SQL.SERVEROUTPUT straight after BEGIN of PL/pgSQL. If ON is specified to have messages output to a window, then specify TRUE. If OFF is specified, then specify FALSE.
3. Specify DBMS_SQL.ENABLE only if SET SERVEROUTPUT is ON. The values to be specified for the argument are as follows:
 - If SIZE is specified for the SET SERVEROUTPUT statement, specify this size for the argument.
 - If SIZE is not specified for the SET SERVEROUTPUT statement, then specify 2000 for Oracle10.1g or earlier, NULL for Oracle10.2g or later.

If DBMS_SQL.ENABLE is specified for the PL/SQL block of the stored procedure, specify the same value as that argument.

(2) NEW_LINE

Specification differences

Oracle database

If there is no argument for *packageName.featureName*, parenthesis can be omitted.

FUJITSU Enterprise Postgres

Even if there is no argument for *packageName.featureName*, parenthesis cannot be omitted.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "DBMS_OUTPUT.NEW_LINE" is used in the stored procedure.
2. If there is no parenthesis after *packageName.featureName*, add the parenthesis.

B.5.2 Receiving a Return Value from a Procedure (PL/SQL) Block (For GET_LINES)

Oracle database

```
set serveroutput off;

DECLARE
    v_num          INTEGER;
BEGIN

    DBMS_OUTPUT.DISABLE; ... (3)
    DBMS_OUTPUT.ENABLE(20000); ... (4)
    DBMS_OUTPUT.PUT_LINE('-- ITEM CHECK --');

    SELECT count(*) INTO v_num FROM t1;

    IF v_num = 0 THEN
        DBMS_OUTPUT.PUT_LINE('-- NO ITEM --');

    ELSE
        DBMS_OUTPUT.PUT_LINE('-- IN ITEM(' || v_num || ') --');
    END IF;
END;
/

set serveroutput on;

DECLARE
    v_buffs        DBMSOUTPUT_LINESARRAY; ... (5)
    v_num          INTEGER := 10;
BEGIN

    DBMS_OUTPUT.GET_LINES(v_buffs, v_num); ... (5)

    FOR i IN 1..v_num LOOP
        DBMS_OUTPUT.PUT_LINE('LOG : ' || v_buffs(i)); ... (5)
    END LOOP;
END;
/
```

FUJITSU Enterprise Postgres

```
DO $$
DECLARE
    v_num          INTEGER;
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(FALSE);
    PERFORM DBMS_OUTPUT.DISABLE(); ... (3)
    PERFORM DBMS_OUTPUT.ENABLE(20000); ... (4)
    PERFORM DBMS_OUTPUT.PUT_LINE('-- ITEM CHECK --');

    SELECT count(*) INTO v_num FROM t1;

    IF v_num = 0 THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- NO ITEM --');
    ELSE
        PERFORM DBMS_OUTPUT.PUT_LINE('-- IN ITEM(' || v_num || ') --');
    END IF;
END;
$$
;

DO $$
DECLARE
    v_buffs        VARCHAR[]; ... (5)
    v_num          INTEGER := 10;
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);
    SELECT lines, numlines INTO v_buffs, v_num FROM DBMS_OUTPUT.GET_LINES(v_num); ... (5)

    FOR i IN 1..v_num LOOP
        PERFORM DBMS_OUTPUT.PUT_LINE('LOG : ' || v_buffs[i]); ... (5)
    END LOOP;
END;
$$
;
```

(3) DISABLE

Same as the NEW_LINE in the DBMS_OUTPUT package. Refer to NEW_LINE for information on specification differences and conversion procedures associated with specification differences.

(4) ENABLE

Same as NEW_LINE in the DBMS_OUTPUT package. Refer to NEW_LINE for information on specification differences and conversion procedures associated with specification differences.

(5) GET_LINES

Specification format for Oracle database

DBMS_OUTPUT.GET_LINES(*firstArg*, *secondArg*)

Specification differences

Oracle database

Obtained values are received with variables specified for arguments.

FUJITSU Enterprise Postgres

Since obtained values are the search results for DBMS_OUTPUT.GET_LINES, they are received with variables specified for the INTO clause of the SELECT statement.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "DBMS_OUTPUT.GET_LINES" is used in the stored procedure.
2. Change the data type (DBMSOUTPUT_LINESARRAY in the example) of the variable (v_buffs in the example) specified as *firstArg* of DBMS_OUTPUT.GET_LINES into a VARCHAR type array (VARCHAR[] in the example).
3. Replace the DBMS_OUTPUT.GET_LINES location called with a SELECT INTO statement.
 - Use the literal "lines, numlines" in the select list.
 - Specify *firstArg* (v_buffs in the example) and *secondArg* (v_num in the example) configured in DBMS_OUTPUT.GET_LINES, in the INTO clause.
 - Use DBMS_OUTPUT.GET_LINES in the FROM clause. Specify only *secondArg* (v_num in the example) before modification.
4. Identify the location that references *firstArg* (v_buffs in the example), and change it to the PL/pgSQL array reference format (v_buffs[i] in the example).

B.5.3 Receiving a Return Value from a Procedure (PL/SQL) Block (For GET_LINE)

Oracle database

```
set serveroutput on;

DECLARE
    v_buff1      VARCHAR2(100);
    v_buff2      VARCHAR2(1000);
    v_num        INTEGER;
BEGIN

    v_buff2 := '';
    LOOP
        DBMS_OUTPUT.GET_LINE(v_buff1, v_num); ... (6)
        EXIT WHEN v_num = 1;
        v_buff2 := v_buff2 || v_buff1;
    END LOOP;

    DBMS_OUTPUT.PUT_LINE(v_buff2);
END;
/
```

* Only the process to obtain a value is stated

FUJITSU Enterprise Postgres

```
DO $$
DECLARE
    v_buff1      VARCHAR(100);
    v_buff2      VARCHAR(1000);
    v_num        INTEGER;
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);
    v_buff2 := '';
    LOOP
        SELECT line, status INTO v_buff1, v_num FROM DBMS_OUTPUT.GET_LINE(); ... (6)
        EXIT WHEN v_num = 1;
        v_buff2 := v_buff2 || v_buff1;
    END LOOP;
END;
```

```
PERFORM DBMS_OUTPUT.PUT_LINE(v_buff2);
END;
$$
;
```

* Only the process to obtain a value is stated

(6) GET_LINE

Specification format for Oracle database

```
DBMS_OUTPUT.GET_LINE(firstArg, secondArg)
```

Specification differences

Oracle database

Obtained values are received with variables specified for arguments.

FUJITSU Enterprise Postgres

Since obtained values are the search results for DBMS_OUTPUT.GET_LINES, they are received with variables specified for the INTO clause of the SELECT statement.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "DBMS_OUTPUT.GET_LINE" is used in the stored procedure.
2. Replace the DBMS_OUTPUT.GET_LINE location called with a SELECT INTO statement.
 - Use the literal "line, status" in the select list.
 - Specify *firstArg* (v_buff1 in the example) and *secondArg* (v_num in the example) configured in DBMS_OUTPUT.GET_LINE, in the INTO clause.
 - Use DBMS_OUTPUT.GET_LINE in the FROM clause. Although arguments are not specified, parenthesis must be specified.

B.6 UTL_FILE (Perform File Operation)

Features

UTL_FILE reads and writes text files from PL/pgSQL.

B.6.1 Registering a Directory to Load and Write Text Files

Oracle database

```
[Oracle9i or earlier]
Configure the following with initialization parameter
  UTL_FILE_DIR='/home/fsep' ... (1)

[Oracle9.2i or later]
Configure the following with CREATE DIRECTORY statement
  CREATE DIRECTORY DIR AS '/home/fsep'; ... (1)
```

FUJITSU Enterprise Postgres

```
INSERT INTO UTL_FILE.UTL_FILE_DIR(dir)
VALUES ('/home/fsep'); ... (1)
```

(1) UTL_FILE_DIR/CREATE DIRECTORY

Feature differences

Oracle database

Configure the directory to be operated, using the CREATE DIRECTORY statement or the initialization parameter UTL_FILE_DIR.

FUJITSU Enterprise Postgres

The directory to be operated cannot be configured using the CREATE DIRECTORY statement or the initialization parameter UTL_FILE_DIR.

Conversion procedure

Configure the target directory information in the UTL_FILE.UTL_FILE_DIR table using the INSERT statement. Note that this conversion procedure should be performed only once before executing the PL/pgSQL function.

- When using the initialization parameter UTL_FILE_DIR:
 1. Check the initialization parameter UTL_FILE_DIR value ('/home/fsep' in the example).
 2. Using the INSERT statement, specify and execute the directory name checked in step 1.
 - Specify UTL_FILE.UTL_FILE_DIR(dir) for the INTO clause.
 - Using the character string literal ('/home/fsep' in the example), specify the target directory name for the VALUES clause.
 - If multiple directories are specified, execute the INSERT statement for each directory.
- When using the CREATE DIRECTORY statement:
 1. Check the directory name ('/home/fsep' in the example) registered with the CREATE DIRECTORY statement. To check, log in SQL*Plus as a user with DBA privileges, and execute "show ALL_DIRECTORIES;".
 2. Using the INSERT statement, specify and execute the directory name checked in step 1. Same steps are used to specify the INSERT statement as when using the initialization parameter UTL_FILE_DIR.

B.6.2 Checking File Information

Oracle database

```
CREATE PROCEDURE read_file(fname VARCHAR2) AS

    v_file      UTL_FILE.FILE_TYPE;
    v_exists    BOOLEAN;
    v_length    NUMBER;
    v_bsize     INTEGER;
    v_rbuff     VARCHAR2(1024);
BEGIN

    UTL_FILE.FGETATTR('DIR', fname, v_exists, v_length, v_bsize); ...(2)

    IF v_exists <> true THEN
        DBMS_OUTPUT.PUT_LINE('-- FILE NOT FOUND --');
        RETURN;
    END IF;

    DBMS_OUTPUT.PUT_LINE('-- FILE DATA --');

    v_file := UTL_FILE.FOPEN('DIR', fname, 'r', 1024); ...(3)
    FOR i IN 1..3 LOOP
        UTL_FILE.GET_LINE(v_file, v_rbuff, 1024); ...(4)
        DBMS_OUTPUT.PUT_LINE(v_rbuff);
    END LOOP;
    DBMS_OUTPUT.PUT_LINE('... more');
    DBMS_OUTPUT.PUT_LINE('-- READ END --');
```

```

    UTL_FILE.FCLOSE(v_file); ...(5)
RETURN;

EXCEPTION
    WHEN NO_DATA_FOUND THEN
        DBMS_OUTPUT.PUT_LINE('-- FILE END --');

        UTL_FILE.FCLOSE(v_file);
        RETURN;
    WHEN OTHERS THEN
        DBMS_OUTPUT.PUT_LINE('-- SQL Error --');

        DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
        UTL_FILE.FCLOSE_ALL; ...(6)
        RETURN;

END;
/

set serveroutput on

call read_file('file01.txt');

```

FUJITSU Enterprise Postgres

```

CREATE FUNCTION read_file(fname VARCHAR) RETURNS void AS $$
DECLARE
    v_file      UTL_FILE.FILE_TYPE;
    v_exists    BOOLEAN;
    v_length    NUMERIC;
    v_bsize     INTEGER;
    v_rbuff     VARCHAR(1024);
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);

    SELECT fexists, file_length, blocksize
        INTO v_exists, v_length, v_bsize
        FROM UTL_FILE.FGETATTR('/home/fsep', fname); ...(2)
    IF v_exists <> true THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- FILE NOT FOUND --');
        RETURN;
    END IF;

    PERFORM DBMS_OUTPUT.PUT_LINE('-- FILE DATA --');
    v_file := UTL_FILE.FOPEN('/home/fsep', fname, 'w', 1024); ...(3)
    FOR i IN 1..3 LOOP
        v_rbuff := UTL_FILE.GET_LINE(v_file, 1024); ...(4)
        PERFORM DBMS_OUTPUT.PUT_LINE(v_rbuff);
    END LOOP;
    PERFORM DBMS_OUTPUT.PUT_LINE('... more');
    PERFORM DBMS_OUTPUT.PUT_LINE('-- READ END --');

    v_file := UTL_FILE.FCLOSE(v_file); ...(5)
    RETURN;

EXCEPTION
    WHEN NO_DATA_FOUND THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- FILE END --');
        v_file := UTL_FILE.FCLOSE(v_file);
        RETURN;
    WHEN OTHERS THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- SQL Error --');
        PERFORM DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );

```

```

        PERFORM UTL_FILE.FCLOSE_ALL(); ... (6)
        RETURN;
END;
$$
LANGUAGE plpgsql;

SELECT read_file('file01.txt');

```

(2) FGETATTR

Specification format for Oracle database

UTL_FILE.FGETATTR(*firstArg*, *secondArg*, *thirdArg*, *fourthArg*, *fifthArg*)

Feature differences

Oracle database

If using a CREATE DIRECTORY statement (Oracle9.2i or later), specify a directory object name for the directory name.

FUJITSU Enterprise Postgres

A directory object name cannot be specified for the directory name.

Specification differences

Oracle database

Obtained values are received with variables specified for arguments.

FUJITSU Enterprise Postgres

Since obtained values are the search results for UTL_FILE.FGETATTR, they are received with variables specified for the INTO clause of the SELECT statement.

Conversion procedure

Convert using the following procedure. Refer to UTL_FILE_DIR/CREATE DIRECTORY for information on how to check if the directory object name corresponds to the actual directory name.

1. Locate the places where the keyword "UTL_FILE.FOPEN" is used in the stored procedure.
2. Check the actual directory name ('/home/fsep' in the example) that corresponds to the directory object name ('DIR' in the example).
3. Replace the directory object name ('DIR' in the example) in *firstArg* with the actual directory name ('/home/fsep' in the example) verified in step 2.
4. Replace the UTL_FILE.FGETATTR location called with a SELECT INTO statement.
 - Use the literal "fexists, file_length, blocksize" in the select list.
 - Specify *thirdArg*, *fourthArg*, and *fifthArg* (v_exists, v_length, v_bsize, in the example) specified for UTL_FILE.FGETATTR to the INTO clause in the same order as that of the arguments.
 - Use UTL_FILE.FGETATTR in the FROM clause. Specify only the actual directory name for *firstArg* ('/home/fsep' in the example) and *secondArg* (fname in the example) before modification for the arguments.

(3) FOPEN

Specification format for Oracle

UTL_FILE.FOPEN(*firstArg*, *secondArg*, *thirdArg*, *fourthArg*, *fifthArg*)

Feature differences

Oracle database

If using a CREATE DIRECTORY statement (Oracle9.2i or later), specify a directory object name for the directory name.

FUJITSU Enterprise Postgres

A directory object name cannot be specified for the directory name.

Conversion procedure

Convert using the following procedure. Refer to UTL_FILE_DIR/CREATE DIRECTORY for information on how to check if the directory object name corresponds to the actual directory name.

1. Locate the places where the keyword "UTL_FILE.FOPEN" is used in the stored procedure.
2. Check the actual directory name ('/home/fsep' in the example) that corresponds to the directory object name ('DIR' in the example).
3. Replace the directory object name ('DIR' in the example) in *firstArg* with the actual directory name ('/home/fsep' in the example) checked in step 1.

(4) GET_LINE

Specification format for Oracle database

UTL_FILE.GET_LINE(*firstArg*, *secondArg*, *thirdArg*, *fourthArg*)

Specification differences

Oracle database

Obtained values are received with variables specified for arguments.

FUJITSU Enterprise Postgres

Since obtained values are the returned value of UTL_FILE.GET_LINE, they are received with variables specified for substitution statement.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "UTL_FILE.GET_LINE" is used in the stored procedure.
2. Replace the UTL_FILE.GET_LINE location called with a value assignment (:=).
 - On the left-hand side, specify *secondArg* (v_rbuff in the example) specified for UTL_FILE.GET_LINE.
 - Use UTL_FILE.GET_LINE in the right-hand side. Specify only *firstArg* (v_file in the example) and *thirdArg* (1024 in the example) before modification.

(5) FCLOSE

Specification format for Oracle database

UTL_FILE.FCLOSE(*firstArg*)

Specification differences

Oracle database

After closing, the file handler specified for the argument becomes NULL.

FUJITSU Enterprise Postgres

After closing, set the file handler to NULL by assigning the return value of UTL_FILE.FCLOSE to it.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "UTL_FILE.FCLOSE" is used in the stored procedure.

2. Replace the UTL_FILE.FCLOSE location called with a value assignment (:=) so that the file handler (v_file in the example) becomes NULL.

- On the left-hand side, specify the argument (v_file in the example) specified for UTL_FILE.FCLOSE.
- Use UTL_FILE.FCLOSE in the right-hand side. For the argument, specify the same value (v_file in the example) as before modification.

(6) FCLOSE_ALL

Same as NEW_LINE in the DBMS_OUTPUT package. Refer to NEW_LINE in the DBMS_OUTPUT for information on specification differences and conversion procedures associated with specification differences.

B.6.3 Copying Files

Oracle database

```
CREATE PROCEDURE copy_file(fromname VARCHAR2, toname VARCHAR2) AS
BEGIN

    UTL_FILE.FCOPY('DIR1', fromname, 'DIR2', toname, 1, NULL); ...(7)

    RETURN;

EXCEPTION
    WHEN OTHERS THEN
        DBMS_OUTPUT.PUT_LINE('-- SQL Error --');

        DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
        RETURN;

END;
/

set serveroutput on

call copy_file('file01.txt','file01_bk.txt');
```

FUJITSU Enterprise Postgres

```
CREATE FUNCTION copy_file(fromname VARCHAR, toname VARCHAR) RETURNS void AS $$
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);

    PERFORM UTL_FILE.FCOPY('/home/fsep', fromname, '/home/backup', toname, 1, NULL); ...(7)
    RETURN;

EXCEPTION
    WHEN OTHERS THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- SQL Error --');
        PERFORM DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
        RETURN;

END;
$$
LANGUAGE plpgsql;

SELECT copy_file('file01.txt','file01_bk.txt');
```

(7) FCOPY

Specification format for Oracle database

UTL_FILE.FCOPY(*firstArg*, *secondArg*, *thirdArg*, *fourthArg*, *fifthArg*, *sixthArg*)

Feature differences

Oracle database

If using a CREATE DIRECTORY statement (Oracle9.2i or later), specify a directory object name for the directory name.

FUJITSU Enterprise Postgres

A directory object name cannot be specified for the directory name.

Conversion procedure

Convert using the following procedure. Refer to UTL_FILE_DIR/CREATE DIRECTORY for information on how to check if the directory object name corresponds to the actual directory name.

1. Locate the places where the keyword "UTL_FILE.FCOPY" is used in the stored procedure.
2. Check the actual directory names ('/home/fsep' and '/home/backup', in the example) that correspond to the directory object names ('DIR1' and 'DIR2', in the example) of *firstArg* and *thirdArg* argument.
3. Replace the directory object name ('DIR1' and 'DIR2', in the example) with the actual directory names ('/home/fsep' in the example) checked in step 1.

B.6.4 Moving/Renaming Files

Oracle database

```
CREATE PROCEDURE move_file(fromname VARCHAR2, toname VARCHAR2) AS
BEGIN

    UTL_FILE.FRENAME('DIR1', fromname, 'DIR2', toname, FALSE); ...(8)
    RETURN;

EXCEPTION
    WHEN OTHERS THEN
        DBMS_OUTPUT.PUT_LINE('-- SQL Error --');

        DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
        RETURN;
END;
/

set serveroutput on

call move_file('file01.txt','file02.txt');
```

FUJITSU Enterprise Postgres

```
CREATE FUNCTION move_file(fromname VARCHAR, toname VARCHAR) RETURNS void AS $$
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);

    PERFORM UTL_FILE.FRENAME('/home/fsep', fromname, '/home/backup', toname, FALSE); ...(8)
    RETURN;

EXCEPTION
    WHEN OTHERS THEN
        PERFORM DBMS_OUTPUT.PUT_LINE('-- SQL Error --');
        PERFORM DBMS_OUTPUT.PUT_LINE('ERROR : ' || SQLERRM );
        RETURN;
END;
```

```

$$
LANGUAGE plpgsql;

SELECT move_file('file01.txt','file02.txt');

```

(8) RENAME

Same as FCOPY for the UTL_FILE package. Refer to FCOPY in the UTL_FILE package for information on specification differences and conversion procedures associated with specification differences.

B.7 DBMS_SQL (Execute Dynamic SQL)

Features

For DBMS_SQL, dynamic SQL can be executed from PL/pgSQL.

B.7.1 Searching Using a Cursor

Oracle database

```

CREATE PROCEDURE search_test(h_where CLOB) AS

    str_sql      CLOB;
    v_cnt        INTEGER;
    v_array      DBMS_SQL.VARCHAR2A;
    v_cur        INTEGER;
    v_smpid      INTEGER;
    v_smpnm      VARCHAR2(20);
    v_addbuff    VARCHAR2(20);
    v_smpage     INTEGER;
    errcd       INTEGER;
    length       INTEGER;
    ret          INTEGER;
BEGIN

    str_sql      := 'SELECT smpid, smpnm FROM smp_tbl WHERE ' || h_where || ' ORDER BY smpid';
    v_smpid     := 0;
    v_smpnm     := '';
    v_smpage    := 0;

    v_cur := DBMS_SQL.OPEN_CURSOR; ... (1)

    v_cnt :=
        CEIL(DBMS_LOB.GETLENGTH(str_sql)/1000);
    FOR idx IN 1 .. v_cnt LOOP
        v_array(idx) :=
            DBMS_LOB.SUBSTR(str_sql,
                            1000,
                            (idx-1)*1000+1);
    END LOOP;
    DBMS_SQL.PARSE(v_cur, v_array, 1, v_cnt, FALSE, DBMS_SQL.NATIVE); ... (2)

    DBMS_SQL.DEFINE_COLUMN(v_cur, 1, v_smpid);

    DBMS_SQL.DEFINE_COLUMN(v_cur, 2, v_smpnm, 10);

    ret := DBMS_SQL.EXECUTE(v_cur);
    LOOP

```

```

v_addbuff := '';

IF DBMS_SQL.FETCH_ROWS(v_cur) = 0 THEN
    EXIT;
END IF;

DBMS_OUTPUT.PUT_LINE('-----');
DBMS_SQL.COLUMN_VALUE(v_cur, 1, v_smpid, errcd, length); ...(3)

IF errcd = 1405 THEN ...(3)

    DBMS_OUTPUT.PUT_LINE('smpid          = (NULL)');
ELSE
    DBMS_OUTPUT.PUT_LINE('smpid          = ' || v_smpid);
END IF;

DBMS_SQL.COLUMN_VALUE(v_cur, 2, v_smpnm, errcd, length);

IF errcd = 1406 THEN
    v_addbuff := '... [len=' || length || ']';
END IF;
IF errcd = 1405 THEN
    DBMS_OUTPUT.PUT_LINE('v_smpnm        = (NULL)');
ELSE
    DBMS_OUTPUT.PUT_LINE('v_smpnm        = ' || v_smpnm || v_addbuff );
END IF;

DBMS_OUTPUT.PUT_LINE('-----');

    DBMS_OUTPUT.NEW_LINE;
END LOOP;

    DBMS_SQL.CLOSE_CURSOR(v_cur); ...(4)

RETURN;
END;
/

Set serveroutput on

call search_test('smpid < 100');

```

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```

CREATE FUNCTION search_test(h_where text) RETURNS void AS $$
DECLARE
    str_sql    text;

    v_cur      INTEGER;
    v_smpid    INTEGER;
    v_smpnm    VARCHAR(20);
    v_addbuff  VARCHAR(20);
    v_smpage   INTEGER;
    errcd      INTEGER;
    length     INTEGER;
    ret        INTEGER;
BEGIN
    PERFORM DBMS_OUTPUT.SERVEROUTPUT(TRUE);
    str_sql    := 'SELECT smpid, smpnm FROM smp_tbl WHERE ' || h_where || ' ORDER BY smpid';

```

```

v_smpid      := 0;
v_smpnm     := '';
v_smpage    := 0;

v_cur := DBMS_SQL.OPEN_CURSOR(); ...(1)

PERFORM DBMS_SQL.PARSE(v_cur, str_sql, 1); ...(2)
PERFORM DBMS_SQL.DEFINE_COLUMN(v_cur, 1, v_smpid);
PERFORM DBMS_SQL.DEFINE_COLUMN(v_cur, 2, v_smpnm, 10);

ret := DBMS_SQL.EXECUTE(v_cur);
LOOP
  v_addbuff := '';

  IF DBMS_SQL.FETCH_ROWS(v_cur) = 0 THEN
    EXIT;
  END IF;

  PERFORM DBMS_OUTPUT.PUT_LINE('-----');
  SELECT value,column_error,actual_length
  INTO v_smpid, errcd, length
  FROM DBMS_SQL.COLUMN_VALUE(v_cur,
                             1,
                             v_smpid); ...(3)
  IF errcd = 22002 THEN ...(3)
    PERFORM DBMS_OUTPUT.PUT_LINE('smpid      = (NULL)');
  ELSE
    PERFORM DBMS_OUTPUT.PUT_LINE('smpid      = ' || v_smpid);
  END IF;

  SELECT value,column_error,actual_length INTO v_smpnm, errcd, length FROM
DBMS_SQL.COLUMN_VALUE(v_cur, 2, v_smpnm);
  IF errcd = 22001 THEN
    v_addbuff := '... [len=' || length || ']';
  END IF;
  IF errcd = 22002 THEN
    PERFORM DBMS_OUTPUT.PUT_LINE('v_smpnm     = (NULL)');
  ELSE
    PERFORM DBMS_OUTPUT.PUT_LINE('v_smpnm     = ' || v_smpnm || v_addbuff );
  END IF;

  PERFORM DBMS_OUTPUT.PUT_LINE('-----');
  PERFORM DBMS_OUTPUT.NEW_LINE();
END LOOP;

v_cur := DBMS_SQL.CLOSE_CURSOR(v_cur); ...(4)
RETURN;
END;
$$
LANGUAGE plpgsql;

SELECT search_test('smpid < 100');

```

(1) OPEN_CURSOR

Same as NEW_LINE in the DBMS_OUTPUT package. Refer to NEW_LINE in the DBMS_OUTPUT package for information on specification differences and conversion procedures associated with specification differences.

(2) PARSE

Specification format for Oracle database

DBMS_SQL.PARSE(*firstArg, secondArg, thirdArg, fourthArg, fifthArg*)

Feature differences

Oracle database

SQL statements can be specified with string table types (VARCHAR2A type, VARCHAR2S type). Specify this for *secondArg*.

DBMS_SQL.NATIVE, DBMS_SQL.V6, DBMS_SQL.V7 can be specified for processing SQL statements.

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SQL statements cannot be specified with string table types.

DBMS_SQL.NATIVE, DBMS_SQL.V6, DBMS_SQL.V7 cannot be specified for processing SQL statements.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "DBMS_SQL.PARSE" is used in the stored procedure.
2. Check the data type of the SQL statement specified for *secondArg* (v_array in the example).
 - If the data type is either DBMS_SQL.VARCHAR2A type or DBMS_SQL.VARCHAR2S type, then it is a table type specification. Execute step 3 and continue the conversion process.
 - If the data type is neither DBMS_SQL.VARCHAR2A type nor DBMS_SQL.VARCHAR2S type, then it is a string specification. Execute step 7 and continue the conversion process.
3. Check the SQL statement (str_sql in the example) before it was divided into DBMS_SQL.VARCHAR2A type and DBMS_SQL.VARCHAR2S type.
4. Delete the sequence of the processes (processes near FOR idx in the example) where SQL is divided into DBMS_SQL.VARCHAR2A type and DBMS_SQL.VARCHAR2S type.
5. Replace *secondArg* with the SQL statement (str_sql in the example) before it is divided, that was checked in step 2.
6. Delete *thirdArg, fourthArg, and fifthArg* (v_cnt, FALSE, DBMS_SQL.NATIVE, in the example).
7. If DBMS_SQL.NATIVE, DBMS_SQL.V6, and DBMS_SQL.V7 are specified, then replace *thirdArg* with a numeric literal 1.
 - If either DBMS_SQL.VARCHAR2A type or DBMS_SQL.VARCHAR2S type is used, then *sixthArg* becomes relevant.
 - If neither DBMS_SQL.VARCHAR2A type nor DBMS_SQL.VARCHAR2S type is used, then *thirdArg* becomes relevant.

(3) COLUMN_VALUE

Specification format for Oracle database

DBMS_SQL.COLUMN_VALUE(*firstArg, secondArg, thirdArg, fourthArg, fifthArg*)

Feature differences

Oracle database

The following error codes are returned for column_error.

- 1406: fetched column value was truncated
- 1405: fetched column value is NULL

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The following error codes are returned for column_error.

- 22001: string_data_right_truncation
- 22002: null_value_no_indicator_parameter

Specification differences

Oracle database

Obtained values are received with variables specified for arguments.

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Since obtained values are the search results for `DBMS_SQL.COLUMN_VALUE`, they are received with variables specified for the `INTO` clause of the `SELECT` statement.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "DBMS_SQL.COLUMN_VALUE" is used in the stored procedure.
2. Replace the `DBMS_SQL.COLUMN_VALUE` location called with a `SELECT INTO` statement.
 - Check the number of arguments (`v_smpid`, `errcd`, and `length` in the example) specified after *secondArg* (1 in the example) of `DBMS_SQL.COLUMN_VALUE`.
 - Specify "value", "column_error", and "actual_length" in the select list, according to the number of arguments checked in the previous step (for example, if only *thirdArg* is specified, then specify "value" only.)
 - Specify *thirdArg*, *fourthArg*, and *fifthArg* (`v_smpid`, `errcd`, `length` in the example) configured for `DBMS_SQL.COLUMN_VALUE`, for the `INTO` clause.
 - Use `DBMS_SQL.COLUMN_VALUE` in the `FROM` clause. Specify *firstArg*, *secondArg*, and *thirdArg* (`v_cur`, 1, `v_smpid`, in the example) before modification.
3. If the *fourthArg* (column_error value in the example) is used, then check the location of the target variable (`errcd` in the example).
4. If a decision process is performed in the location checked, then modify the values used in the decision process as below:
 - 1406 to 22001
 - 1405 to 22002

(4) CLOSE_CURSOR

Specification format for Oracle database

`DBMS_SQL.CLOSE_CURSOR(firstArg)`

Specification differences

Oracle database

After closing, the cursor specified in *firstArg* becomes NULL.

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After closing, set the cursor to NULL by assigning the return value of `DBMS_SQL.CLOSE_CURSOR` to it.

Conversion procedure

Convert using the following procedure:

1. Locate the places where the keyword "DBMS_SQL.CLOSE_CURSOR" is used in the stored procedure.
2. Set the cursor to NULL by assigning (`:=`) the return value of `DBMS_SQL.CLOSE_CURSOR` to it.
 - On the left-hand side, specify the argument (`v_cur` in the example) specified for `DBMS_SQL.CLOSE_CURSOR`.
 - Use `DBMS_SQL.CLOSE_CURSOR` in the right-hand side. For the argument, specify the same value (`v_cur` in the example) as before modification.

Appendix C Tables Used by the Features Compatible with Oracle Databases

This chapter describes the tables used by the features compatible with Oracle databases.

C.1 UTL_FILE.UTL_FILE_DIR

Register the directory handled by the UTL_FILE package in the UTL_FILE.UTL_FILE_DIR table.

Name	Type	Description
<i>dir</i>	text	Name of the directory handled by the UTL_FILE package

Appendix D Quantitative Limits

This appendix lists the quantitative limits of FUJITSU Enterprise Postgres.

Table D.1 Length of identifier

Item	Limit
Database name	Up to 63 bytes (*1) (*2)
Schema name	Up to 63 bytes (*1) (*2)
Table name	Up to 63 bytes (*1) (*2)
View name	Up to 63 bytes (*1) (*2)
Index name	Up to 63 bytes (*1) (*2)
Table space name	Up to 63 bytes (*1) (*2)
Cursor name	Up to 63 bytes (*1) (*2)
Function name	Up to 63 bytes (*1) (*2)
Aggregate function name	Up to 63 bytes (*1) (*2)
Trigger name	Up to 63 bytes (*1) (*2)
Constraint name	Up to 63 bytes (*1) (*2)
Conversion name	Up to 63 bytes (*1) (*2)
Role name	Up to 63 bytes (*1) (*2)
Cast name	Up to 63 bytes (*1) (*2)
Collation sequence name	Up to 63 bytes (*1) (*2)
Encoding method conversion name	Up to 63 bytes (*1) (*2)
Domain name	Up to 63 bytes (*1) (*2)
Extension name	Up to 63 bytes (*1) (*2)
Operator name	Up to 63 bytes (*1) (*2)
Operator class name	Up to 63 bytes (*1) (*2)
Operator family name	Up to 63 bytes (*1) (*2)
Rewrite rule name	Up to 63 bytes (*1) (*2)
Sequence name	Up to 63 bytes (*1) (*2)
Text search settings name	Up to 63 bytes (*1) (*2)
Text search dictionary name	Up to 63 bytes (*1) (*2)
Text search parser name	Up to 63 bytes (*1) (*2)
Text search template name	Up to 63 bytes (*1) (*2)
Data type name	Up to 63 bytes (*1) (*2)
Enumerator type label	Up to 63 bytes (*1) (*2)

*1: This is the character string byte length when converted by the server character set character code.

*2: If an identifier that exceeds 63 bytes in length is specified, the excess characters are truncated and it is processed.

Table D.2 Database object

Item	Limit
Number of databases	Less than 4,294,967,296 (*1)

Item	Limit
Number of schemas	Less than 4,294,967,296 (*1)
Number of tables	Less than 4,294,967,296 (*1)
Number of views	Less than 4,294,967,296 (*1)
Number of indexes	Less than 4,294,967,296 (*1)
Number of table spaces	Less than 4,294,967,296 (*1)
Number of functions	Less than 4,294,967,296 (*1)
Number of aggregate functions	Less than 4,294,967,296 (*1)
Number of triggers	Less than 4,294,967,296 (*1)
Number of constraints	Less than 4,294,967,296 (*1)
Number of conversion	Less than 4,294,967,296 (*1)
Number of roles	Less than 4,294,967,296 (*1)
Number of casts	Less than 4,294,967,296 (*1)
Number of collation sequences	Less than 4,294,967,296 (*1)
Number of encoding method conversions	Less than 4,294,967,296 (*1)
Number of domains	Less than 4,294,967,296 (*1)
Number of extensions	Less than 4,294,967,296 (*1)
Number of operators	Less than 4,294,967,296 (*1)
Number of operator classes	Less than 4,294,967,296 (*1)
Number of operator families	Less than 4,294,967,296 (*1)
Number of rewrite rules	Less than 4,294,967,296 (*1)
Number of sequences	Less than 4,294,967,296 (*1)
Number of text search settings	Less than 4,294,967,296 (*1)
Number of text search dictionaries	Less than 4,294,967,296 (*1)
Number of text search parsers	Less than 4,294,967,296 (*1)
Number of text search templates	Less than 4,294,967,296 (*1)
Number of data types	Less than 4,294,967,296 (*1)
Number of enumerator type labels	Less than 4,294,967,296 (*1)
Number of default access privileges defined in the ALTER DEFAULT PRIVILEGES statement	Less than 4,294,967,296 (*1)
Number of large objects	Less than 4,294,967,296 (*1)
Number of index access methods	Less than 4,294,967,296 (*1)

*1: The total number of all database objects must be less than 4,294,967,296.

Table D.3 Schema element

Item	Limit
Number of columns that can be defined in one table	From 250 to 1600 (according to the data type)
Table row length	Up to 400 gigabytes
Number of columns comprising a unique constraint	Up to 32 columns
Data length comprising a unique constraint	Less than 2,000 bytes (*1) (*2)

Item	Limit
Table size	Up to one terabyte
Search condition character string length in a trigger definition statement	Up to 800 megabytes (*1) (*2)
Item size	Up to 1 gigabyte

*1: Operation might proceed correctly even if operations are performed with a quantity outside the limits.

*2: This is the character string byte length when converted by the server character set character code.

Table D.4 Index

Item	Limit
Number of columns comprising a key (including VCI)	Up to 32 columns
Key length (other than VCI)	Less than 2,000 bytes (*1)

*1: This is the character string byte length when converted by the server character set character code.

Table D.5 Data types and attributes that can be handled

Item		Limit	
Character	Data length	Data types and attributes that can be handled (*1)	
	Specification length (<i>n</i>)	Up to 10,485,760 characters (*1)	
Numeric	External decimal expression	Up to 131,072 digits before the decimal point, and up to 16,383 digits after the decimal point	
	Internal binary expression	2 bytes	From -32,768 to 32,767
		4 bytes	From -2,147,483,648 to 2,147,483,647
		8 bytes	From -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
	Internal decimal expression		Up to 13,1072 digits before the decimal point, and up to 16,383 digits after the decimal point
	Floating point expression	4 bytes	From -3.4E+38 to -7.1E-46, 0, or from 7.1E-46 to 3.4E+38
		8 bytes	From -1.7E+308 to -2.5E-324, 0, or from 2.5E-324 to 1.7E+308
bytea		Up to one gigabyte minus 53 bytes	
Large object		Up to two gigabytes	

*1: This is the character string byte length when converted by the server character set character code.

Table D.6 Function definition

Item	Limit
Number of arguments that can be specified	Up to 100
Number of variable names that can be specified in the declarations section	No limit
Number of SQL statements or control statements that can be specified in a function processing implementation	No limit

Table D.7 Data operation statement

Item	Limit
Maximum number of connections for one process in an application (remote access)	4,000 connections
Number of expressions that can be specified in a selection list	Up to 1,664
Number of tables that can be specified in a FROM clause	No limit
Number of unique expressions that can be specified in a selection list/DISTINCT clause/ORDER BY clause/GROUP BY clause within one SELECT statement	Up to 1,664
Number of expressions that can be specified in a GROUP BY clause	No limit
Number of expressions that can be specified in an ORDER BY clause	No limit
Number of SELECT statements that can be specified in a UNION clause/INTERSECT clause/EXCEPT clause	Up to 4,000 (*1)
Number of nestings in joined tables that can be specified in one view	Up to 4,000 (*1)
Number of functions or operator expressions that can be specified in one expression	Up to 4,000 (*1)
Number of expressions that can be specified in one row constructor	Up to 1,664
Number of expressions that can be specified in an UPDATE statement SET clause	Up to 1,664
Number of expressions that can be specified in one row of a VALUES list	Up to 1,664
Number of expressions that can be specified in a RETURNING clause	Up to 1,664
Total expression length that can be specified in the argument list of one function specification	Up to 800 megabytes (*2)
Number of cursors that can be processed simultaneously by one session	No limit
Character string length of one SQL statement	Up to 800 megabytes (*1) (*3)
Number of input parameter specifications that can be specified in one dynamic SQL statement	No limit
Number of tokens that can be specified in one SQL statement	Up to 10,000
Number of values that can be specified as a list in a WHERE clause IN syntax	No limit
Number of expressions that can be specified in a USING clause	No limit
Number of JOINS that can be specified in a joined table	Up to 4,000 (*1)
Number of expressions that can be specified in COALESCE	No limit
Number of WHEN clauses that can be specified for CASE in a simple format or a searched format	No limit
Data size per record that can be updated or inserted by one SQL statement	Up to one gigabyte minus 53 bytes
Number of objects that can share a lock simultaneously	Up to 256,000 (*1)

*1: Operation might proceed correctly even if operations are performed with a quantity outside the limits.

*2: The total number of all database objects must be less than 4,294,967,296.

*3: This is the character string byte length when converted by the server character set character code.

Table D.8 Data sizes

Item	Limit
Data size per record for input data files (COPY statement, psql command \copy meta command)	Up to 800 megabytes (*1)
Data size per record for output data files (COPY statement, psql command \copy meta command)	Up to 800 megabytes (*1)

*1: Operation might proceed correctly even if operations are performed with a quantity outside the limits.

Appendix E Reference

E.1 JDBC Driver



Refer to the Java API Reference for information on PostgreSQL JDBC driver.

E.2 ODBC Driver

E.2.1 List of Supported APIs

The following table shows the support status of APIs:

Function name	Support status
SQLAllocConnect	Y
SQLAllocEnv	Y
SQLAllocHandle	Y
SQLAllocStmt	Y
SQLBindCol	Y
SQLBindParameter	Y
SQLBindParam	Y
SQLBrowseConnect	Y
SQLBulkOperations	Y
SQLCancel	Y
SQLCancelHandle	N
SQLCloseCursor	Y
SQLColAttribute	Y
SQLColAttributeW	Y
SQLColAttributes	Y
SQLColAttributesW	Y
SQLColumnPrivileges	Y
SQLColumnPrivilegesW	Y
SQLColumns	Y
SQLColumnsW	Y
SQLCompleteAsync	N
SQLConnect	Y
SQLConnectW	Y
SQLCopyDesc	Y
SQLDataSources	Y
SQLDataSourcesW	Y
SQLDescribeCol	Y

Function name	Support status
SQLDescribeColW	Y
SQLDescribeParam	Y
SQLDisconnect	Y
SQLDriverConnect	Y
SQLDriverConnectW	Y
SQLDrivers	Y
SQLEndTran	Y
SQLError	Y
SQLErrorW	Y
SQLExecDirect	Y
SQLExecDirectW	Y
SQLExecute	Y
SQLExtendedFetch	Y
SQLFetch	Y
SQLFetchScroll	Y
SQLForeignKeys	Y
SQLForeignKeysW	Y
SQLFreeConnect	Y
SQLFreeEnv	Y
SQLFreeHandle	Y
SQLFreeStmt	Y
SQLGetConnectAttr	Y
SQLGetConnectAttrW	Y
SQLGetConnectOption	Y
SQLGetConnectOptionW	Y
SQLGetCursorName	Y
SQLGetCursorNameW	Y
SQLGetData	Y
SQLGetDescField	Y
SQLGetDescFieldW	Y
SQLGetDescRec	Y
SQLGetDescRecW	Y
SQLGetDiagField	Y
SQLGetDiagFieldW	Y
SQLGetDiagRec	Y
SQLGetDiagRecW	Y
SQLGetEnvAttr	Y
SQLGetFunctions	Y
SQLGetInfo	Y

Function name	Support status
SQLGetInfoW	Y
SQLGetStmtAttr	Y
SQLGetStmtAttrW	Y
SQLGetStmtOption	Y
SQLGetTypeInfo	Y
SQLGetTypeInfoW	Y
SQLMoreResults	Y
SQLNativeSql	Y
SQLNativeSqlW	Y
SQLNumParams	Y
SQLNumResultCols	Y
SQLParamData	Y
SQLParamOptions	Y
SQLPrepare	Y
SQLPrepareW	Y
SQLPrimaryKeys	Y
SQLPrimaryKeysW	Y
SQLProcedureColumns	Y
SQLProcedureColumnsW	Y
SQLProcedures	Y
SQLProceduresW	Y
SQLPutData	Y
SQLRowCount	Y
SQLSetConnectAttr	Y
SQLSetConnectAttrW	Y
SQLSetConnectOption	Y
SQLSetConnectOptionW	Y
SQLSetCursorName	Y
SQLSetCursorNameW	Y
SQLSetDescField	Y
SQLSetDescRec	Y
SQLSetEnvAttr	Y
SQLSetParam	Y
SQLSetPos	Y
SQLSetScrollOptions	N
SQLSetStmtAttr	Y
SQLSetStmtAttrW	Y
SQLSetStmtOption	Y
SQLSpecialColumns	Y

Function name	Support status
SQLSpecialColumnsW	Y
SQLStatistics	Y
SQLStatisticsW	Y
SQLTablePrivileges	Y
SQLTablePrivilegesW	Y
SQLTables	Y
SQLTablesW	Y
SQLTransact	Y

Y: Supported
N: Not supported

E.3 C Library (libpq)



See

.....
Refer to "libpq - C Library" in "Client Interfaces" in the PostgreSQL Documentation.
.....

E.4 Embedded SQL in C



See

.....
Refer to "ECPG - Embedded SQL in C" in "Client Interfaces" in the PostgreSQL Documentation.
.....

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Operation Guide

Preface

Purpose of this document

The FUJITSU Enterprise Postgres database system extends the PostgreSQL features and runs on the Linux platform. This document is the FUJITSU Enterprise Postgres Operation Guide.

Intended readers

This document is intended for those who install and operate FUJITSU Enterprise Postgres. Readers of this document are assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Operating FUJITSU Enterprise Postgres](#)

Describes how to operate FUJITSU Enterprise Postgres.

[Chapter 2 Starting an Instance and Creating a Database](#)

Describes how to start a FUJITSU Enterprise Postgres instance, and how to create a database.

[Chapter 3 Backing Up the Database](#)

Describes how to back up the database.

[Chapter 4 Configuring Secure Communication Using Secure Sockets Layer](#)

Describes communication data encryption between the client and the server.

[Chapter 5 Protecting Storage Data Using Transparent Data Encryption](#)

Describes how to encrypt the data to be stored in the database.

[Chapter 6 Data Masking](#)

Describes the data masking feature.

[Chapter 7 Periodic Operations](#)

Describes the periodic database operations that must be performed on FUJITSU Enterprise Postgres.

[Chapter 8 Streaming Replication Using WebAdmin](#)

Describes how to create a streaming replication cluster using WebAdmin.

[Chapter 9 Installing and Operating the In-memory Feature](#)

Describes how to install and operate the in-memory feature.

[Chapter 10 Parallel Query](#)

Describes the factors taken into consideration by FUJITSU Enterprise Postgres when performing parallel queries.

[Chapter 11 High-Speed Data Load](#)

Describes how to install and operate high-speed data load.

[Chapter 12 Global Meta Cache](#)

Describes how to use Global Meta Cache feature.

[Chapter 13 Backup/Recovery Using the Copy Command](#)

Describes backup and recovery using the copy command created by the user.

[Chapter 14 Actions when an Error Occurs](#)

Describes how to perform recovery when disk failure or data corruption occurs.

[Appendix A Parameters](#)

Describes the FUJITSU Enterprise Postgres parameters.

[Appendix B System Administration Functions](#)

Describes the system administration functions of FUJITSU Enterprise Postgres.

[Appendix C System Views](#)

Describes how to use the system view in FUJITSU Enterprise Postgres.

[Appendix D Tables Used by Data Masking](#)

Describes the tables used by the data masking feature.

[Appendix E Tables Used by High-Speed Data Load](#)

Describes the tables used by high-speed data load.

[Appendix F Starting and Stopping the Web Server Feature of WebAdmin](#)

Describes how to start and stop WebAdmin (Web server feature).

[Appendix G WebAdmin Wallet](#)

Describes how to use the Wallet feature of WebAdmin.

[Appendix H WebAdmin Disallow User Inputs Containing Hazardous Characters](#)

Describes characters not allowed in WebAdmin.

[Appendix I Collecting Failure Investigation Data](#)

Describes how to collect information for initial investigation.

[Appendix J Operation of Transparent data Encryption in File-based Keystores](#)

Describes operation of transparent data Encryption in file-based keystores.

[Appendix K Utilize zEnterprise Data Compression \(zEDC\)](#)

Describes cooperation with zEDC.

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Chapter 1 Operating FUJITSU Enterprise Postgres

This chapter describes how to operate FUJITSU Enterprise Postgres.

1.1 Operating Methods

There are two methods of managing FUJITSU Enterprise Postgres operations:

- Operation management using GUI tools
- Operation management using commands



See

Before performing database multiplexing using database multiplexing, refer to "Database Multiplexing Mode" in the Cluster Operation Guide (Database Multiplexing).

Operation management using GUI tools

This involves managing operations using the WebAdmin.

- Management using WebAdmin

This removes the requirement for complex environment settings and operational design for backup and recovery that is usually required for running a database. It enables you to easily and reliably monitor the state of the database, create a streaming replication cluster, back up the database, and restore it even if you do not have expert knowledge of databases.

Operation management using commands

You can use commands for configuring and operating the database and managing operations.



Note

- You cannot combine WebAdmin and server commands to perform the following operations:
 - Use commands to operate an instance created using WebAdmin.
 - Use WebAdmin to recover a database backed up using commands.

For instances created with WebAdmin, however, backup can be obtained with the `pgx_dmpall` command. Also, WebAdmin can perform recovery by using the backup obtained with the `pgx_dmpall` command.

To compress the backup files, use the `pgx_dmpall` command in WebAdmin operations as well.

- To operate an instance created using the `initdb` command in WebAdmin, the instance needs to be imported using WebAdmin.

Features used in each phase

The following table lists the features used in each phase for GUI-based operations and command-based operations.

Operation		Operation with the GUI	Operation with commands
Setup	Creating an instance	WebAdmin is used. The server machine capacity, and the optimum parameter for operations using WebAdmin, are set automatically.	The configuration file is edited directly using the <code>initdb</code> command.
	Creating a standby instance	WebAdmin is used.	A standby instance is created using the <code>pg_basebackup</code> command.

Operation		Operation with the GUI	Operation with commands
		WebAdmin performs a base backup of the source instance and creates a standby instance.	
	Changing the configuration files	WebAdmin is used.	The configuration file is edited directly.
Starting and stopping an instance		WebAdmin is used.	The <code>pg_ctl</code> command is used.
Creating a database		None.	This is defined using the <code>psql</code> command or the application after specifying the DDL statement.
Backing up the database		WebAdmin, or the <code>pgx_dmpall</code> command, is used.	It is recommended that the <code>pgx_dmpall</code> command be used. Recovery to the latest database can be performed.
Database recovery		WebAdmin is used.	To use the backup that was performed using the <code>pgx_dmpall</code> command, the <code>pgx_rcvall</code> command is used.
Monitoring	Database errors	The status in the WebAdmin window can be checked.	The messages that are output to the database server log are monitored.
	Disk space	The status in the WebAdmin window can be checked. A warning will be displayed if the free space falls below 20%.	This is monitored using the <code>df</code> command of the operating system, for example.
	Connection status	None.	This can be checked referencing <code>pg_stat_activity</code> of the standard statistics view from <code>psql</code> or the application.

1.2 Starting WebAdmin

This section describes how to start and log in to WebAdmin.

1.2.1 Logging in to WebAdmin

This section describes how to log in to WebAdmin.

User environment

It is recommended to use the following browsers with WebAdmin:

- Internet Explorer 11
- Microsoft Edge (Build41 or later)

WebAdmin will work with other browsers, such as Firefox and Chrome, however, the look and feel may be slightly different.

Startup URL for WebAdmin

In the browser address bar, type the startup URL of the WebAdmin window in the following format:

```
http://hostNameOrIpAddress:portNumber/
```

- *hostNameOrIpAddress*: The host name or IP address of the server where WebAdmin is installed.
- *portNumber*: The port number of WebAdmin. The default port number is 27515.

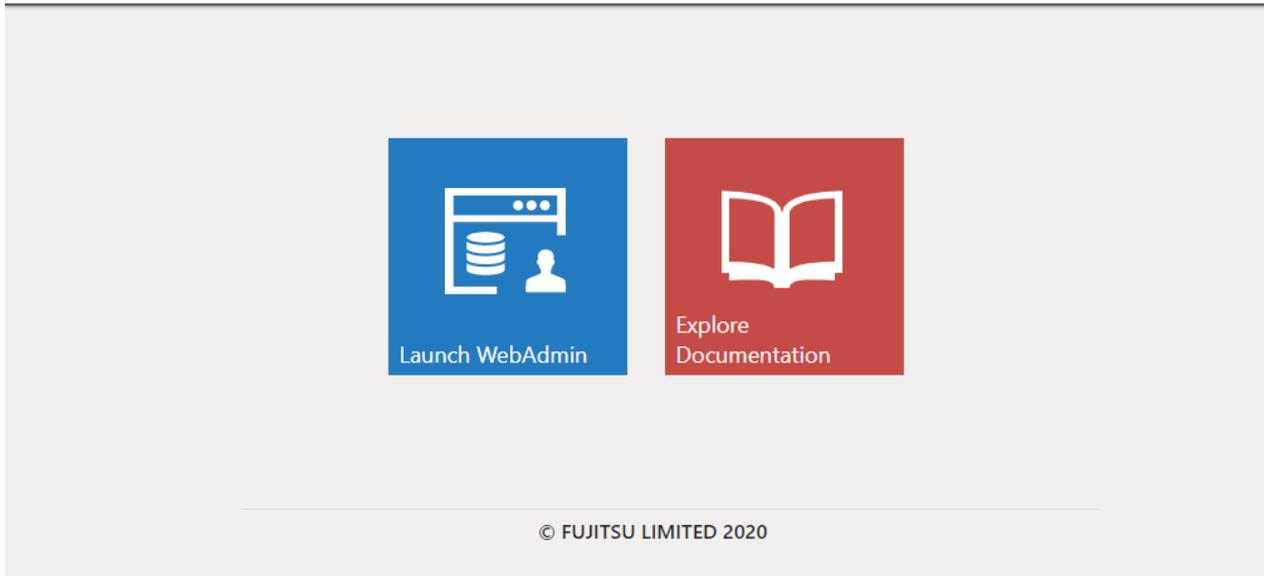
Example

For a server with IP address "192.0.2.0" and port number "27515"

```
http://192.0.2.0:27515/
```

The startup URL window shown below is displayed. From this window you can log in to WebAdmin or access the product documentation.

FUJITSU Enterprise Postgres



Note

- You must start the Web server feature of WebAdmin before using WebAdmin.
- Refer to "[Appendix F Starting and Stopping the Web Server Feature of WebAdmin](#)" for information on how to start the Web server feature of WebAdmin.

Log in to WebAdmin

Click [Launch WebAdmin] in the startup URL window to start WebAdmin and display the login window.

To log in, specify the following values:

- [User name]: User name (OS user account) of the instance administrator
- [Password]: Password corresponding to the user name

Point

Use the OS user account as the user name of the instance administrator. Refer to "Creating an Instance Administrator" in the Installation and Setup Guide for Server for details.

1.3 Operations Using Commands

You can operate and manage the database using the following commands:

- Server commands

This group of commands includes commands for creating a database cluster and controlling the database. You can run these commands on the server where the database is operating.

To use these commands, you must configure the environment variables.



- Refer to "PostgreSQL Server Applications" under "Reference" in the PostgreSQL Documentation, or "Reference" for information on server commands.
- Refer to "Configure the environment variables" in the procedure to create instances in "Using the initdb Command" in the Installation and Setup Guide for Server for information on configuring the environment variables.

- Client commands

This group of commands includes the psql command and commands for extracting the database cluster to a script file. These commands can be executed on the client that can connect to the database, or on the server on which the database is running.

To use these commands, you must configure the environment variables.



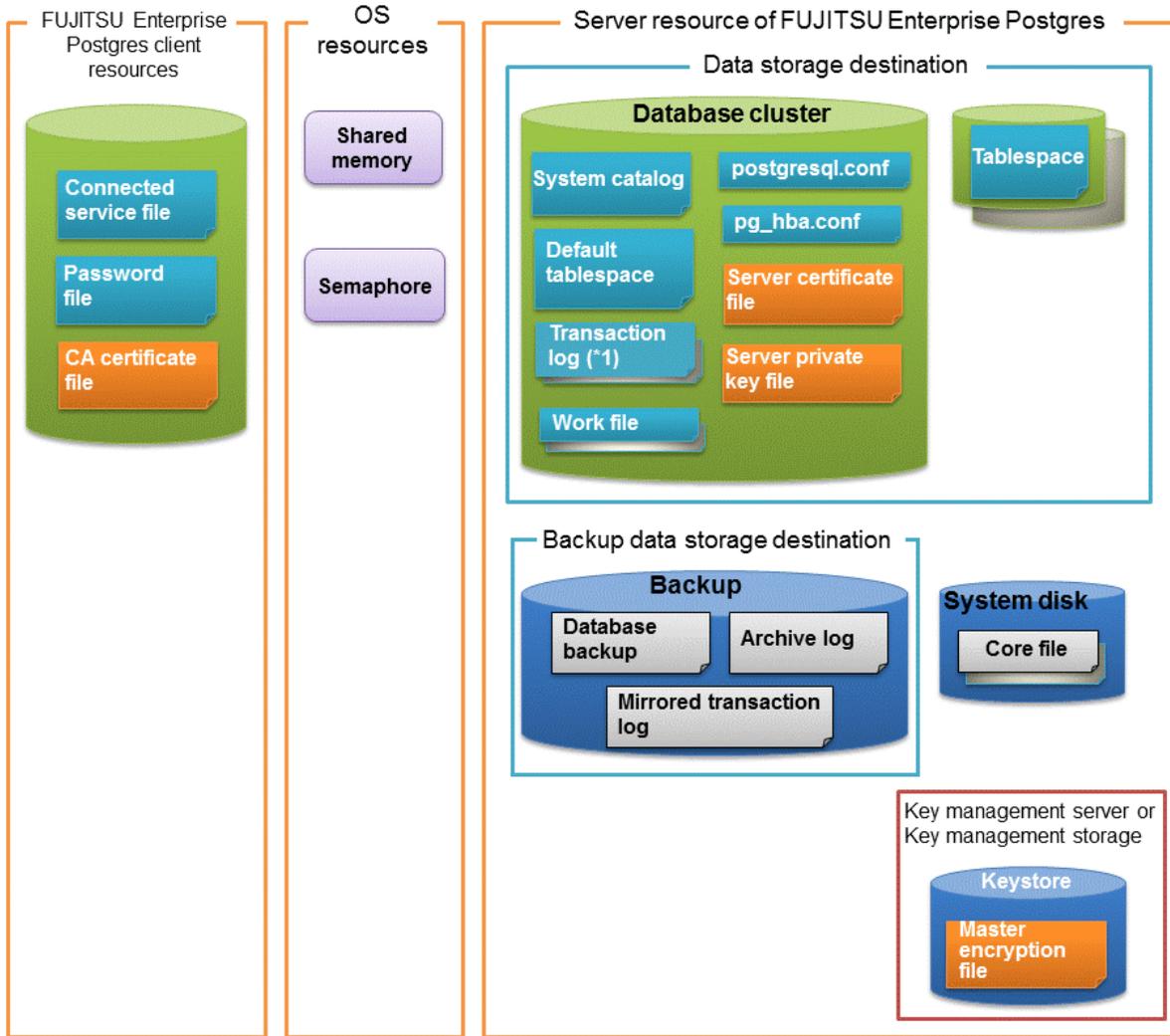
- Refer to "PostgreSQL Client Applications" under "Reference" in the PostgreSQL Documentation, or "Reference" for information on client commands.
- Refer to "Configuring Environment Variables" in the Installation and Setup Guide for Client for information on the values to be set in the environment variables.

1.4 Operating Environment of FUJITSU Enterprise Postgres

This section describes the operating environment and the file composition of FUJITSU Enterprise Postgres.

1.4.1 Operating Environment

The following figure shows the configuration of the FUJITSU Enterprise Postgres operating environment. The tables given below list the roles of the OS resources and FUJITSU Enterprise Postgres resources.



*1: To distribute the I/O load, place the transaction log on a different disk from the data storage destination.

Table 1.1 OS resources

Type	Role
Shared memory	Used when a database process exchanges information with an external process.
Semaphore	

Table 1.2 FUJITSU Enterprise Postgres client resources

Type	Role
Connection service file	Specifies information, such as the host name, user name, and password, for connecting to FUJITSU Enterprise Postgres.
Password file	Securely manages the password for connecting to FUJITSU Enterprise Postgres.
CA certificate file	CA (certificate authority) certificate used for server authentication when encrypting communication data.

Table 1.3 Server resources of FUJITSU Enterprise Postgres

Type	Role
Database cluster	Database storage area on the database storage disk. It is a collection of databases managed by an instance.
System catalog	Contains information required for the system to run, including the database definition information and the operation information created by the user.
Default tablespace	Contains table files and index files stored by default.
Transaction log	Contains log information in case of a crash recovery or rollback. This is the same as the WAL (Write Ahead Log).
Work file	Work file used when executing applications or commands.
postgresql.conf	Contains information that defines the operating environment of FUJITSU Enterprise Postgres.
pg_hba.conf	FUJITSU Enterprise Postgres uses this file to authenticate individual client hosts.
Server certificate file	Contains information about the server certificate to be used when encrypting communication data and authenticating a server.
Server private key file	Contains information about the server private key to be used when encrypting communication data and authenticating a server
Tablespace	Stores table files and index files in a separate area from the database cluster. Specify a space other than that under the database cluster.
Backup	Stores the data required for recovering the database when an error, such as disk failure, occurs.
Database backup	Contains the backup data for the database.
Archive log	Contains the log information for recovery.
Mirrored transaction log (mirrored WAL)	Enables a database cluster to be restored to the state immediately before an error even if both the database cluster and transaction log fail when performing backup/recovery operations using the pgx_dmpall command or WebAdmin.
Core file	FUJITSU Enterprise Postgres process core file that is output when an error occurs during a FUJITSU Enterprise Postgres process.
Key management server or key management storage	Server or storage where the master encryption key file is located.
Master encryption key file	Contains the master encryption key to be used when encrypting storage data. The master encryption key file is managed on the key management server or key management storage.

1.4.2 File Composition

FUJITSU Enterprise Postgres consists of the following files for controlling and storing the database. The table below shows the relationship between the number of such files and their location within a single instance.

Table 1.4 Number of files within a single instance and how to specify their location

File type	Required	Quantity	How to specify the location
Program files	Y	Multiple	Note that "<x>" indicates the product version. /opt/fsepv<x>server64
Database cluster	Y	1	Specify using WebAdmin or server commands.
Tablespace	Y	Multiple	Specify a space other than that under the database cluster, using the DDL statement.

File type	Required	Quantity	How to specify the location
Backup	Y	Multiple	Specify using WebAdmin or server commands.
Core file	Y	Multiple	Specify using WebAdmin, server commands, or postgresql.conf.
Server certificate file (*1)	N	1	Specify using postgresql.conf.
Server private key file (*1)	N	1	Specify using postgresql.conf.
Master encryption key file (*1)	N	1	Specify the directory created as the key store using postgresql.conf.
Connection service file (*1)	N	1	Specify using environment variables.
Password file (*1)	N	1	Specify using environment variables.
CA certificate file (*1)	N	1	Specify using environment variables.

Y: Mandatory

N: Optional

*1: Set manually when using the applicable feature.



Note

- Do not use an NFS for files used in FUJITSU Enterprise Postgres except when creating a database space in a storage device on a network.
- If anti-virus software is used, set scan exception settings for directories so that none of the files that comprise FUJITSU Enterprise Postgres are scanned for viruses. Alternatively, if the files that comprise FUJITSU Enterprise Postgres are to be scanned for viruses, stop FUJITSU Enterprise Postgres and perform the scan when tasks that use FUJITSU Enterprise Postgres are not operating.

1.5 Notes on Compatibility of Applications Used for Operations

When you upgrade FUJITSU Enterprise Postgres to a newer version, there may be some effect on applications due to improvements or enhancements in functionality.

Take this into account when creating applications so that you can maintain compatibility after upgrading to a newer version of FUJITSU Enterprise Postgres.



See

Refer to "Notes on Application Compatibility" in the Application Development Guide for details.

1.6 Notes on Upgrading Database Instances

When upgrading FUJITSU Enterprise Postgres 11 or newer database instances using `pg_upgrade`, there are certain steps you need to follow.

Before using `pg_upgrade`, remove the following extensions from all databases in the instance, except "template0":

- `pg_stat_statements`
- `oracle_compatible`
- `pg_dbms_stats`
- `pg_hint_plan`

For all databases except "template0", execute the following command to remove these extensions:

```
DROP EXTENSION extensionName;
```

Once the `pg_upgrade` operation is complete, for all databases except "template0", execute the following command to re-create these extensions as required:

```
CREATE EXTENSION extensionName;
```



- It is strongly recommended to back up the database using `pg_dump` before performing `pg_upgrade` or using `DROP EXTENSION`.
- If there are any columns created in the user tables using a data type from these extensions, then `DROP EXTENSION` will also drop these columns. Therefore, it is essential that alternate upgrade mechanisms are considered instead of `pg_upgrade`, in such scenarios. These may include `pg_dump/pg_restore`.

1.6.1 Additional Steps for upgrading to FUJITSU Enterprise Postgres with Vertical Clustered Index (VCI) Enabled

When upgrading FUJITSU Enterprise Postgres 11 instances that are using the VCI extension to FUJITSU Enterprise Postgres 12 using `pg_upgrade`, additional steps must be performed because of the incompatibility of the VCI extension between FUJITSU Enterprise Postgres 12 and FUJITSU Enterprise Postgres 11 or earlier.

Follow the procedure below in all databases in the FUJITSU Enterprise Postgres 11 instance, except "template0".

Before upgrading

1. Obtain the CREATE INDEX Definitions

Run the query below to list all the VCI indexes created in the database. Ensure that these indexes are re-created in the FUJITSU Enterprise Postgres 12 or later instance after `pg_upgrade` has finished.

```
SELECT nspname || '.' || relname AS index_relname,* FROM pg_class, pg_namespace  
WHERE relnamespace = pg_namespace.oid AND relam IN (SELECT oid FROM pg_am WHERE amname='vci');
```

For each `index_relname` listed above, execute the commands below to obtain the CREATE INDEX definition (to use the same SQL syntax while re-creating the indexes on the FUJITSU Enterprise Postgres 12 or later instance).

```
SELECT pg_get_indexdef('indexName'::regclass);
```

2. Drop the VCI indexes and VCI extension along with all its dependencies.

To remove all the VCI indexes and VCI internal objects that are created in FUJITSU Enterprise Postgres, execute the commands below. VCI internal objects will be created in FUJITSU Enterprise Postgres 12 or later automatically when `CREATE EXTENSION` for VCI is executed.

```
DROP EXTENSION VCI CASCADE;
```



To restore the VCI extension in the FUJITSU Enterprise Postgres 11 instance, execute `CREATE EXTENSION`.

After upgrading

Once the `pg_upgrade` operation is complete, for all databases except "template0", execute `CREATE EXTENSION` to create the VCI extension, and then execute `CREATE INDEX` for all the VCI indexes as required.

Chapter 2 Starting an Instance and Creating a Database

This chapter describes basic operations, from starting an instance to creating a database.

2.1 Starting and Stopping an Instance

This section describes how to start and stop an instance.

- [2.1.1 Using WebAdmin](#)
- [2.1.2 Using Server Commands](#)

Point

To automatically start or stop an instance when the operating system on the database server is started or stopped, refer to "Configuring Automatic Start and Stop of an Instance" in the Installation and Setup Guide for Server and configure the settings.

Note

The collected statistics are initialized if an instance is stopped in the "Immediate" mode or if it is abnormally terminated. To prepare for such initialization of statistics, consider regular collection of the statistics by using the SELECT statement. Refer to "The Statistics Collector" in "Server Administration" in the PostgreSQL Documentation for information on the statistics.

2.1.1 Using WebAdmin

WebAdmin enables you to start or stop an instance and check its operating status.

Starting an instance

Start an instance by using the [Instances] tab in WebAdmin.

 is displayed when an instance is stopped.

To start a stopped instance, click .

Stopping an instance

Stop an instance by using the [Instances] tab in WebAdmin.

 is displayed when an instance is active.

To stop an active instance, click .

Stop mode

Select the mode in which to stop the instance. The following describes the operations of the modes:

Stop mode	Connected clients	Backup being executed using the command
Smart mode (*1)	Waits for all connected clients to be disconnected.	Waits for backups being executed using the command to finish.
Fast mode	Rolls back all transactions being executed and forcibly disconnects clients.	Terminates backups being executed using the command.
Immediate mode	All server processes are terminated immediately. Crash recovery is executed the next time the instance is started.	

Stop mode	Connected clients	Backup being executed using the command
Kill process mode	Send SIGKILL to the process and abort all active transactions. This will lead to a crash-recovery run at the next restart.	

*1: When the processing to stop the instance in the Smart mode has started and you want to stop immediately, use the following procedure:

1. Restart the Web server feature of WebAdmin.
2. In the [Instances] tab, click .
3. In the [Instances] tab, click , and select the Immediate mode to stop the instance.

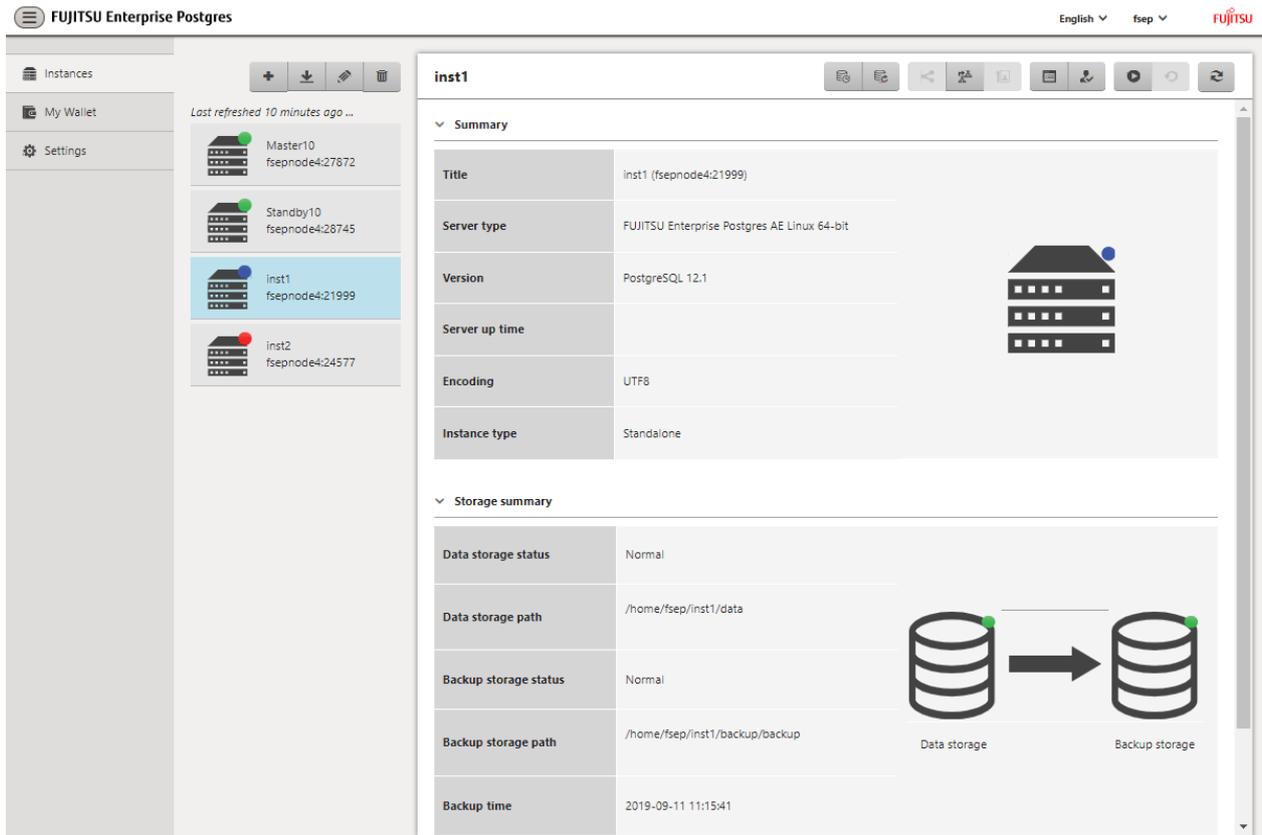
Checking the operating status of an instance

You can check the operating status of an instance by using the [Instances] tab. The following indicators are used to show the status of a resource.

Status indicator	Explanation
	The resource is operating normally.
	The resource is stopped.
	There is an error in the resource.
	An operation is in progress on this resource or the status is being checked.
	The resource is not operating optimally and needs intervention.

If an instance stops abnormally, remove the cause of the stoppage and start the instance by using WebAdmin.

Figure 2.1 Example of operating status indicators



Note

- When operating WebAdmin, click  to update the status. WebAdmin will reflect the latest status of the operation or the instance resources from the server.
- If an error occurs while communicating with the server, there may be no response from WebAdmin. When this happens, close the browser and then log in again. If this does not resolve the issue, check the system log of the server and confirm whether a communication error has occurred.
- The following message is output during startup of an instance when the startup process is operating normally, therefore, the user does not need to be aware of this message:

```
FATAL: the database system is starting up
```

2.1.2 Using Server Commands

Server commands enable you to start or stop an instance and check its operating status.

To use sever commands, configure the environment variables.

See

Refer to "Configure the environment variables" in the procedure to create instances in "Using the initdb Command" in the Installation and Setup Guide for Server for information on configuring the environment variables.

Starting an instance

Use the `pg_ctl` command to start an instance.

Specify the following values in the `pg_ctl` command:

- Specify "start" as the mode.
- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

If an application, command, or process tries to connect to the database while the instance is starting up, the message "FATAL:the database system is starting up(11189)" is output. However, this message may also be output if the instance is started without the `-W` option specified. This message is output by the `pg_ctl` command to check if the instance has started successfully. Therefore, ignore this message if there are no other applications, commands, or processes that connect to the database.



Example

```
> pg_ctl start -D /database/inst1
```



Note

If the `-W` option is specified, the command will return without waiting for the instance to start. Therefore, it may be unclear as to whether the instance startup was successful or failed.

Stopping an instance

Use the `pg_ctl` command to stop an instance.

Specify the following values in the `pg_ctl` command:

- Specify "stop" as the mode.
- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.



Example

```
> pg_ctl stop -D /database/inst1
```

Checking the operating status of an instance

Use the `pg_ctl` command to check the operating status of an instance.

Specify the following values in the `pg_ctl` command:

- Specify "status" as the mode.
- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.



Example

When the instance is active:

```
> pg_ctl status -D /database/inst1
pg_ctl: server is running (PID: 1234)
```

When the instance is inactive:

```
> pg_ctl status -D /database/inst1
pg_ctl: no server running.
```



See

Refer to "pg_ctl" under "Reference" in the PostgreSQL Documentation for information on pg_ctl command.

2.2 Creating a Database

This section explains how to create a database.

Follow the procedure below to define a database using client commands.

An example of operations on the server is shown below.

1. Use psql command to connect to the postgres database.
Execute psql postgres.

```
> psql postgres
psql (12.1)
Type "help" for help.
```

2. Create the database.
To create the database, execute the CREATE DATABASE databaseName; statement.

```
postgres=# CREATE DATABASE db01;
CREATE DATABASE
```

3. Confirm that the database is created.
Execute \l+, and confirm that the name of the database created in step 2 is displayed.

```
postgres=# \l+
```

4. Disconnect from the postgres database.
Execute \q to terminate the psql command.

```
postgres=# \q
```

You can create a database using the createdb command.



See

Refer to "Creating a Database" in "Tutorial" in the PostgreSQL Documentation for information on creating a database using the createdb command.

Chapter 3 Backing Up the Database

This chapter describes how to back up the database.

Backup methods

The following backup methods enable you to recover data to a backup point or to the state immediately preceding disk physical breakdown or data logical failure.

- Backup using WebAdmin

This method enables you to back up data through intuitive window operations using the GUI.

WebAdmin is used for recovery.

- Backup using the `pgx_dmpall` command

Execute the `pgx_dmpall` command with a script to perform automatic backup.

To back up data automatically, you must register the process in the automation software of the operating system. Follow the procedure given in the documentation for your operating system.

The `pgx_rcvall` command is used for recovery.



Information

By using a copy command created by the user, the `pgx_dmpall` command and the `pgx_rcvall` command can back up database clusters and tablespaces to any destination and recover them from any destination using any copy method. Refer to "[Chapter 13 Backup/Recovery Using the Copy Command](#)" for details.

Approximate backup time

The formula for deriving the approximate backup time when you use WebAdmin or the `pgx_dmpall` command is as follows:

$$\text{backupTime} = \text{dataStorageDestinationUsage} / \text{diskWritePerformance} \times 1.5 \times \text{EffectOfCompression}$$

- *dataStorageDestinationUsage*: Disk usage at the data storage destination
- *diskWritePerformance*: Maximum data volume (bytes/second) that can be written per second in the system environment where operation is performed
- 1.5: Coefficient to factor in tasks other than disk write (which is the most time-consuming step)
- *EffectOfCompression*: Specify 0.6 to use compression, or 1 to not use compression

If using the copy command with the `pgx_dmpall` command, the backup time will depend on the implementation of the copy command.



Note

- Backup operation cannot be performed on an instance that is part of a streaming replication cluster in standby mode.
- Use the selected backup method continuously.

There are several differences, such as the data format, across the backup methods. For this reason, the following restrictions apply:

- It is not possible to use one method for backup and another for recovery.
- It is not possible to convert one type of backup data to a different type of backup data.
- Mirrored WALs can be used only for backup/recovery using the `pgx_dmpall` command or WebAdmin.
- There are several considerations for the backup of the keystore and backup of the database in case the data stored in the database is encrypted. Refer to the following for details:
 - [5.7.5 Backing Up and Recovering the Keystore](#)
 - [5.8 Backing Up and Restoring/Recovering the Database](#)

- If you have defined a tablespace, back it up. If you do not back it up, directories for the tablespace are not created during recovery, which may cause the recovery to fail. If the recovery fails, refer to the system log, create the tablespace, and then perform the recovery process again.

 **Information**

The following methods can also be used to perform backup. Performing a backup using these methods allows you to restore to the point when the backup was performed.

- Backup using an SQL-based dump
Dump the data by using SQL. This backup method also enables data migration.
- File system level backup
This backup method requires you to stop the instance and use OS commands to backup database resources as files.
- Backup by continuous archiving
This is the standard backup method for PostgreSQL.

Refer to "Backup and Restore" in "Server Administration" in the PostgreSQL Documentation for information on these backup methods.

3.1 Periodic Backup

It is recommended that you perform backup periodically.

Backing up data periodically using WebAdmin or the `pgx_dmpall` command has the following advantages:

- This method reduces disk usage, because obsolete archive logs (transaction logs copied to the backup data storage destination) are deleted. It also minimizes the recovery time when an error occurs.

Backup cycle

The time interval when backup is performed periodically is called the backup cycle. For example, if backup is performed every morning, the backup cycle is 1 day.

The backup cycle depends on the jobs being run, but on FUJITSU Enterprise Postgres it is recommended that operations are run with a backup cycle of at least once per day.

3.2 Backup Methods

This section describes the methods for backing up the database.

- [3.2.1 Using WebAdmin](#)
- [3.2.2 Using Server Commands](#)

3.2.1 Using WebAdmin

You can use WebAdmin to perform backup and check the backup status.

 **Note**

- If backup is disabled for an instance, you will not be able to back up or restore the instance. Refer to "[Backup]" in "Creating an Instance" in the Installation and Setup Guide for Server for details.
- If the data to be stored in the database is to be encrypted, it is necessary to enable the automatic opening of the keystore before doing so. Refer to "[5.7.4 Enabling Automatic Opening of the Keystore](#)" for details.

- WebAdmin uses the labels "Data storage path", "Backup storage path" and "Transaction log path" to indicate "data storage destination", "backup data storage destination" and "transaction log storage destination" respectively. In this manual these terms are used interchangeably.
- To compress the backup data, use the `pgx_dmpall` command with `-z` or `-Z` or `--compress` option specified. Add `-z` or `-Z` level to the end of the `archive_command` arguments that is set automatically by WebAdmin. `-z` option compresses by the default compression level. `-Z` option compresses by the level specified. The level can be set to a value from 0 to 9. (0 no compression, 9 high compression)

For example:

```
archive_command = 'installationDirectory/bin/pgx_walcopy.cmd "%p"
"backupDataStorageDestinationDirectory/archived_wal/%f" ' discard "DatabaseCulsterPath/
waldiscard.txt" -z
```

```
archive_command = 'installationDirectory/bin/pgx_walcopy.cmd "%p"
"backupDataStorageDestinationDirectory/archived_wal/%f" ' discard "DatabaseCulsterPath/
waldiscard.txt" -Z 1
```

Backup operation

Follow the procedure below to back up the database.

1. Select the database to back up

In the [Instances] tab, select the instance to be backed up and click .

2. Back up the database

The [Backup] dialog box is displayed. To perform backup, click [Yes].
An instance is automatically started when backup is performed.

Backup status

If an error occurs and backup fails, [Error] is displayed adjacent to [Data storage status] or [Backup storage status] in the [Instances] tab. An error message is also displayed in the message list.

In this case, the backup data is not optimized. Ensure that you check the backup result whenever you perform backup. If backup fails, [Solution] appears to the right of the error message. Clicking this button displays information explaining how to resolve the cause of the error. Remove the cause of failure, and perform backup again.

3.2.2 Using Server Commands

Use the `pgx_dmpall` command and `pgx_rcvall` command to perform backup and check the backup result.

Preparing for backup

You must prepare for backup before actually starting the backup process.

Follow the procedure below.



Refer to "Preparing Directories to Deploy Resources" in the Installation and Setup Guide for Server for information on the location of directories required for backup and for points to take into account.

1. Prepare the backup data storage disk

For backup, prepare a separate disk unit from the database storage disk and mount it using the operating system commands.

2. Create a directory where the backup data will be stored

Create an empty directory.

Set appropriate permissions so that only the instance administrator can access the directory.

Example

```
# mkdir /backup/inst1
# chown fsepuser:fsepuser /backup/inst1
# chmod 700 /backup/inst1
```

3. Specify the settings required for backup

Stop the instance, and set the following parameters in the postgresql.conf file.

Start the instance after editing the postgresql.conf file.

Parameter name	Setting	Description
backup_destination	Name of the directory where the backup data will be stored	Specify the name of the directory where the backup data will be stored. Appropriate privileges that allow only the instance administrator to access the directory must already be set. Place the backup data storage destination directory outside the data storage destination directory, the tablespace directory, and the transaction log storage destination directory.
archive_mode	on	Specify the archive log mode. Specify [on] (execute).
archive_command	<i>'installationDirectory/bin/pgx_walcopy.cmd "%p" "backupDataStorageDestinationDirectory/archived_wal/%f" [-z -Z level]</i>	Specify the path name of the command that will save the transaction log and the storage destination. Use the -z or -Z option to compress the backup data. This allows archive logs to be compressed. -z option compresses by the default compression level. -Z option compresses by the level specified. The level can be set to a value from 0 to 9. (0 no compression, 9 high compression)

Refer to "[Appendix A Parameters](#)" and "Write Ahead Log" under "Server Administration" in the PostgreSQL Documentation for information on the parameters.

Backup operation (file backup)

Use the pgx_dmpall command to perform file backup. You can even embed the pgx_dmpall command in OS automation software to perform backup.

The backup data is stored in the directory specified in the backup_destination parameter of postgresql.conf.

Specify the data storage destination in the -D option. If the -D option is omitted, the value of the PGDATA environment variable is used by default.

 **Example**

```
> pgx_dmpall -D /database/inst1
```

Note

Backup stores the data obtained during the backup and the backup data of the data obtained during previous backup.

If the data to be stored in the database is encrypted, refer to the following and back up the keystore:

- [5.7.5 Backing Up and Recovering the Keystore](#)

To compress the backup data, specify the `-z` option, etc. Refer to "pgx_dmpall" in the Reference for information on the `pgx_dmpall` command.

Backup status

Use the `pgx_rcvall` command to check the backup status.

Specify the following values in the `pgx_rcvall` command:

- The `-l` option indicates backup data information.
- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

```
> pgx_rcvall -l -D /database/inst1
Date                Status              Dir
2020-05-01 13:30:40 COMPLETE           /backup/inst1/2020-05-01_13-30-40
```

If an error occurs and backup fails, a message is output to the system log.

In this case, the backup data is not optimized. Ensure that you check the backup result whenever you perform backup. If backup fails, remove the cause of failure and perform backup again.

See

Refer to "pgx_dmpall" and "pgx_rcvall" in the Reference for information on the `pgx_dmpall` command and `pgx_rcvall` command.

Setting a restore point

In case you want to recover your database to a certain point in time, you can name this particular point in time, which is referred to as the restore point, by using the `psql` command.

By setting a restore point before executing an application, it becomes easy to identify up to which point in time the data will be reverted.

A restore point can be set to any point in time after a backup is executed. However, if a restore point is set before a backup is executed, the database cannot be recovered to that point in time. This is because restore points are recorded in the archive logs, and the archive logs are discarded when backups are executed.

Example

The following example uses the `psql` command to connect to the database and execute the SQL statement to set a restore point.

However, when considering continued compatibility of applications, do not use functions directly in SQL statements. Refer to "Notes on Application Compatibility" in the Application Development Guide for details.

```
postgres=# SELECT pg_create_restore_point('batch_20200503_1');
LOG:  restore point "batch_20200503_1" created at 0/20000E8
STATEMENT:  select pg_create_restore_point('batch_20200503_1');
 pg_create_restore_point
-----
0/20000E8
(1 row)
```

Refer to "[14.3.2 Using the pgx_rcvall Command](#)" for information on using a restore point to recover the database.

Note

- Name restore points so that they are unique within the database. Add the date and time of setting a restore point to distinguish it from other restore points, as shown below:
 - YYMMDD_HHMMSS
 - YYMMDD: Indicates the date
 - HHMMSS: Indicates the time
 - There is no way to check restore points you have set. Keep a record in, for example, a file.
-

See

Refer to "System Administration Functions" under "Functions and Operators" in the PostgreSQL Documentation for information on `pg_create_restore_point`.

Chapter 4 Configuring Secure Communication Using Secure Sockets Layer

If communication data transferred between a client and a server contains confidential information, encrypting the communication data can protect it against threats, such as eavesdropping on the network.

4.1 Configuring Communication Data Encryption

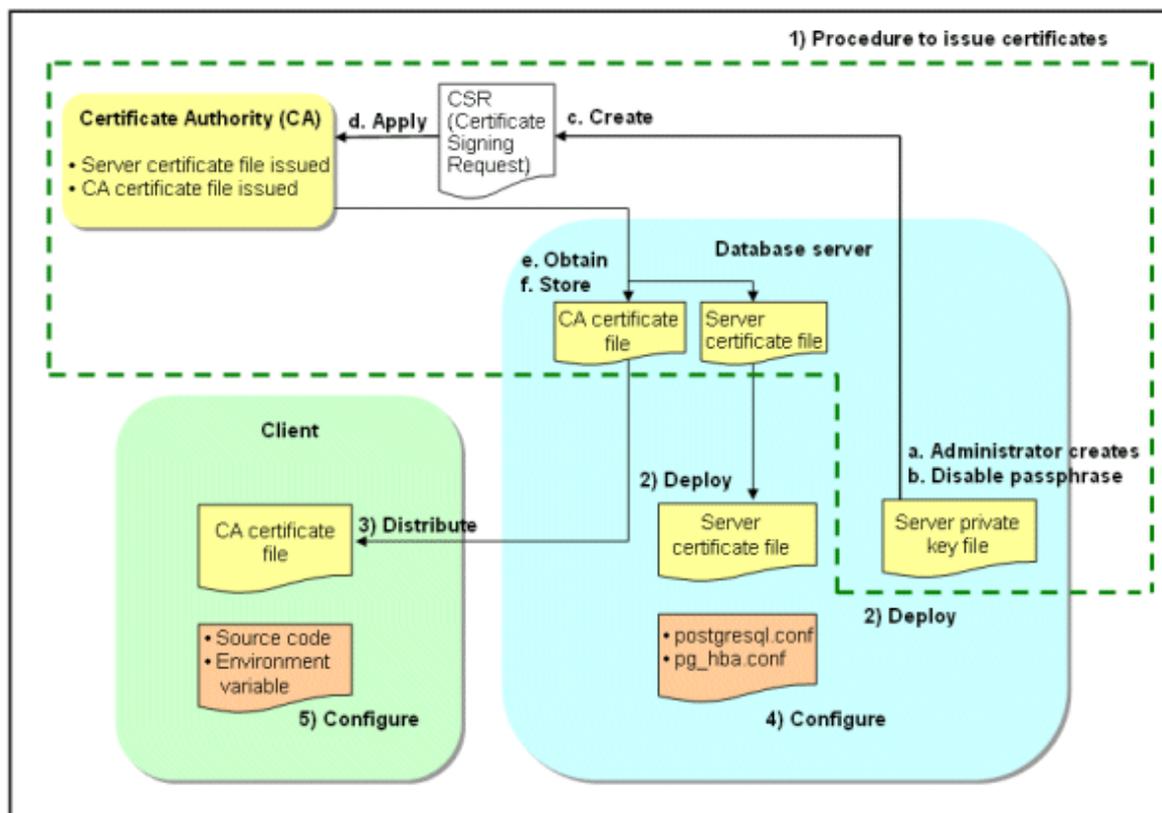
To encrypt communication data transferred between a client and a server, configure communication data encryption as described below. Communication data encryption not only protects the communication content, but it also guards against man-in-the-middle (MITM) attacks (for example, data and password theft through server impersonation).

Table 4.1 Configuration procedure

Configuration procedure
1) Issue a certificate
2) Deploy a server certificate file and a server private key file
3) Distribute a CA certificate file to the client
4) Configure the operating environment for the database server
5) Configure the operating environment for the client

The following figure illustrates the environment for communication data encryption.

Figure 4.1 Environment for communication data encryption



4.1.1 Issuing a Certificate

For authenticating servers, you must acquire a certificate issued by the certificate authority (CA).

FUJITSU Enterprise Postgres supports X.509 standard PEM format files. If the certificate authority issues a file in DER format, use a tool such as the openssl command to convert the DER format file to PEM format.

The following provides an overview of the procedure. Refer to the procedure published by the public or independent certificate authority (CA) that provides the certificate file for details.

- a. Create a server private key file
- b. Disable the passphrase for the server private key file
- c. Create a CSR (signing request for obtaining a server certificate) from the server private key file
- d. Apply to the certificate authority (CA) for a server certificate
- e. Obtain a server certificate file and a CA certificate file from the certificate authority (CA)
- f. Store the server certificate file and the CA certificate file

Note: If you lose or destroy the certificates, you will need to have them re-issued.

The above procedure enables you to prepare the following files:

- Server private key file
- Server certificate file
- CA certificate file

4.1.2 Deploying a Server Certificate File and a Server Private Key File

Create a directory on the local disk of the database server and store the server certificate file and the server private key file in it.

Use the operating system features to set access privileges for the server certificate file and the server private key file so that only the database administrator has load privileges.

Back up the server certificate file and the server private key file in the event that data corruption occurs and store them securely.

4.1.3 Distributing a CA Certificate File to the Client

Create a directory on the local disk of the client and place the distributed CA certificate file there. Use the operating system features to set load privileges to protect the CA certificate file against accidental deletion.

4.1.4 Configuring the Operating Environment for the Database Server



See

.....
Refer to "Secure TCP/IP Connections with SSL" under "Server Administration" in the PostgreSQL Documentation for details.
.....

4.1.5 Configuring the Operating Environment for the Client



See

.....
Refer to the following sections in the Application Development Guide for details, depending on your application development environment:

- "Settings for Encrypting Communication Data" under "Setup" in "JDBC Driver"
 - "Settings for Encrypting Communication Data" under "Setup" in "C Library (libpq)"
 - "Settings for Encrypting Communication Data" under "Setup" in "Embedded SQL in C"
-

4.1.6 Performing Database Multiplexing

When you perform communication that uses database multiplexing and a Secure Socket Layer server certificate, take one of the following actions:

- Create one server certificate, replicate it, and place a copy on each server used for database multiplexing.
If sslmode is set to verify-full, add all domain names in subjectAltName.
- Create server certificate for each server used for database multiplexing.



See

.....
Refer to "Using the Application Connection Switch Feature" in the Application Development Guide for information on how to specify applications on the client.
.....

Chapter 5 Protecting Storage Data Using Transparent Data Encryption

This chapter describes how to encrypt data to be stored in the database.

5.1 Protecting Data Using Encryption

With PostgreSQL, data in a database is protected from access by unauthorized database users through the use of authentication and access controls. However, the OS file is not protected from attackers who bypass the database server's authentication and access controls.

With FUJITSU Enterprise Postgres, data inside the OS file is encrypted, so valuable information is protected even if the file or disk is stolen.

Data to be stored in a database is encrypted when it is written to the data file, and decrypted when it is read.

This is performed automatically by the instance, so the user and the application need not be aware of key management and encryption or decryption. This process is called TDE (Transparent Data Encryption).

The characteristics of TDE are described below.

Encryption mechanisms

Two-layer encryption key and the keystore

In each tablespace, there is a tablespace encryption key that encrypts and decrypts all the data within. The tablespace encryption key is encrypted by the master encryption key and saved.

There is only one master encryption key in the database cluster, which is encrypted and stored in the keystore.

Therefore, an attacker cannot read the master encryption key from the keystore.

Keystore management

FUJITSU Enterprise Postgres works in conjunction with the IBM Z Hardware Security Module (HSM) to provide hardware management of master encryption keys for robust security. The master encryption key is encrypted based on the master key in the HSM and is never leaked out over its lifetime. Use hardware-stored keystores to reduce deployment and operating costs for keystore management.

File-based keystores that do not work with the HSM are also possible. The master encryption key is then encrypted based on the passphrase that you specify and stored in the keystore. Refer to "[Appendix J Operation of Transparent data Encryption in File-based Keystores](#)" for information about the operation of transparent data encryption in file-based.

Strong encryption algorithms

TDE uses the Advanced Encryption Standard (AES) as its encryption algorithm. AES was adopted as a standard in 2002 by the United States Federal Government, and is used throughout the world.

Faster hardware-based encryption/decryption

Take advantage of the CPACF (CP Assist for Cryptographic Functions) in the IBM Z processor to minimize encryption and decryption overhead. This means that even in situations where previously the minimum encryption target was selected as a tradeoff between performance and security, it is now possible to encrypt all the data of an application.

Zero overhead storage areas

Encryption does not change the size of data stored in tables, indexes, or WAL. There is, therefore, no need for additional estimates or disks.

Scope of encryption

All user data within the specified tablespace

The tablespace is the unit for specifying encryption. All tables, indexes, temporary tables, and temporary indexes created in the encrypted tablespace are encrypted. There is no need for the user to consider which tables and strings to encrypt.

Refer to "[5.5 Encrypting a Tablespace](#)" for details.

Backup data

The `pgx_dmpall` command and `pg_basebackup` command create backup data by copying the OS file. Backups of the encrypted data are, therefore, also encrypted. Information is protected from leakage even if the backup medium is stolen.

WAL and temporary files

WAL, which is created by updating encrypted tables and indexes, is encrypted with the same security strength as the update target. When large merges and sorts are performed, the encrypted data is written to a temporary file in encrypted format.

Streaming replication support

You can combine streaming replication and transparent data encryption. The data and WAL encrypted on the primary server is transferred to the standby server in its encrypted format and stored.



Note

The following are not encrypted:

- `pg_dump` and `pg_dumpall` output files
- Files output by the `COPY` command
- Notification event payloads that communicate using the `LISTEN` or `NOTIFY` command

5.2 Preparing for HSM Collaboration

FUJITSU Enterprise Postgres manages master encryption keys with the IBM Z Crypto Express Adapter Card. To work with the Crypto Express Adapter Card, use `openCryptoki`, a PKCS#11 compliant API implementation. Use the `openCryptoki` CCA token or the EP 11 token.

FUJITSU Enterprise Postgres uses the slot assigned to each instance to access the token through a user pin. You must configure `Crypto Express Adapter Card` and `openCryptoki` to access the token.

Refer to the IBM documentation for the IBM Z Crypto Express Adapter Card configuration.

Refer to the `openCryptoki` project documentation for `openCryptoki` configuration. Note that the `tokname` attribute must be specified because FUJITSU Enterprise Postgres requires a unique token directory.

5.3 Setting the Master Encryption Key

To use transparent data encryption, you must create a keystore and set the master encryption key.

1. Set `postgresql.conf` parameters.

Set the `keystore_location` parameter to the directory where you want to store the keystore.

Specify a different location for each database cluster.

The `shared_preload_libraries` parameter also sets the extension to be enabled.

The `tde_z.SLOT_ID` parameter specifies the slot ID that was set in ["5.2 Preparing for HSM Collaboration"](#).

```
keystore_location = '/key/store/location'  
shared_preload_libraries = 'tde_z'  
tde_z.SLOT_ID = 5
```

When the token model "CCA" is used, it is necessary to take care of multi-coprocessor and multi-domain selection. Specify the `postgresql.conf` parameter for CCA configuration so that FUJITSU Enterprise Postgres can use the specific coprocessor and domain.

- `tde_z.IBM_CCA_CSU_DEFAULT_ADAPTER`: this parameter enables to change a default CCA coprocessor.
- `tde_z.IBM_CCA_CSU_DEFAULT_DOMAIN`: this parameter enables to select a single domain.

The values of these parameters are taken over to CCA service via CCA environment variable `CSU_DEFAULT_ADAPTER` or `CSU_DEFAULT_DOMAIN`.

```
tde_z.IBM_CCA_CSU_DEFAULT_ADAPTER = 'CRP01'  
tde_z.IBM_CCA_CSU_DEFAULT_DOMAIN = '3'
```

Refer to "[Appendix A Parameters](#)" for information on postgresql.conf.

Refer to IBM documentaion for CCA environment variable CSU_DEFAULT_ADAPTER, CSU_DEFAULT_DOMAIN, the multi-processor selection capabilities and domain selection capabilities.

After editing the postgresql.conf file, either start or restart the instance.

- Using WebAdmin

Refer to "[2.1.1 Using WebAdmin](#)", and restart the instance.

- Using the pg_ctl command

Specify the following in the pg_ctl command:

- Specify "restart" as the mode.
- Specify the data storage destination directory in the -D option. If the -D option is omitted, the value of the PGDATA environment variable is used by default.
- Specify the -w option. This means that the command returns after waiting for the instance to start. If the -w option is not specified, it may not be possible to determine if the starting of the instance completed successfully or if it failed.

Example

```
> pg_ctl restart -w -D /database/inst1
```

2. Execute an SQL function, such as the one below, to set the master encryption key. This must be performed by the database superuser.

```
SELECT pgx_set_master_key('user pin');
```

The argument should be the user pin set in "[5.2 Preparing for HSM Collaboration](#)".

5.4 Opening the Keystore

To create encrypted tablespaces and access the encrypted data, you must first open the keystore. When you open the keystore, the master encryption key in the token becomes accessible and becomes usable for encryption and decryption.

You need to open the keystore each time you start the instance. To open the keystore, the database superuser must execute the following SQL function.

```
SELECT pgx_open_keystore('user pin');
```

user pin is the user pin configured in "[5.2 Preparing for HSM Collaboration](#)".

Refer to "[B.2 Transparent Data Encryption Control Functions](#)" for information on the pgx_open_keystore function.

Note that, in the following cases, the user pin must be entered when starting the instance, because the encrypted WAL must be decrypted for recovery. In this case, the above-mentioned pgx_open_keystore function cannot be executed.

- If performing crash recovery at the time of starting the instance
- If performing recovery using continuous archiving

For the above cases, specify the --user-pin option in the pg_ctl command, and then start the instance. This will display the prompt for the user-pin to be entered, as shown below.

```
> pg_ctl --user-pin start  
Enter User PIN:  
The server is starting  
>
```

Point

When using an automatically opening keystore, you do not need to enter the user pin and you can automatically open the keystore when the database server starts. Refer to "[5.7.4 Enabling Automatic Opening of the Keystore](#)" for details.

5.5 Encrypting a Tablespace

The keystore must be open before you can create an encrypted tablespace.

When creating a tablespace that will be encrypted, configure the encryption algorithm in the runtime parameters. For example, to create a tablespace with the name `secure_tablespace` using AES with a key length of 256 bits as the encryption algorithm, configure as shown below.

```
-- Specify the encryption algorithm for the tablespace to be created below
SET tablespace_encryption_algorithm = 'AES256';
CREATE TABLESPACE secure_tablespace LOCATION '/My/Data/Dir';
-- Specify that the tablespace to be created below is not to be encrypted
SET tablespace_encryption_algorithm = 'none';
```

Or

```
CREATE TABLESPACE secure_tablespace LOCATION '/My/Data/Dir' WITH (tablespace_encryption_algorithm =
'AES256' );
```

When the tablespace is empty and not set with encryption algorithm, the encryption algorithm can be set with the command below.

```
ALTER TABLESPACE db_tablespace SET (tablespace_encryption_algorithm=AES256);
```

Trying to set the encryption algorithm for a non-empty tablespace causes an error.

You can use AES with a key length of 128 bits or 256 bits as the encryption algorithm. It is recommended that you use 256-bit AES. Refer to "[Appendix A Parameters](#)" for information on how to specify the runtime parameters.

If user provides both GUC and command line options while creating the tablespace, the preference is given to the command line option.

The `pg_default` and `pg_global` tablespaces cannot be encrypted.

Create tables and indexes in the encrypted tablespace that you created. Relations created in the encrypted tablespace are automatically encrypted.

Example

Example 1: Specifying an encrypted tablespace when creating it

```
CREATE TABLE my_table (... )
    TABLESPACE secure_tablespace;
```

Example 2: Not explicitly specifying a tablespace when creating it and instead using the default tablespace

```
SET default_tablespace = 'secure_tablespace';
CREATE TABLE my_table (... );
```

The process is the same for encrypting temporary tables and temporary indexes. In other words, either explicitly specify the `TABLESPACE` clause or list encrypted tablespaces in the `temp_tablespaces` parameter, and then execute `CREATE TEMPORARY TABLE` or `CREATE INDEX`.

Point

If an encrypted tablespace is specified in the `TABLESPACE` clause of the `CREATE DATABASE` statement, relations created in the database without explicitly specifying a tablespace will be encrypted. Furthermore, the system catalog will also be encrypted, so the source code of user-defined functions is also protected.

Example: Specifying a tablespace in a database definition statement

```
CREATE DATABASE DB01 TABLESPACE=SP01 ... ;
```

Part of the data is also stored in the system catalog - to encrypt this data as well, specify an encrypted tablespace as above and create a database.

5.6 Checking an Encrypted Tablespace

The `pgx_tablespaces` system view displays information about whether each tablespace has been encrypted, and about the encryption algorithm. Refer to "C.1 `pgx_tablespaces`" for information on strings.

You can discover which tablespaces have been encrypted by executing the following SQL statements.

However, when considering continued compatibility of applications, do not reference system catalogs (`pg_tablespace`) directly in SQL statements.

```
SELECT spcname, spcencalgo
FROM pg_tablespace ts, pgx_tablespaces tsx
WHERE ts.oid = tsx.spctablespace;
```



Example

```
postgres=# SELECT spcname, spcencalgo FROM pg_tablespace ts, pgx_tablespaces tsx WHERE ts.oid =
tsx.spctablespace;
 spcname | spcencalgo
-----+-----
 pg_default | none
 pg_global | none
 secure_tablespace | AES256
(3 rows)
```



See

Refer to "Notes on Application Compatibility" in the Application Development Guide for information on how to maintain application compatibility.

5.7 Managing the Keystore

This section describes how to manage the keystore and the master encryption key to guard against the threat of theft.

5.7.1 Changing the Master Encryption Key

Using the same encryption key for an extended period gives attackers an opportunity to decipher the encrypted data. It is recommended that you change the key at regular intervals, or whenever the key is exposed to risk.

Adhere to the industry's best practices for encryption algorithms and key management when considering how often the key should be changed. For example, the NIST in the United States has published "NIST Special Publication 800-57". The PCI DSS also refers to this publication. This publication recommends changing the master encryption key once a year.

To change the master encryption key, execute the `pgx_set_master_key` function, which is the same function used for configuring the key. Refer to "5.3 Setting the Master Encryption Key" for details.

After changing the master encryption key, you must immediately back up the keystore and the entire `opencryptoki` token directory of the slot you assigned to FUJITSU Enterprise Postgres. (This token directory has same name as was set to the `tokname` attribute in "5.2 Preparing for HSM Collaboration").

5.7.2 Changing the HSM master key

The master encryption key is encrypted with the master key hidden by the HSM, and the master key is highly secure, but the HSM master key can be changed. Refer to the IBM documentation for instructions on how to do this. First, stop the database server. As soon as you have change the HSM master key, back up the entire opencryptoki token directory of the slot assigned to FUJITSU Enterprise Postgres.

5.7.3 Changing User Pins

You can change the user pin used for authentication when the keystore is opened.

Refer to the openCryptoki project documentation for instructions on how to do this.

You must then either reopen the keystore with the following SQL or restart the database server.

```
SELECT pgx_open_keystore('newUserpin');
```

As soon as you change the user pin, back up the entire opencryptoki token directory of the slot you assigned to FUJITSU Enterprise Postgres.

5.7.4 Enabling Automatic Opening of the Keystore

Auto-open keystores allow you to automatically open a keystore when you start an instance without entering user pins. To enable automatic keystore opening, specify the following postgresql.conf parameters:

Example

```
tde_z.USER_PIN = 'user pin'
```

Specify the user pin as set in "[5.2 Preparing for HSM Collaboration](#)".

5.7.5 Backing Up and Recovering the Keystore

Back up the keystore and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres at the following times in case they are corrupted or lost.

- When the master encryption key is first configured
- When the master encryption key is changed
- When the database is backed up
- When the HSM master key is changed
- When a user pin is changed

Point

Do not overwrite an old keystore when backing up a keystore. This is because during database recovery, you must restore the keystore to its state at the time of database backup. When the backup data of the database is no longer required, delete the corresponding keystore.

Example

- Back up the database and the keystore on May 1, 2020.

```
> pgx_dmpall -D /database/inst1
> cp -p /key/store/location/keystore.ks /keybackup/keystore_20200501.ks
> tar -cf token_directory_fep_20200501.tar /var/lib/opencryptoki/fep
```

Specify the following in the pgx_dmpall command:

- Specify the data storage destination in the -D option. If the -D option is omitted, the value of the PGDATA environment variable is used by default.

- Change the master encryption key, and back up the keystore on May 5, 2020.

```
> psql -c "SELECT pgx_set_master_key('user pin')" postgres
> cp -p /key/store/location/keystore.ks /keybackup/keystore_20200505.ks
> tar -cf token_directory_fep_20200505.tar /var/lib/opencryptoki/fep
```

Specify the following in the psql command:

- Specify the SQL function that sets the master encryption key in the -c option.
- Specify the name of the database to be connected to as the argument.

.....

If the keystore is corrupted or lost, restore the keystore (containing the latest master encryption key) and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres. If there is no keystore containing the latest master encryption key, restore the keystore and the entire opencryptoki token directory of the slot assigned to FUJITSU Enterprise Postgres to their state at the time of database backup, and recover the database from the database backup. This action recovers the keystore to its latest state.

Example

.....

- Restore the keystore containing the latest master encryption key as of May 5, 2020.

```
> cp -p /keybackup/keystore_20200505.ks /key/store/location/keystore.ks
> tar -xf token_directory_fep_20200505.tar
```

- If there is no backup of the keystore containing the latest master encryption key, recover the keystore by restoring the keystore that was backed up along with the database on 1 May 2020.

```
> cp -p /keybackup/keystore_20200501.ks /key/store/location/keystore.ks
> tar -xf token_directory_fep_20200501.tar
> pgx_rcvall -B /backup/inst1 -D /database/inst1 --user-pin
```

Specify the following in the pgx_rcvall command:

- Specify the data storage directory in the -D option. If the -D option is omitted, the value of the PGDATA environment variable is used by default.
 - Specify the backup data storage directory in the -B option.
 - The --user-pin option prompts you to enter the user pin to open the keystore.
-

See

.....

Refer to "pgx_rcvall" and "pgx_dmpall" in the Reference for information on the pgx_rcvall and pgx_dmpall commands.

Refer to "psql" under "Reference" in the PostgreSQL Documentation for information on the psql command.

Refer to "[B.2 Transparent Data Encryption Control Functions](#)" for information on the pgx_set_master_key function.

Refer to "[5.7.4 Enabling Automatic Opening of the Keystore](#)" for information on how to enable automatic opening of the keystore.

.....

5.8 Backing Up and Restoring/Recovering the Database

FUJITSU Enterprise Postgres enables you to use the five backup and recovery methods described below. Regardless of the method you use, you must back up the keystore and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres at the same time.

Note that you must store the database and the keystore on separate data storage media. Storing both on the same data storage medium risks the danger of the encrypted data being deciphered if the medium is stolen.



Note

When recovering the database, it is necessary to restore the configuration of both Crypto Express Adapter Card and openCryptoki which contains the same key as was set at the time of taking backup so that the recovered database can cooperate with hardware security module.

Backup and recovery using WebAdmin

- Backup

WebAdmin backs up encrypted data.

Back up the key store and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres after backing up the database.

- Recovery

Restore the keystore and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres to their state at the time of database backup. Refer to "[5.7.5 Backing Up and Recovering the Keystore](#)" for details.

Enable automatic opening of the keystore in accordance with the procedure described in "[5.7.4 Enabling Automatic Opening of the Keystore](#)". Then, use WebAdmin to recover the database.

Backup and recovery using the `pgx_dmpall` and `pgx_rcvall` commands

- Backup

The `pgx_dmpall` command backs up the encrypted data.

Back up the key store and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres after backing up the database.

- Recovery

Restore the keystore and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres to their state at the time of the database backup.

Configure automatic opening of the key store as necessary.

If automatic opening of the keystore is not enabled, execute the `pgx_rcvall` command with the `--user-pin` option specified. This will display the prompt for the user pin to be entered.



Example

- Back up the database and the keystore on May 1, 2020.

```
> pgx_dmpall -D /database/inst1
> cp -p /key/store/location/keystore.ks /keybackup/keystore_20200501.ks
> tar -cf token_directory_fep_20200501.tar /var/lib/opencryptoki/fep
```

Specify the following in the `pgx_dmpall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

- Recover the database and the keystore from the backup taken on May 1, 2020.

```
> cp -p /keybackup/keystore_20200501.ks /key/store/location/keystore.ks
> pgx_rcvall -B /backup/inst1 -D /database/inst1 --user-pin
```

Specify the following in the `pgx_rcvall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup data storage directory in the `-B` option.

- The --user-pin option prompts you to enter the user pin to open the keystore.
-

Dump and restore using SQL

- Backup

The files output by the `pg_dump` and `pg_dumpall` commands are not encrypted. You should, therefore, encrypt the files using OpenSSL commands or other means before saving them, as described in "5.9 Importing and Exporting the Database" below.

Back up the key store and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres after backing up the database.

- Restore

If the backup data has been encrypted using, for example Open SSL commands, decrypt that data.

The data generated by the `pg_dumpall` command includes a specification to encrypt tablespaces by default. For this reason, the `psql` command encrypts tablespaces during restoration.

File system level backup and restore

- Backup

Stop the instance and backup the data directory and the tablespace directory using the file copy command of the operating system. The files of encrypted tablespaces are backed up in the encrypted state.

Back up the key store and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres after performing the backup.

- Restore

Restore the keystore and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres to their state at the time of the database backup.

Stop the instance and restore the data directory and the tablespace directory using the file copy command of the operating system.

Continuous archiving and point-in-time recovery

- Backup

The `pg_basebackup` command backs up the encrypted data as is.

Back up the key store and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres after performing the backup.

- Recovery

Restore the keystore and the entire opencryptoki token directory of the slot allocated to FUJITSU Enterprise Postgres to their state at the time of the database backup.

Configure automatic opening of the key store as necessary.

If automatic opening of the keystore is not enabled, execute the `pg_ctl` command to start the instance with the --user-pin option specified. This will display the prompt for the user pin to be entered.



- Refer to "pg_ctl" under "Reference" in the PostgreSQL Documentation for information on the `pg_ctl` command.
- Refer to "Reference" in the PostgreSQL Documentation for information on the following commands:
 - `psql`
 - `pg_dump`
 - `pg_basebackup`

- Refer to the Reference for information on the following commands:
 - pgx_rcvall
 - pgx_dmpall
 - pg_dumpall

5.9 Importing and Exporting the Database

The files output by the COPY TO command are not encrypted. Therefore, when transferring files to other systems, you should encrypt files using OpenSSL commands or other means and use scp or sftp to encrypt the data being transferred.

Use a safe method to delete obsolete plain text files.

You can use the following methods to safely delete files:

- shred command



Example

```
# Export the contents of the table my_table to a CSV file.
> psql -c "COPY my_table TO '/tmp/my_table.csv' (FORMAT CSV)" postgres

# Encrypt the exported file.
> openssl enc -e -aes256 -in my_table.csv -out my_table.csv.enc
(The user is prompted to enter the passphrase to be used for encryption)

# Safely delete plain text files.
> shred -u -x my_table.csv
(Transfer encrypted files to other systems)

# Decrypt the encrypted files on other systems.
> openssl enc -d -aes256 -in my_table.csv.enc -out my_table.csv
(The user is prompted to enter the passphrase to be used for decryption)
```

If you use COPY FROM to import data to tables and indexes in an encrypted tablespace, the imported data is automatically encrypted before being stored.

5.10 Encrypting Existing Data

You cannot encrypt existing unencrypted tablespaces. In addition, you cannot change encrypted tablespaces so that they do not encrypt.

As an alternative, transfer the tables and indexes to other tablespaces. You can use the following SQL commands for this.

```
ALTER TABLE table_name SET TABLESPACE new_tablespace;
ALTER INDEX index_name SET TABLESPACE new_tablespace;
ALTER DATABASE database_name SET TABLESPACE new_tablespace;
```



See

Refer to "SQL Commands" under "Reference" in the PostgreSQL Documentation for information on SQL commands.

5.11 Operations in Cluster Systems

This section describes how to use transparent data encryption on cluster systems such as streaming replication, and database multiplexing.

5.11.1 Database Multiplexing Mode

Note the following when using transparent data encryption in environments that use streaming replication, or database multiplexing with streaming replication.

HSM Master Key Configuration

Because the master encryption key is encrypted with the HSM master key, you must load the same HSM master key on all servers that will be part of the database multiplexing operation.

For instructions on loading the primary server's HSM master key on the standby server, refer to the IBM documentation.

Placing the keystore file

Place a copy of the primary server keystore file on the standby server.

This is required as the keystore file cannot be shared, and both servers may need to access it simultaneously.

Copy procedure for the opencryptoki token directory

Execute the following operations as the system administrator (root).

1. On source machine
 - a. Backup the token directory of the source machine (retain file owners and groups) in the backup
2. On target machine
 - a. Update the opencryptoki.conf file
Add new Slot/tokname to use on the target machine
 - b. Restart Slot Manager daemon (pkcsslotd)
This will create the openCryptoki token folders including a new one for new slot
 - c. Copy all the backed-up token directory files into this new token directory (preserving the file owners and groups)
 - d. Be sure to remove any shared memory files in /dev/shm which are associated with the new tokname
 - e. Restart Slot Manager daemon (pkcsslotd)
 - f. New token should be ready to use.
(The SO PIN and User PIN are same as they were on the source machine)

Automatically opening the keystore

You must enable automatic opening of the keystore.

To do this, enable automatic opening of the keystore in all servers that make up database multiplexing.

Building and starting a standby server

Before using the `pg_basebackup` command or `pgx_rcvall` command to build a standby server, copy the keystore file and the entire opencryptoki token directory of the slot assigned to FUJITSU Enterprise Postgres from the primary server to the standby server.

Open the keystore each time you start the standby server. This step is necessary for decrypting and restoring encrypted WAL received from the primary server. To open the keystore, specify the `--user-pin` option in the `pg_ctl` command or `pgx_rcvall` command and enter the user pin, or use an automatically opening keystore.



Note

- If you start a standby server without copying the openCryptoki token directory from the primary server to the standby server, an error occurs during the following operations.
 - Accessing tables defined in an encrypted tablespace on the standby server
 - Changing the master encryption key on the primary server

- If an error occurs, you can recover by copying the opencryptoki token directory from the primary server to the standby server and restarting the standby server.

Changing the master encryption key

Change the master encryption key on the primary server. You need not copy the keystore from the primary server to the standby server. You need not even restart the standby server or reopen the keystore. Changes to the master encryption key are reflected in the keystore on the standby server.



Refer to "pgx_rcvall " in the Reference for information on pgx_rcvall command.

Refer to "pg_ctl" under "Reference" in the PostgreSQL Documentation for information on pg_ctl command.

Refer to "pg_basebackup" under "Reference" in the PostgreSQL Documentation for information on pg_basebackup command.

Refer to "High Availability, Load Balancing, and Replication" under "Server Administration" in the PostgreSQL Documentation for information on how to set up streaming replication.

5.12 Security-Related Notes

- Decrypted data is cached in the database server memory (shared buffer). As a result, unencrypted data is stored in a core file, which is a process memory dump. You should, therefore, safely delete the memory dump.
You can safely delete files by using the following command:
 - shred command
- Unencrypted data may be written from the database server memory to the operating system's swap area. To prevent leakage of information from the swap area, consider either disabling the use of swap area or encrypting the swap area using a full-disk encryption product.
- The content of the server log file is not encrypted. Therefore, in some cases the value of a constant specified in a SQL statement is output to the server log file. To prevent this, consider setting a parameter such as log_min_error_statement.
- When executing an SQL function that opens the keystore and modifies the master encryption key, ensure that the SQL statement containing the passphrase is not output to the server log file. To prevent this, consider setting a parameter such as log_min_error_statement. If you are executing this type of SQL function on a different computer from the database server, encrypt the communication between the client and the database server with SSL.
- The logical replication is available which allows non-backed up clusters to subscribe to databases where transparent data encryption is enabled. Logical replication does not need to have the same encryption strategy between publisher and subscriber.

In this scenario, if the user wants to encrypt the subscribed copy of data as well, then it is the user's responsibility to create encryption policies to the subscribed databases. By default, published encrypted tablespace data will not be encrypted in the subscriber side.

5.13 Tips for Installing Built Applications

With transparent data encryption, you can easily encrypt all the data in an application without modifying the application. Database administrators install built applications in the following manner. However, this procedure stores data to the default tablespace, so take necessary action if processing differs from the original design.

1. (Normal procedure) Create an owner and a database for the built application.

```
CREATE USER crm_admin ...;  
CREATE DATABASE crm_db ...;
```

2. (Procedure for encryption) Create an encrypted tablespace to store the data for the built application.

```
SET tablespace_encryption_algorithm = 'AES256';  
CREATE TABLESPACE crm_tablespace LOCATION '/crm/data';
```

3. (Procedure for encryption) Configure an encrypted tablespace as the default tablespace for the owner of the built application.

```
ALTER USER crm_admin SET default_tablespace = 'crm_tablespace';  
ALTER USER crm_admin SET temp_tablespaces = 'crm_tablespace';
```

4. (Normal procedure) Install the built application. The application installer prompts you to enter the host name and the port number of the database server, the user name, and the database name. The installer uses the entered information to connect to the database server and execute the SQL script. For applications that do not have an installer, the database administrator must manually execute the SQL script.

Normally, the application's SQL script includes logic definition SQL statements, such as CREATE TABLE, CREATE INDEX, and GRANT or REVOKE, converted from the entity-relationship diagram. It does not include SQL statements that create databases, users, and tablespaces. Configuring the default tablespace of the users who will execute the SQL script deploys the objects generated by the SQL script to the tablespace.

Chapter 6 Data Masking

Data masking is a feature that can change the returned data for queries generated by applications, so that it can be referenced by users. For example, for a query of employee data, digits except the last four digits of an eight-digit employee number can be changed to "*" so that it can be used for reference.

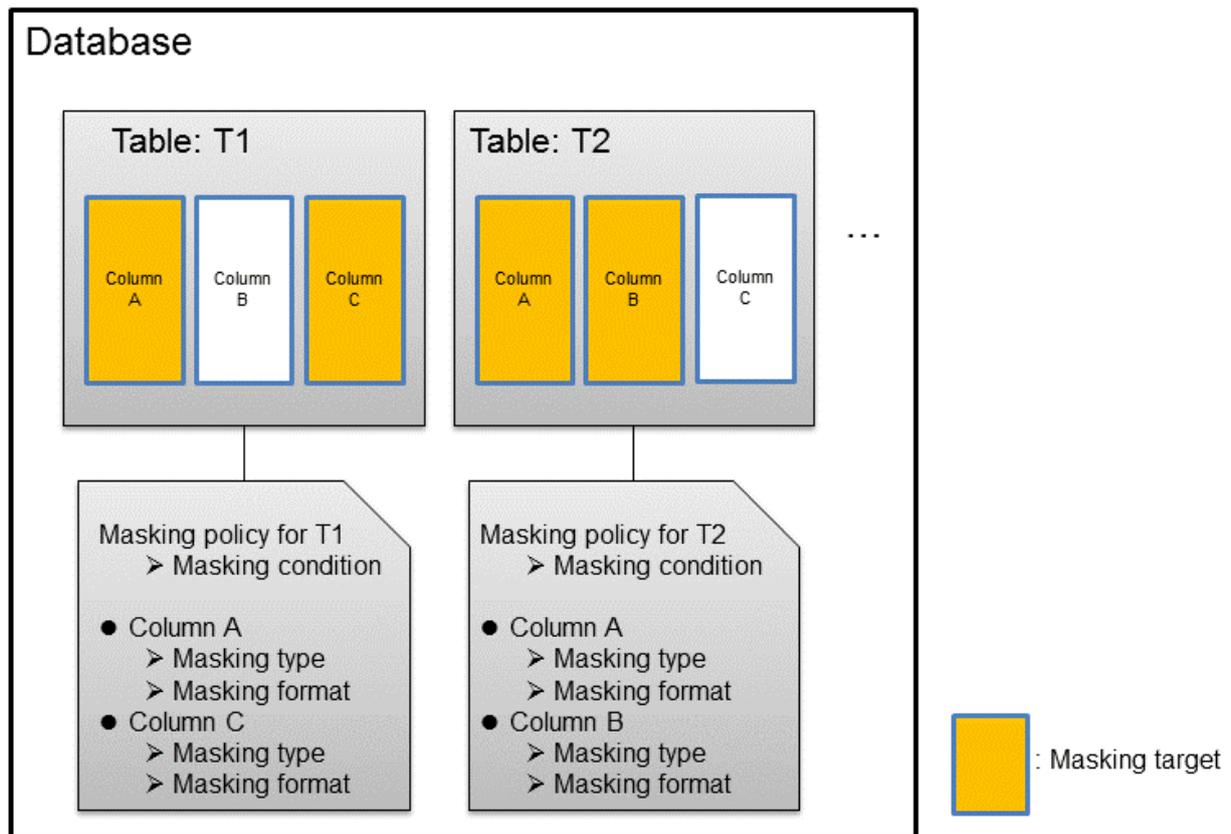
Note

When using this feature, it is recommended that the changed data be transferred to another medium for users to reference. This is because, if users directly access the database to extract the masked data, there is a possibility that they can deduce the original data by analyzing the masking policy or query result to the masking target column.

6.1 Masking Policy

Masking policy is a method of changing data under specific conditions when it is returned for a query from an application. One masking policy can be created per table. You can configure masking target, masking type, masking condition and masking format in a masking policy.

Figure 6.1 Masking policy



Note

When a masking policy is defined, the search performance for the corresponding table may deteriorate.

6.1.1 Masking Target

Masking target refers to a column to which a masking policy will be applied. When referring to a masking target or a function that includes a masking target, the execution result will be changed and obtained.

The following commands can change the execution result:

- SELECT
- COPY
- pg_dump
- pg_dumpall



- If a masking target is specified to INSERT...SELECT target columns, processing will be performed using data before change.
- If a masking target other than SELECT target columns is specified, processing will be performed using data before change.
- If a masking target is specified in a function where the data type will be converted, an error will occur.

6.1.2 Masking Type

Masking type is a method to change column data that is returned from queries. Specify the masking type in the function_type parameter. The following masking types can be specified and selected depending on the masking target data type.

Full masking

All the data in the specified column is changed. The changed value returned to the application that made the query varies depending on the column data type.

For example, 0 is used for a numeric type column and a space is used for a character type column.

Partial masking

The data in the specified column is partially changed.

For example, digits except the last four digits of an employee number can be changed to "*".

Regular expression masking

The data in the specified column is changed via a search that uses a regular expression.

For example, for strings such as email address that can have variable length, "*" can be used to change characters preceding "@" by using a regular expression. Regular expression masking can only be used for character type data.



- If multiple valid masking targets are specified for a function, the masking type for the left-most masking target will be applied. For example, if "SELECT GREATEST(c1, c2) FROM t1" is executed for numeric type masking target c1 and c2, the masking type for c1 will be applied.
- When masking the data that includes multibyte characters, do not specify partial masking for masking type. The result may not be as expected.

6.1.3 Masking Condition

Masking condition refers to the conditions configured to perform masking. Specify the masking condition in the expression parameter. Changed or actual data can be displayed for different users by defining masking condition. An expression that returns a boolean type result needs to be specified in masking condition and masking is performed only when TRUE is returned. Refer to "Value Expressions" in the PostgreSQL Documentation for information on the expressions that can be specified. Note that expressions that include a column cannot

be specified.

For example, when masking data only for "postgres" users, specify 'current_user = "postgres"' in the masking condition.



Information

Specify '1=1' so the masking condition is always evaluated to be TRUE and masking is performed all the time.

6.1.4 Masking Format

Masking format is a combination of change method and displayed characters when the masking condition is met. Masking format varies depending on the masking type. The following describes the masking format.

Full masking

With full masking, all characters are changed to values as determined by the database. Changed characters can be referenced in the `pgx_confidential_values` table. Also, replacement characters can be changed using the `pgx_update_confidential_values` system management function.



See

Refer to "6.3 Data Types for Masking" for information on the data types for which data masking can be performed.

Partial masking

With partial masking, data is changed according to the content in the `function_parameters` parameter. The method of specifying `function_parameters` varies depending on the data type.

Category	Method of specifying <code>function_parameters</code>
Numeric type	<p><i>'replacementCharacter, startPosition, endPosition'</i></p> <ul style="list-style-type: none"> - <i>replacementCharacter</i>: Specify the number to display. Specify a value from 0 to 9. - <i>startPosition</i>: Specify the start position of masking. Specify a positive integer. - <i>endPosition</i>: Specify the end position of masking. Specify a positive integer that is greater than <i>startPosition</i>. <p> Example</p> <p>Specify as below to change the values from the 1st to 5th digits to 9.</p> <p><code>function_parameters := '9, 1, 5'</code></p> <p>In this example, if the original data is "123456789", it will be changed to "999996789".</p>
Character type	<p><i>'inputFormat, outputFormat, replacementCharacter, startPosition, endPosition'</i></p> <ul style="list-style-type: none"> - <i>inputFormat</i>: Specify the current format of the data. Specify "V" for characters that will potentially be masked, and specify "F" for values such as spaces or hyphens that will not be masked. - <i>outputFormat</i>: Define the method to format the displayed data. Specify "V" for characters that will potentially be masked. Any character to be output can be specified for each character "F" in <i>inputFormat</i>. If you want to output a single quotation mark, specify two of them consecutively. - <i>replacementCharacter</i>: Specify any single character. If you want to output a single quotation mark, specify two of them consecutively. - <i>startPosition</i>: Specify the position of "V" as the start position of masking. For example, to specify the position of the 4th "V" from the left, specify 4. Specify a positive integer.

Category	Method of specifying function_parameters
	<p>- <i>endPosition</i>: Specify the position of "V" as an end position of masking. When working out the end position, do not include positions of "F". For example, to specify the position of the 11th "V" from the left, specify 11. Specify a positive integer that is greater than <i>startPosition</i>.</p> <p> Example</p> <p>.....</p> <p>Specify as below to mask a telephone number other than the first three digits using *.</p> <p>function_parameters := 'VVVFVVVVFVVVV, VVV-VVVV-VVVV, *, 4, 11'</p> <p>In this example, if the original data is "012-3156-7890", it will be changed to "012-****-*****".</p> <p>.....</p>
Date/timestamp type	<p>'MDYHMS'</p> <ul style="list-style-type: none"> - M: Masks month. To mask month, enter the month from 1 to 12 after a lowercase letter m. Specify an uppercase letter M to not mask month. - D: Masks date. To mask date, enter the date from 1 to 31 after a lowercase letter d. If a value bigger than the last day of the month is entered, the last day of the month will be displayed. Specify an uppercase letter D to not mask date. - Y: Masks year. To mask year, enter the year from 1 to 9999 after a lowercase letter y. Specify an uppercase letter Y to not mask year. - H: Masks hour. To mask hour, enter the hour from 0 to 23 after a lowercase letter h. Specify an uppercase letter H to not mask hour. - M: Masks minute. To mask minute, enter the minute from 0 to 59 after a lowercase letter m. Specify an uppercase letter M to not mask minute. - S: Masks second. To mask second, enter the second from 0 to 59 after a lowercase letter s. Specify an uppercase letter S to not mask second. <p> Example</p> <p>.....</p> <p>Specify as below to mask hour, minute, and second and display 00:00:00.</p> <p>function_parameters := 'MDYh0m0s0'</p> <p>In this example, if the original data is "2010-10-10 10:10:10", it will be changed to "2010-10-10 00:00:00".</p> <p>.....</p>

 **See**

- Refer to "B.3.2 pgx_create_confidential_policy" for information on function_parameters.
- Refer to "6.3 Data Types for Masking" for information on the data types for which masking can be performed.

Regular expression masking

With regular expression masking, data is changed according to the content of the `regexp_pattern`, `regexp_replacement` and `regexp_flags` parameters. For `regexp_pattern`, specify the search pattern using a regular expression. For `regexp_replacement`, specify the replacement character to use when data matches the search pattern. For `regexp_flags`, specify the regular expression flags.

 **Example**

Specify as below to change all three characters starting from b to X.

`regexp_pattern := 'b..'`

regexp_replacement:= 'X'

regexp_flags := 'g'

In this example, if the original data is "foobarbaz", it will be changed to "fooXX".



See



- Refer to "POSIX Regular Expressions" in the PostgreSQL Documentation and check pattern, replacement, and flags for information on the values that can be specified for regexp_pattern, regexp_replacement, and regexp_flags.
- Refer to "6.3 Data Types for Masking" for information on the data types for which masking can be performed.



Note



- When column data type is character(*n*) or char(*n*) and if the string length after change exceeds *n*, the extra characters will be truncated and only characters up to the *n*th character will be displayed.
- When column data type is character varying(*n*) or varchar(*n*) and if the string length after change exceeds the length before the change, the extra characters will be truncated and only characters up to the length before change will be displayed.



6.2 Usage Method

Preparation

The following preparation is required to use this feature.

1. Set the postgresql.conf file parameters.
Prepend "pgx_datamasking" to the shared_preload_libraries parameter.
2. Restart the instance.
3. Execute CREATE EXTENSION for the database that will use this feature.

The target database is described as "postgres" here.

Use the psql command to connect to the "postgres" database.

Example

```
postgres=# CREATE EXTENSION pgx_datamasking;
CREATE EXTENSION
```



Note



You must always prepend "pgx_datamasking" to the "shared_preload_libraries" parameter.



Information



- Specify "false" for pgx_datamasking.enable to not use this feature. Data will not be masked even if a masking policy is configured. This feature becomes available again once "true" is specified for pgx_datamasking.enable. This setting can be made

by specifying a SET statement or specifying a parameter in the postgresql.conf file.

Example

```
postgres=# SET pgx_datamasking.enable=false;
```

- Hereafter, also perform this preparatory task for the "template1" database, so that this feature can be used by default when creating a new database.

Usage

To perform masking, a masking policy needs to be configured. The masking policy can be created, changed, confirmed, enabled, disabled or deleted during operation.

The procedures to perform these tasks are explained below with examples.

1. Creating a masking policy
2. Changing a masking policy
3. Confirming a masking policy
4. Enabling and disabling a masking policy
5. Deleting a masking policy



Note

Only database superusers can configure masking policies.

6.2.1 Creating a Masking Policy

An example of the operation on the server is shown below.

1. Create a masking policy
Execute the `pgx_create_confidential_policy` system management function to create a masking policy.
The following values are configured in this example.
 - Masking target: Numeric type c1
 - Masking type: FULL
 - Masking condition: 'l=1'

```
postgres=# select pgx_create_confidential_policy(table_name := 't1', policy_name := 'p1',
expression := 'l=1', column_name := 'c1', function_type := 'FULL');
pgx_create_confidential_policy
-----
t
(1 row)
```

2. Confirm the displayed data
Confirm that the masking target data (column c1) has been correctly changed.

```
postgres=# select * from t1;
 c1 |      c2
----+-----
  0 | 012-3456-7890
  0 | 012-3456-7891
  0 | 012-3456-7892
(3 row)
```



See

- Refer to "[B.3.2 pgx_create_confidential_policy](#)" for information on the `pgx_create_confidential_policy` system management function.


```

public      | t1      | p1      | c2      | PARTIAL      | VVVFVVVVFVVVV, VVV-VVVV-
VVVV, *, 4, 11 |
(2 row)

```

2. Confirm information about the masking policy content
Refer to `pgx_confidential_policies` to confirm the masking policy content.

```

postgres=# select * from pgx_confidential_policies;
 schema_name | table_name | policy_name | expression | enable | policy_description
-----+-----+-----+-----+-----+-----
public      | t1      | p1      | 1=1      | t      |
(1 row)

```



- Refer to "D.1 `pgx_confidential_columns`" for information on the `pgx_confidential_columns` table.
- Refer to "D.2 `pgx_confidential_policies`" for information on the `pgx_confidential_policies` table.

6.2.4 Enabling and Disabling a Masking Policy

An example of the operation on the server is shown below.

1. Disable a masking policy
Execute the `pgx_enable_confidential_policy` system management function to disable a masking policy.

```

postgres=# select pgx_enable_confidential_policy(table_name := 't1', policy_name := 'p1',
enable := 'f');
 pgx_enable_confidential_policy
-----
t
(1 row)

```

2. Confirm the displayed data
Confirm that the original data is displayed by disabling the masking policy.

```

postgres=# select * from t1;
 c1 |      c2
-----+-----
  1 | 012-3456-7890
  2 | 012-3456-7891
  3 | 012-3456-7892
(3 row)

```

3. Enable a masking policy
Execute the `pgx_enable_confidential_policy` system management function to enable a masking policy.

```

postgres=# select pgx_enable_confidential_policy(table_name := 't1', policy_name := 'p1',
enable := 't');
 pgx_enable_confidential_policy
-----
t
(1 row)

```

4. Confirm the displayed data
Confirm that the masking target data has been correctly changed.

```

postgres=# select * from t1;
 c1 |      c2
-----+-----
  0 | 012-****-****
  0 | 012-****-****

```

```

0 | 012-****-****
(3 row)

```



- Refer to "B.3.4 [pgx_enable_confidential_policy](#)" for information on the `pgx_enable_confidential_policy` system management function.

6.2.5 Deleting a Masking Policy

An example of the operation on the server is shown below.

1. Delete a masking policy

Execute the `pgx_drop_confidential_policy` system management function to delete a masking policy.

```

postgres=# select pgx_drop_confidential_policy(table_name := 't1', policy_name := 'p1');
pgx_drop_confidential_policy
-----
t
(1 row)

```

2. Confirm the displayed data

Confirm that the original data is displayed by deleting the masking policy.

```

postgres=# select * from t1;
 c1 |      c2
-----+-----
  1 | 012-3456-7890
  2 | 012-3456-7891
  3 | 012-3456-7892
(3 row)

```



- Refer to "B.3.3 [pgx_drop_confidential_policy](#)" for information on the `pgx_drop_confidential_policy` function.

6.3 Data Types for Masking

The data types for which data masking can be performed are shown below.

Category	Data type	Masking type		
		Full masking	Partial masking	Regular expression masking
Numeric type	smallint	Y	Y	N
	integer	Y	Y	N
	bigint	Y	Y	N
	decimal	Y	Y	N
	numeric	Y	Y	N
	float	Y	Y	N
	real	Y	Y	N
	double precision	Y	Y	N

Category	Data type	Masking type		
		Full masking	Partial masking	Regular expression masking
Character type	character varying(<i>n</i>)	Y	Y	Y
	varchar(<i>n</i>)	Y	Y	Y
	character(<i>n</i>)	Y	Y	Y
	char(<i>n</i>)	Y	Y	Y
Date/timestamp type	date	Y	Y	N
	timestamp	Y	Y	N

6.4 Security Notes

- The logical replication is available, which allows non-backed up clusters to subscribe to databases where data masking policies are enabled. Logical replication allows publisher and subscriber databases to have their own or the same data masking policies.

In this scenario, the user must disable data masking on the publisher database whenever a subscription is created. This ensures that subscribers are able to obtain the original data (initial copy) instead of the masked version. Then, it is the user's responsibility to set masking policies to each subscribed database.

- Take strong caution in publishing data masking's confidential tables (pgx_confidential_policies, pgx_confidential_columns, etc.) unless the user is publishing all tables of the database and wants to apply the same data masking's policies on the subscribed database for all of them.

Otherwise, as these confidential tables contain the masking policies for all tables of the database, confidential policies of unpublished tables may be unintentionally published. Additionally, it is not possible to apply different data masking policies on the subscriber database.

Chapter 7 Periodic Operations

This chapter describes the operations that must be performed periodically when running daily database jobs.

7.1 Configuring and Monitoring the Log

FUJITSU Enterprise Postgres enables you to output database errors and warnings to a log file.

This information is useful for identifying if errors have occurred and the causes of those errors.

By default, this information is output to the system log. It is recommended that you configure FUJITSU Enterprise Postgres to collect logs from its log files (for example, `log_destination`) before operating FUJITSU Enterprise Postgres.

Periodically monitor the log files to check if any errors have occurred.



See

- Refer to "Error Reporting and Logging" under "Server Administration" in the PostgreSQL Documentation for information on logs.
- Refer to "Configuring Parameters" in the Installation and Setup Guide for Server for information on log settings when operating with WebAdmin.

7.2 Monitoring Disk Usage and Securing Free Space

When a database is used for an extended period, free space on the disk is continuously consumed and in some cases the disk space runs out. When this happens, database jobs may stop and no longer run.

You should, therefore, periodically monitor the usage of disk space, and delete obsolete files located in the disk.

Monitor the disk usage of the disk where the following directories are located:

- Data storage destination directory
- Transaction log storage destination (if the transaction log is stored in a different directory from the data storage destination directory)
- Backup data storage destination directory
- Tablespace storage destination directory

7.2.1 Monitoring Disk Usage

To check the disk usage, use the following operating system commands:

- `df` command

You can even use SQL statements to check tables and indexes individually.

Refer to "Determining Disk Usage" under "Server Administration" in the PostgreSQL Documentation for information on this method.



Information

If you are using WebAdmin for operations, a warning is displayed when disk usage reaches 80%

7.2.2 Securing Free Disk Space

Secure free disk space by using the following operating system commands to delete unnecessary files, other than the database, from the same disk unit.

- `rm` command

You can also secure disk space by performing the following tasks periodically:

- To secure space on the data storage destination disk:

Execute the REINDEX statement. Refer to "7.5 Reorganizing Indexes" for details.

- To secure space on the backup data storage destination disk:

Execute backup using WebAdmin or the pgx_dmpall command.

7.3 Automatically Closing Connections

If an application stops responding and abnormally terminates for any reason, the connection from the application may remain active on the database server. If this situation continues for an extended period, other applications attempting to connect to the database server may encounter an error, or an error indicating that the tables are unavailable may occur.

It is, therefore, recommended that idle connections be closed automatically at regular intervals.

Set the following parameters in the postgresql.conf file to indicate the time permitted to elapse before a connection is closed.

Parameter name	Setting	Description
tcp_keepalives_idle	Time until keepalive is sent (seconds) If 0, the default value of the system is used.	Sends keepalive to an idle connection at the specified interval in seconds It is recommended to specify 30 seconds.
tcp_keepalives_interval	keepalive send interval (seconds) If 0, the default value of the system is used.	Sends keepalive at the specified interval It is recommended to specify 10 seconds.
tcp_user_timeout	Time to wait for a response from the server (milliseconds) If 0, the default value of the system is used. If not set, the behavior is the same as if 0 were specified.	After establishing the connection, when sending from the client to the server, if the TCP resend process operates, specify the time until it is considered to be disconnected. If a value other than 0 is specified in this parameter, the time until automatic disconnection is determined by the waiting time specified in this parameter. The actual wait time is until the timing of the first keepalive retransmission after the time specified by this parameter has elapsed.

Note

If a value other than 0 is specified for the tcp_user_timeout parameter, the waiting time set by the tcp_keepalives_idle parameter and tcp_keepalives_interval parameter will be invalid and the waiting time specified by the tcp_user_timeout parameter will be used.

See

Refer to "Connection Settings" under "Server Administration" in the PostgreSQL Documentation for information on the parameters.

7.4 Monitoring the Connection State of an Application

FUJITSU Enterprise Postgres does not immediately delete the updated or deleted data. If the VACUUM determines there are no transactions that reference the database, FUJITSU Enterprise Postgres collects obsolete data.

However, obsolete data is not collected if there are connections that have remained active for an extended period or connections occupying resources. In this case the database may expand, causing performance degradation.



See

Refer to "Routine Vacuuming" under "Server Administration" in the PostgreSQL Documentation for information on the VACUUM command.

In such cases, you can minimize performance degradation of the database by monitoring problematic connections.

The following method is supported for monitoring connections that have been in the waiting status for an extended period:

- [7.4.1 Using the View \(pg_stat_activity\)](#)

7.4.1 Using the View (pg_stat_activity)

Use the view (pg_stat_activity) to identify and monitor connections where the client has been in the waiting status for an extended period.



Example

The example below shows connections where the client has been in the waiting status for at least 60 minutes.

However, when considering continued compatibility of applications, do not reference system catalogs directly in the following SQL statements.

```
postgres=# select * from pg_stat_activity where state='idle in transaction' and current_timestamp >
cast(query_start + interval '60 minutes' as timestamp);
-[ RECORD 1 ]-----+-----
datid          | 13003
datname        | db01
pid            | 4638
usesysid       | 10
username       | fsep
application_name | ap101
client_addr    | 192.33.44.15
client_hostname |
client_port    | 27500
backend_start  | 2020-02-24 09:09:21.730641+09
xact_start     | 2020-02-24 09:09:23.858727+09
query_start    | 2020-02-24 09:09:23.858727+09
state_change   | 2020-02-24 09:09:23.858834+09
wait_event_type | Client
wait_event     | ClientRead
state          | idle in transaction
backend_xid    |
backend_xmin   |
query         | begin;
backend_type   | client backend
```



See

- Refer to "Notes on Application Compatibility" in the Application Development Guide for information on maintaining application compatibility.
- Refer to "The Statistics Collector" under "Server Administration" in the PostgreSQL Documentation for information on pg_stat_activity.

7.5 Reorganizing Indexes

Normally, a database defines indexes in tables, but if data is frequently updated, indexes can no longer use free space in the disk efficiently. This situation can also cause a gradual decline in database access performance.

To rearrange used space on the disk and prevent the database access performance from declining, it is recommended that you periodically execute the REINDEX command to reorganize indexes.

Check the disk usage of the data storage destination using the method described in "7.2 Monitoring Disk Usage and Securing Free Space".

Note

Because the REINDEX command retrieves the exclusive lock for an index being processed and locks writing of tables that are the source of the index, other processes that access these may stop while waiting to be locked.

Therefore, it is necessary to consider measures such as executing the command after the task is completed.

See

Refer to "Routine Reindexing" under "Server Administration" in the PostgreSQL Documentation for information on reorganizing indexes by periodically executing the REINDEX command.

Point

Typically, reorganize indexes once a month at a suitable time such as when conducting database maintenance. Use SQL statements to check index usage. If this usage is increasing on a daily basis, adjust the frequency of recreating the index as compared to the free disk space.

The following example shows the SQL statements and the output.

However, when considering continued compatibility of applications, do not reference system catalogs and functions directly in the following SQL statements. Refer to "Notes on Application Compatibility" in the Application Development Guide for details.

[SQL statements]

```
SELECT
  nspname AS schema_name,
  relname AS index_name,
  round(100 * pg_relation_size(indexrelid) / pg_relation_size(indrelid)) / 100 AS index_ratio,
  pg_size_pretty(pg_relation_size(indexrelid)) AS index_size,
  pg_size_pretty(pg_relation_size(indrelid)) AS table_size
FROM pg_index I
  LEFT JOIN pg_class C ON (C.oid = I.indexrelid)
  LEFT JOIN pg_namespace N ON (N.oid = C.relnamespace)
WHERE
  C.relkind = 'i' AND
  pg_relation_size(indrelid) > 0
ORDER BY pg_relation_size(indexrelid) DESC, index_ratio DESC;
```

[Output]

schema_name	index_name	index_ratio	index_size	table_size
public	pgbench_accounts_pkey	0.16	2208 KB	13 MB
pg_catalog	pg_depend_depender_index	0.6	224 KB	368 KB
pg_catalog	pg_depend_reference_index	0.58	216 KB	368 KB
...				

See

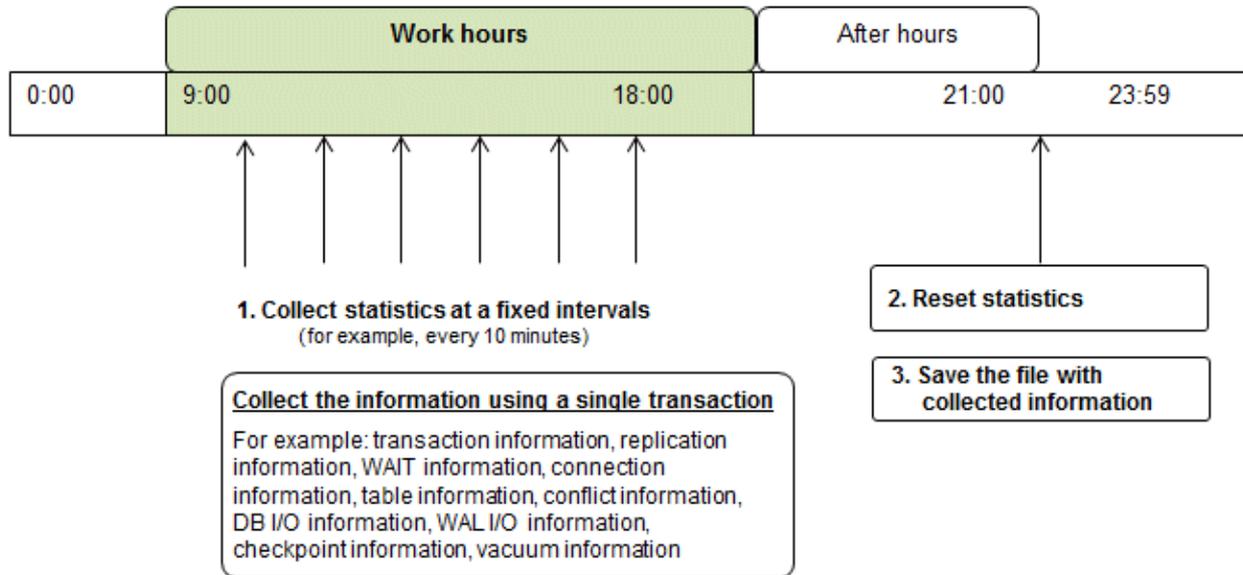
Refer to "Notes on Application Compatibility" in the Application Development Guide for information on maintaining application compatibility.

7.6 Monitoring Database Activity

FUJITSU Enterprise Postgres enables you to collect information related to database activity. By monitoring this information, you can check changes in the database status.

This information includes wait information for resources such as internal locks, and is useful for detecting performance bottlenecks. Furthermore, you should collect this information in case you need to request Fujitsu technical support for an investigation.

Figure 7.1 Overview of information collection



1. Collect statistics at fixed intervals during work hours.

Accumulate the collected information into a file.

Wherever possible, collect data from the various statistics views using a single transaction, because it enables you to take a snapshot of system performance at a given moment.

Refer to "[7.6.1 Information that can be Collected](#)" for information on the system views that can be collected.

2. Reset statistics after work hours, that is, after jobs have finished.

Refer to "[7.6.3 Information Reset](#)" for information on how to reset statistics.

3. Save the file with collected information.

Keep the file with collected information for at least two days, in order to check daily changes in performance and to ensure that the information is not deleted until you have sent a query to Fujitsu technical support.

Where jobs run 24 hours a day, reset statistics and save the file with collected information when the workload is low, for example, at night.

Note

Statistics cumulatively add the daily database value, so if you do not reset them, the values will exceed the upper limit, and therefore will not provide accurate information.

The subsections below explain the following:

- Information that can be collected
- Collection configuration
- Information reset

7.6.1 Information that can be Collected

Information that can be collected is categorized into the following types:

- Information common to PostgreSQL
- Information added by FUJITSU Enterprise Postgres

Information common to PostgreSQL



See

.....
Refer to "Monitoring Database Activity" under "Server Administration" in the PostgreSQL Documentation for information on information common to PostgreSQL.
.....

Information added by FUJITSU Enterprise Postgres

You can collect the following information added by FUJITSU Enterprise Postgres.

Table 7.1 Information added by FUJITSU Enterprise Postgres

View name	Description
pgx_stat_lwlock	Displays statistic related to lightweight lock, with each type of content displayed on a separate line. This information helps to detect bottlenecks. Refer to " C.2 pgx_stat_lwlock " for details.
pgx_stat_latch	Displays statistics related latches, with each type of wait information within FUJITSU Enterprise Postgres displayed on a separate line. This information helps to detect bottlenecks. Refer to " C.3 pgx_stat_latch " for details.
pgx_stat_walwriter	Displays statistics related to WAL writing, in a single line. Refer to " C.4 pgx_stat_walwriter " for details.
pgx_stat_sql	Displays statistics related to SQL statement executions, with each type of SQL statement displayed on a separate line. Refer to " C.5 pgx_stat_sql " for details.
pgx_stat_gmc	Displays statistics related to Global Meta Cache hit ration and used memory size. Refer to " C.6 pgx_stat_gmc " for detail. Also refer to Chapter 12 Global Meta Cache for information on the Global Meta Cache.

7.6.2 Collection Configuration

The procedure for configuring collection depends on the information content.

- Information common to PostgreSQL
- Information added by FUJITSU Enterprise Postgres

Information common to PostgreSQL



See

.....
Refer to "The Statistics Collector" in "Monitoring Database Activity" under "Server Administration" in the PostgreSQL Documentation for information on information common to PostgreSQL.
.....

Information added by FUJITSU Enterprise Postgres

Information added by FUJITSU Enterprise Postgres is collected by default.

To enable or disable information collection, change the configuration parameters in `postgresql.conf`. The following table lists the views for which you can enable or disable information collection, and the configuration parameters.

View name	Parameter
<code>pgx_stat_lwlock</code>	<code>track_waits (*1)</code>
<code>pgx_stat_latch</code>	
<code>pgx_stat_sql</code>	<code>track_sql</code>
<code>pgx_stat_gmc</code>	<code>track_gmc</code>

Remarks: You cannot change the collection status for `pgx_stat_walwriter`.

*1: When executing the SQL statement with `EXPLAIN ANALYZE`, processing time may increase because of this information collection. It is recommended to set this parameter to "off" when executing `EXPLAIN ANALYZE` to check the processing time.

Refer to "[Appendix A Parameters](#)" for information on the parameters.

7.6.3 Information Reset

This section describes how to reset information.

Information added by FUJITSU Enterprise Postgres

You can reset information added by FUJITSU Enterprise Postgres by using the `pg_stat_reset_shared` function in the same way as for information common to PostgreSQL.

Configure the following parameters in the `pg_stat_reset_shared` function:

Function	Type of return value	Description
<code>pg_stat_reset_shared(text)</code>	void	<p>Reset some cluster-wide statistics counters to zero, depending on the argument (requires superuser privileges).</p> <p>Calling <code>pg_stat_reset_shared('lwlock')</code> will zero all counters shown in <code>pgx_stat_lwlock</code>.</p> <p>Similarly, in the following cases, all values of the pertinent statistics counter are reset:</p> <ul style="list-style-type: none">- If <code>pg_stat_reset_shared('latch')</code> is called: All values displayed in <code>pgx_stat_latch</code>- If <code>pg_stat_reset_shared('walwriter')</code> is called: All values displayed in <code>pgx_stat_walwriter</code>- If <code>pg_stat_reset_shared('sql')</code> is called: All values displayed in <code>pgx_stat_sql</code>- If <code>pg_stat_reset_shared('gmc')</code> is called: All values except size column in <code>pgx_stat_gmc</code>



See

.....
Refer to "Statistics Functions" in "Monitoring Database Activity" under "Server Administration" in the PostgreSQL Documentation for information on other parameters of the `pg_stat_reset_shared` function.
.....

Chapter 8 Streaming Replication Using WebAdmin

This chapter describes how to create a streaming replication cluster using WebAdmin.

Streaming replication allows the creation of one or more standby instances, which connect to the master instances and replicate the data using WAL records. The standby instance can be used for read-only operations.

WebAdmin can be used to create a streaming replication cluster. WebAdmin allows the creation of a cluster in the following configurations:

- Master-Standby Configuration: This configuration creates a master and standby instance together.
- Standby Only Configuration: This configuration creates a standby instance from an already existing instance.



Point

- A standby instance can be created from a standalone instance, a master instance, or even from another standby instance.
- If a streaming replication cluster is created using WebAdmin, the network with the host name (or IP address) specified in [Host name] will be used across sessions of WebAdmin, and also used as the log transfer network.
- To use a network other than the job network as the log transfer network, specify the host name other than the job network one in [Host name].

8.1 Creating a Standby Instance

Follow the procedure below to create a standby instance.

1. In the [Instances] tab, select the instance from which a standby instance is to be created.
2. Click .

3. Enter the information for the standby instance to be created. In the example below, a standby instance is created from instance "inst1". The instance name, host address and port of the selected instance are already displayed for easy reference.

The screenshot shows the 'Create instance' configuration page in the Fujitsu Enterprise Postgres interface. The page is divided into several sections:

- Configuration type:** Standby only configuration
- Server product type:** FUJITSU Enterprise Postgres 12
- Existing master configuration:**
 - Instance name: inst1
 - Host name: osboxes
 - Port: 27500
- New standby configuration:**
 - Location: Local
 - Replication credential: Cred1
 - User name: webadminser
 - Password: [masked]
 - Instance name: inst1s
 - Instance port: 27502
 - Host IP address: 192.168.56.101
 - Data storage path: /home/fsepuser/inst1s/data
 - Backup: Enabled
 - Backup storage path: /home/fsepuser/inst1s/backup
 - Transaction log path: /home/fsepuser/inst1s/transactionlog
 - Encoding: UTF8
 - Replication mode: Asynchronous
 - Application name: hacluster

Enter the following items:

- [Location]: Whether to create the instance in the server that the current user is logged in to, or in a remote server. The default is "Local", which will create the instance in the server machine where WebAdmin is currently running.
- [Replication credential]: The user name and password required for the standby instance to connect to the master instance. The user name and password can be entered or selected from the Wallet. Refer to "[Appendix G WebAdmin Wallet](#)" for information on creating wallet entries.
- [Instance name]: Name of the standby database instance to create.

The name must meet the conditions below:

- Maximum of 16 characters
 - The first character must be an ASCII alphabetic character
 - The other characters must be ASCII alphanumeric characters
- [Instance port]: Port number of the standby database instance.
 - [Host IP address]: The IP address of the server machine where the standby instance is to be created. This information is needed to configure the standby instance to be connected to the master.
 - [Data storage path]: Directory where the database data will be stored
 - [Backup storage path]: Directory where the database backup will be stored
 - [Transaction log path]: Directory where the transaction log will be stored

- [Encoding]: Database encoding system
- [Replication mode]: Replication mode of the standby instance to be created ("Asynchronous" or "Synchronous")
- [Application name]: The reference name of the standby instance used to identify it to the master instance.

The name must meet the conditions below:

- Maximum of 16 characters
- The first character must be an ASCII alphabetic character
- The other characters must be ASCII alphanumeric characters

4. Click to create the standby instance.

5. Once the standby instance is created successfully, select standby instance in the [Instances] tab. The following page will be displayed:

The screenshot displays the 'inst1s' configuration page in the FUJITSU Enterprise Postgres WebAdmin. The interface includes a sidebar with navigation options like 'Instances', 'My Wallet', and 'Settings'. The main content area is divided into two sections: 'Summary' and 'Storage summary'.

Summary:

Title	inst1s (osboxes:27502)
Server type	FUJITSU Enterprise Postgres AE Linux 64-bit
Version	PostgreSQL 12.1
Server up time	43 seconds
Encoding	UTF8
Instance type	Asynchronous Standby
Last WAL applied time	
Application name	hacluster

Storage summary:

Data storage status	Normal
Data storage path	/home/fsepuser/inst1s/data
Backup storage status	--
Backup storage path	/home/fsepuser/inst1s/backup/backup
Backup time	--

Visual elements include a diagram showing 'inst1' connected to 'inst1s' and another diagram showing 'Data storage' and 'Backup storage' with an arrow between them.

Note

- Backups are not possible for standby instances in WebAdmin. As a result, and are disabled and no value is shown for [Backup storage status] and [Backup time].
- If using WebAdmin to manage Mirroring Controller, the message below may be output to the server log or system log in the standby instance. No action is required, as the instance is running normally.

```
ERROR: pgx_rcvall failed (16491)
ERROR: pgx_rcvall: backup of the database has not yet been performed, or an incorrect backup
storage directory was specified
```

- Replication credential (user name and password) should not contain hazardous characters. Refer to "[Appendix H WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".

8.2 Promoting a Standby Instance

Streaming replication between a master and standby instance can be discontinued using WebAdmin.

Follow the procedure below to promote a standby instance to a standalone instance, thereby discontinuing the streaming replication.

1. In the [Instances] tab, select the standby instance that needs to be promoted.
2. Click .
3. Click [Yes] from the confirmation dialog box.

The standby instance will be promoted and will become a standalone instance, which is not part of a streaming replication cluster.

Once the standby instance is promoted to become a standalone instance, the backup storage status will be "Error". This is because no backups are available when the instance is newly promoted to a standalone instance. The status will be reset if a new backup is performed by clicking [Solution] or .

8.3 Converting an Asynchronous Replication to Synchronous

Streaming replication between a master and standby instance can be configured to be in Asynchronous or Synchronous mode. This mode can be changed even after the standby instance was successfully created.

Follow the procedure below to convert an Asynchronous standby instance to Synchronous.

1. In the [Instances] tab, select the master instance of the relevant cluster.
2. Click .
3. In the [Streaming replication] section, edit the value for [Synchronous standby names].
 - Add the "Application name" of the standby instance you want to be in Synchronous mode.
4. Click .
5. Select the master instance and click .
6. Select the standby instance. [Instance type] will now show the updated status.

Note

- Converting an Asynchronous standby instance to Synchronous can cause the master instance to queue the incoming transactions until the standby instance is ready. For this reason, it is recommended that this operation be performed during a scheduled maintenance period.
- When adding a synchronous standby instance, FUJITSU Enterprise Postgres will only keep the first entry in [Synchronous standby names] in synchronous state.
- To learn more about the differences between synchronous and asynchronous standby modes and their behavior, refer to "Streaming Replication" in "High Availability, Load Balancing, and Replication" in the PostgreSQL Documentation.

8.4 Converting a Synchronous Replication to Asynchronous

Streaming replication between a master and standby instance can be configured to be in Asynchronous or Synchronous Mode. This mode can be changed even after the standby instance was successfully created.

Follow the procedure below to convert a Synchronous standby instance to Asynchronous.

1. In the [Instances] tab, select the master instance of the relevant cluster.
2. Click .

3. In the [Streaming replication] section, edit the value for [Synchronous standby names].
 - Remove the "Application name" of the standby instance you want to be in Asynchronous mode.
4. Click .
5. Select the master instance and click .
6. Select the standby instance. [Instance type] will now show the updated status.

Note

To learn more about the differences between synchronous and asynchronous standby modes and their behavior, refer to "Streaming Replication" in "High Availability, Load Balancing, and Replication" in the PostgreSQL Documentation.

8.5 Joining a Replication Cluster

WebAdmin facilitates the joining of an old master of the cluster as a standby node.

1. In the [Instances] tab, select the remote instance (from where the new cluster node will stream WAL entries), and then click .
2. Configure the node to accept streaming requests from the new node.
3. In the [Instances] tab, select the new standby instance (which needs to be connected to the cluster), and then click .
4. Set [Replication host name] to the remote instance.
5. Enter [Replication credential].

Specify the user name and password required for the standby instance to connect to the remote instance. The user name and password can be entered or selected from the Wallet. Refer to "[Appendix G WebAdmin Wallet](#)" for information on creating wallet entries. Replication credential (user name and password) should not contain hazardous characters. Refer to "[Appendix H WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".
6. Enter [Host IP address].

Specify the IP address of the node where the standby instance was created.
7. Click  to open the [Join replication cluster] dialog box.
8. Select [Restart later] or [Restart now], and then click [Yes] to set up the standby instance.
9. Upon successful completion, the confirmation dialog box will be displayed.
10. Click [Close] to return to the instance details window.

The instance will become a standby instance, and will be part of the streaming replication cluster. The replication diagram will display the relationship between the standby instance and the remote instance. The user can change the replication relationship of the remote instance from asynchronous to synchronous (and vice versa) using the [Configuration] window.

Chapter 9 Installing and Operating the In-memory Feature

The in-memory feature enables fast aggregation using Vertical Clustered Index (VCI) and memory-resident feature.

VCI has a data structure suitable for aggregation, and features parallel scan and disk compression, which enable faster aggregation through reduced disk I/O.

The memory-resident feature reduces disk I/O that occurs during aggregation. It consists of the preload feature that reads VCI data to memory in advance, and the stable buffer feature that suppresses VCI data eviction from memory. The stable buffer feature secures the proportion specified by parameter in the shared memory for VCI.

This chapter describes how to install and operate the in-memory feature.

9.1 Installing Vertical Clustered Index (VCI)

This section describes the installation of VCI.

1. [Evaluating whether to Install VCI](#)
2. [Estimating Resources](#)
3. [Setting up](#)

9.1.1 Evaluating whether to Install VCI

VCI uses available resources within the server to increase scan performance.

It speeds up processing in many situations, and can be more effective in the following situations:

- Single table processing
- Processing that handles many rows in the table
- Processing that handles some columns in the table
- Processing that performs very heavy aggregation such as simultaneous sum and average aggregation

VCI will not be used in the following cases, so it is necessary to determine its effectiveness in advance:

- The data type of the target table or column contains VCI restrictions.
- The SQL statement does not meet the VCI operating conditions
- VCI is determined to be slower based on cost estimation



Note

If performing operations that use VCI, the `full_page_writes` parameter setting in `postgresql.conf` must be enabled (on). For this reason, if this parameter is disabled (off), operations that use VCI return an error. In addition, to perform operations for tables that do not create a VCI when the `full_page_writes` parameter setting is temporarily disabled (off), do not create a VCI or perform operations to tables that created a VCI during that time.



See

- Refer to "9.1.4 Data that can Use VCI" for information on VCI restrictions.
- Refer to "Scan Using a Vertical Clustered Index (VCI)" - "Operating Conditions" in the Application Development Guide for information on VCI operating conditions.

9.1.2 Estimating Resources

Estimate resources before setting up VCI.

Select the aggregation that you want to speed up and identify the required column data. The additional resources below are required according to the number of columns.

- Memory

Secure additional capacity required for the disk space for the column for which VCI is to be created.

- Disk

Secure additional disks based on the disk space required for the column for which VCI is to be created, as VCI stores column data as well as existing table data on the disk. It is recommended to provide a separate disk in addition to the existing one, and specify it as the tablespace to avoid impact on any other jobs caused by I/O.

 **Information**

The operations on VCI can continue even if the memory configured for VCI is insufficient by using VCI data on the disk.

 **See**

Refer to "Estimating Memory Requirements" and "Estimating Database Disk Space Requirements" in the Installation and Setup Guide for Server for information on how to estimate required memory and disk space.

9.1.3 Setting up

This section describes how to set up VCI.

Setup flow

1. [Setting Parameters](#)
2. [Installing the Extensions](#)
3. [Creating VCI](#)
4. [Confirming that VCI has been Created](#)

9.1.3.1 Setting Parameters

Edit postgresql.conf to set the required parameters for VCI. After that, start or restart the instance.

The following table lists the parameters that need or are recommended to be configured in advance:

Parameter name	Setting value	Description	Required
shared_preload_libraries	Literal 'vci, pg_prewarm'	VCI and shared library to be preloaded at server start.	Y
session_preload_libraries	Literal 'vci, pg_prewarm'	VCI and shared library to be preloaded at connection start.	Y
reserve_buffer_ratio	Percentage of shared memory to be used for stable buffer table	Proportion of shared memory to be used for a stable buffer table.	N
vci.control_max_workers	Number of background workers that manage VCI	Number of background workers that manage VCI. Add this value to max_worker_processes.	N
vci.max_parallel_degree	Maximum number of background workers used for parallel scan	Maximum number of background workers used for parallel scan. Add this value to max_worker_processes.	N

Example

```
shared_preload_libraries = 'vci, pg_prewarm'  
session_preload_libraries = 'vci, pg_prewarm'  
reserve_buffer_ratio = 20  
vci.control_max_workers = 8  
vci.max_parallel_degree = 4  
max_worker_processes = 18 # Example: If the initial value was 6, 6 + 8 + 4 = 18
```

Note

An error occurs if you use VCI to start instances when procs is not mounted. Ensure that procs is mounted before starting instances.

See

- Refer to "[Appendix A Parameters](#)" for information on all parameters for VCI. Refer also to default value for each parameter and details such as specification range in the same chapter. Refer to "Server Configuration" under "Server Administration" in the PostgreSQL documentation for information on `shared_preload_libraries`, `session_preload_libraries`, and `max_worker_processes`.

9.1.3.2 Installing the Extensions

Execute CREATE EXTENSION to install the VCI and pg_prewarm extensions. Both extensions need to be installed for each database.

- Installing VCI

```
db01=# CREATE EXTENSION vci;
```

- Installing pg_prewarm

```
db01=# CREATE EXTENSION pg_prewarm;
```

Note

- Only superusers can install VCI extensions.
- VCI extensions can only be installed in public schema.
- Some operations cannot be performed for VCI extensions. Refer to "[9.2.1 Commands that cannot be Used for VCI](#)" for details.

9.1.3.3 Creating a VCI

Execute the CREATE INDEX statement with the "USING vci" clause to create a VCI for the desired columns and the "WITH (stable_buffer=true)" clause to enable the stable buffer feature.

To use a separate disk for the VCI, specify the TABLESPACE clause.

```
db01=# CREATE INDEX idx_vci ON table01 USING vci (col01, col02) WITH (stable_buffer=true);
```

Note

- Some table types cannot be specified on the ON clause of CREATE INDEX. Refer to "[9.1.4.1 Relation Types](#)" for details.
- Some data types cannot be specified on the column specification of CREATE INDEX. Refer to "[9.1.4.2 Data Types](#)" for details.
- Some operations cannot be performed for VCI. Refer to "[9.2.1 Commands that cannot be Used for VCI](#)" for details.

- The same column cannot be specified more than once on the column specification of CREATE INDEX.
- VCI cannot be created for table columns that belong to the template database.
- CREATE INDEX creates multiple views named `vci_10digitRelOid_5digitRelAttr_1charRelType` alongside VCI itself. These are called VCI internal relations. Do not update or delete them as they are used for VCI aggregation.
- All data for the specified column will be replaced in columnar format when VCI is created, so executing CREATE INDEX on an existing table with data inserted takes more time compared with a general index (B-tree). Jobs can continue while CREATE INDEX is running.
- When CREATE INDEX USING VCI is invoked on a partitioned table, the default behavior is to recurse to all partitions to ensure they all have matching indexes. Each partition is first checked to determine whether an equivalent index already exists, and if so, that index will become attached as a partition index to the index being created, which will become its parent index. If no matching index exists, a new index will be created and automatically attached; the name of the new index in each partition will be determined as if no index name had been specified in the command. If the ONLY option is specified, no recursion is done, and the index is marked invalid. (ALTER INDEX ... ATTACH PARTITION marks the index valid, once all partitions acquire matching indexes.) Note, however, that any partition that is created in the future using CREATE TABLE ... PARTITION OF will automatically have a matching index, regardless of whether ONLY is specified.
- Parallel index build is not supported on VCI indexes.

9.1.3.4 Confirming that the VCI has been Created

Execute the SELECT statement to reference the `pg_indexes` catalog, and confirm that the VCI was created for the target columns.



Example

```
db01=# SELECT indexdef FROM pg_indexes WHERE indexdef LIKE '%vci%';
          indexdef
-----
CREATE INDEX idx_vci ON table01 USING vci (col01, col02)
(1 row)
```

9.1.4 Data that can Use VCI

This section describes on which relation types and for which data types VCIs can be created.

9.1.4.1 Relation Types

VCIs cannot be created on some relation types.

The ON clause of CREATE INDEX described in "9.1.3.3 Creating a VCI" cannot specify relations on which VCIs cannot be created.

- Relations on which VCIs can be created
 - Normal tables
 - UNLOGGED TABLEs
- Relations on which VCIs cannot be created
 - Materialized views
 - Temporary tables
 - Views
 - Temporary views
 - Foreign tables

9.1.4.2 Data Types

VCI's cannot be created for some data types.

The column specification of CREATE INDEX described in "9.1.3.3 Creating a VCI" cannot specify a column with data type on which VCI's cannot be created.

Category	Data type	Supported by VCI?
Numeric	smallint	Y
	integer	Y
	bigint	Y
	decimal	Y
	numeric	Y
	real	Y
	double precision	Y
	serial	Y
	bigserial	Y
Monetary	money	Y
Character	varchar(<i>n</i>)	Y
	char(<i>n</i>)	Y
	nchar	Y
	nvarchar(<i>n</i>)	Y
	text	Y
Binary	bytea	Y
Date/time	timestamp	Y
	timestamp with time zone	Y
	date	Y
	time	Y
	time with time zone	Y
	interval	Y
Boolean	boolean	Y
Geometric	point	N
	line	N
	lseg	N
	box	N
	path	N
	polygon	N
	circle	N
Network address	cidr	N
	inet	N
	macaddr	N
	macaddr8	N

Category	Data type	Supported by VCI?
Bit string	bit(<i>n</i>)	Y
	bit varying(<i>n</i>)	Y
Text search	tsvector	N
	tsquery	N
UUID	uuid	Y
XML	xml	N
JSON	json	N
	jsonb	N
Range	int4range	N
	int8range	N
	numrange	N
	tsrange	N
	tstzrange	N
	daterange	N
Object identifier	oid	N
	regproc	N
	regprocedure	N
	regoper	N
	regoperator	N
	regclass	N
	regtype	N
	regconfig	N
	regdictionary	N
pg_lsn type	pg_lsn	N
Array type	-	N
User-defined type (Basic type, enumerated type, composite type, and range type)	-	N

9.2 Operating VCI

This section describes how to operate VCI.

9.2.1 Commands that cannot be Used for VCI

Some operations cannot be performed for VCI extensions and VCI itself.

This section describes SQL commands that cannot be executed for the VCI extensions and VCI itself, and client application commands.

SQL commands

- Operations that cannot be performed for the VCI extension

Command	Subcommand	Description
ALTER EXTENSION	UPDATE	The VCI extension cannot be specified.
	SET SCHEMA	This operation is not required for VCI.
	ADD	
	DROP	
CREATE EXTENSION	SCHEMA	The subcommands on the left cannot be performed if the VCI extension is specified. This operation is not required for VCI.

- Operations that cannot be performed on relations containing a VCI

Command	Subcommand	Description
ALTER INDEX	SET	The subcommands on the left cannot be performed if a VCI is specified.
	SET TABLESPACE	
	ALL IN TABLESPACE	If the operation is required, delete the VCI using DROP INDEX, and re-create it using CREATE INDEX after completing the operation.
ALTER OPERATOR CLASS	RENAME TO	The subcommands on the left cannot be performed if a VCI is specified.
	OWNER TO	
	SET SCHEMA	This operation is not supported in VCI.
ALTER OPERATOR FAMILY	ADD	
	DROP	
	RENAME TO	
	OWNER TO	
	SET SCHEMA	
ALTER TABLE	ALL IN TABLESPACE <i>name</i> [OWNED BY <i>roleName</i>] SET TABLESPACE <i>newTablespace</i>	A tablespace that contains a VCI cannot be specified. If the operation is required, delete the VCI using DROP INDEX, and re-create it using CREATE INDEX after completing the operation.
	DROP [COLUMN] [IF EXISTS] <i>colName</i> [RESTRICT CASCADE]	A column that contains a VCI cannot be specified. If the operation is required, delete the VCI using DROP INDEX, and re-create it using CREATE INDEX after completing the operation.
	ALTER [COLUMN] <i>colName</i> [SET DATA] TYPE <i>dataType</i> [COLLATE <i>collation</i>] [USING <i>expr</i>]	
	CLUSTER ON <i>indexName</i>	A VCI cannot be specified.
	REPLICA IDENTITY {DEFAULT USING INDEX <i>indexName</i> FULL NOTHING}	This operation is not supported in VCI.
CLUSTER	-	A table that contains a VCI and VCI cannot be specified. If the operation is required, delete the VCI using DROP INDEX, and re-create it using CREATE INDEX after completing the operation.
CREATE INDEX	UNIQUE	The subcommands on the left cannot be performed if a VCI is specified.
	CONCURRENTLY	
		This operation is not supported in VCI.

Command	Subcommand	Description
	[ASC DESC]	
	[NULLS { FIRST LAST }]	
	WITH	
	WHERE	
	INCLUDE	
CREATE OPERATOR CLASS	-	A VCI cannot be specified. This operation is not supported in VCI.
CREATE OPERATOR FAMILY	-	
CREATE TABLE	EXCLUDE	
DROP INDEX	CONCURRENTLY	The subcommands on the left cannot be performed if a VCI is specified. This operation is not supported in VCI.
REINDEX	-	A VCI cannot be specified. This command is not required as VCI uses daemon's automatic maintenance to prevent disk space from increasing.

Client application command

- Operations that cannot be performed on relations containing a VCI

Command	Description
clusterdb	Clustering cannot be performed for tables that contain a VCI.
reindexdb	VCIs cannot be specified on the --index option.

9.2.2 Data Preload Feature

The first aggregation using VCI immediately after an instance is started may take time, because the VCI data has not been loaded to buffer. Therefore, use the preload feature to load the VCI data to buffer in advance when performing VCI aggregation after an instance is started. When using the preload feature, execute the function `pgx_prewarm_vci` to each VCI created with `CREATE INDEX`.

```
db01=# SELECT pgx_prewarm_vci('idx_vci');
```



See

Refer to "[B.4 VCI Data Load Control Function](#)" for information on `pgx_prewarm_vci`.

Chapter 10 Parallel Query

FUJITSU Enterprise Postgres enhances parallel queries, by taking into consideration the aspects below:

- CPU load calculation
- Increase of workers during runtime

10.1 CPU Load Calculation

There may be a case when the user tries to execute a parallel query but there is not enough CPU available.

Adding dynamic workers at this stage will provide no benefits - instead, it may add overhead due to context switching.

FUJITSU Enterprise Postgres takes into consideration the current CPU load when deciding on the number of workers for parallel query.

10.2 Increase of Workers during Runtime

This FUJITSU Enterprise Postgres enhancement allows systems to allocate additional workers during query execution (if there are workers available at the time). This improves query performance, which could otherwise starve of CPU if there were fewer or no workers when the query started.



.....
The ability to increase workers during runtime is available only with parallel sequence scan.
.....

Chapter 11 High-Speed Data Load

High-speed data load uses the `pgx_loader` command to load data from files at high speed into FUJITSU Enterprise Postgres.



- This feature is not available in single-user mode. This is because in single-user mode instances run in a single process, and it cannot start parallel workers.

11.1 Installing High-Speed Data Load

This section describes how to install high-speed data load.

Installation flow

1. [Deciding whether to Install](#)
2. [Estimating Resources](#)
3. [Setup](#)

11.1.1 Deciding whether to Install

The feature achieves high speed data load by executing the COPY FROM command in parallel. If the database system is unable to use sufficient resources due to the feature using more resources than the COPY FROM command of PostgreSQL, load performance may be inferior to that of the COPY FROM command of PostgreSQL. Therefore, determine if the feature will be effective by considering the factors below before deciding to install.

Database server memory

If the value of `shared_buffers` in `postgresql.conf` is small, fewer data pages are cached to the shared memory of the database server. This will result in multiple parallel workers more often having to wait for write exclusive locks to the same data page. Moreover, the smaller the number of data pages, the more often the table expands. During table expansion, access to the table is exclusive (standby event name: `extend`), so write time increases. To cater for that, increase the value of `shared_buffers`.



See

The standby event name is stored in the `wait_event` column of the `pg_stat_activity` view. Refer to "wait_event Description" in "The Statistics Collector" in the PostgreSQL Documentation for details.

Frequency of checkpoints

If checkpoints are issued at short intervals, write performance is reduced. If the messages below are output to the server log during data writes, increase the values of `max_wal_size` and `checkpoint_timeout` in `postgresql.conf` to reduce the frequency of checkpoints.



Example

```
LOG:  checkpoints are occurring too frequently (19 seconds apart)
HINT:  Consider increasing the configuration parameter "max_wal_size".
```

11.1.2 Estimating Resources

Estimate the memory requirements for high-speed data load.

Up to 128 parallel workers to perform data load can be specified for this feature. The additional resources below are required depending on the number of parallel workers.

- Dynamic shared memory created during data load

The feature creates shared memory and shared memory message queues during data load. These are used to send external data from the back end to the parallel workers, and for error notifications.

Note

If the value of `shared_buffers` in `postgresql.conf` is small, the system will often have to wait for write exclusive locks to the same data page (as described in "Database server memory" in "11.1.1 Deciding whether to Install"). Since input data cannot be loaded from the shared memory message queues during such waits, they will often be full. In these cases, it will not be possible to write to the shared memory message queues, resulting in degraded data load performance.

See

Refer to "High-Speed Data Load Memory Requirements" in the Installation and Setup Guide for Server for information on the formula for estimating memory requirements.

11.1.3 Setup

This section describes how to set up high-speed data load.

Setup flow

1. [Setting Parameters](#)
2. [Installing the Extension](#)

11.1.3.1 Setting Parameters

Set the parameters required for high-speed data load in `postgresql.conf`. After that, start or restart the instance.

The table below lists the `postgresql.conf` parameters that must be changed, and the values that must be added to their current values. After editing `postgresql.conf`, start or restart the instance.

Parameter	Setting	Required
<code>max_prepared_transactions</code>	Add the number of transactions that can be prepared by parallel workers during data load to the parameter's current value. The resulting value must be equal to or greater than the maximum number of parallel workers used with this feature.	Mandatory
<code>max_worker_processes</code>	Number of parallel workers to perform data load.	Mandatory
<code>max_parallel_workers</code>	Add the maximum number of parallel workers to be used in a parallel query by this feature to the parameter's current value. The resulting value must be equal to or greater than the number of parallel workers used with this feature.	Mandatory

Example

The example below shows how to configure 2 instances of high-speed data load being executed simultaneously using a degree of parallelism of 4.

```
max_prepared_transactions = 13 #Example if the initial value was 5: 5 + 2 x 4 = 13
max_worker_processes = 16 #Example if the initial value was 8: 8 + 2 x 4 = 16
max_parallel_workers = 12 #Example if the initial value was 4: 4 + 2 x 4 = 12
```

Note

As shown in the example above, set the value of `max_prepared_transactions`, `max_worker_processes` and `max_parallel_workers` multiplied by the number of instances of this feature executed simultaneously.

The table below lists the `postgresql.conf` parameters that must also be checked.

Parameter	Setting	Required
<code>dynamic_shared_memory_type</code>	Implementation of dynamic shared memory to be used by the instance. The default value is recommended.	Mandatory

See

Refer to "Resource Consumption" in the PostgreSQL Documentation for information on the parameters.

11.1.3.2 Installing the Extension

Execute `CREATE EXTENSION` to install the high-speed data load extension. The extension needs to be installed on each database.

Example

The example below installs the extension on the "postgres" database.

```
postgres=# CREATE EXTENSION pgx_loader;  
CREATE EXTENSION
```

Note

- Only superusers can install the high-speed data load extension.
- The high-speed data load extension can only be installed on the public schema.

11.2 Using High-Speed Data Load

This section describes how to use high-speed data load.

11.2.1 Loading Data

To load data from a file into a FUJITSU Enterprise Postgres table, execute the `pgx_loader` command in load mode.

Example

The example below loads the file `/path/to/data.csv` (2000 records) into table `tbl` using a degree of parallelism of 3.

```
$ pgx_loader load -j 3 -c "COPY tbl FROM '/path/to/data.csv' WITH CSV"  
LOAD 2000
```

Point

If an external file contains data that violates the format or constraints, the data load may fail partway through, resulting in delays for routine tasks such as nightly batch processing. Therefore, it is recommended to remove the invalid data before executing the data load.

Note

The data inserted using this feature is dumped as a COPY command by the `pg_dump` command and the `pg_dumpall` command.

See

- Refer to "pgx_loader" in the Reference for information on the command.
- Refer to "COPY" in the PostgreSQL Documentation for information on the deployment destination and access privileges for external files.

11.2.2 Recovering from a Data Load that Ended Abnormally

If a system interruption such as a server failure occurs while high-speed data load is being performed, transactions prepared using this feature may be changed to the in-doubt state. At that point, resources occupied by the transaction will be locked, and access to the relevant resources from other transactions will be blocked, rendering them unusable.

In such cases, check transactions that are in an in-doubt state, and resolve them.

Checking for in-doubt transactions

This section describes how to check for in-doubt transactions.

1. Refer to the `pgx_loader_state` table in the `pgx_loader` schema.

Retrieve the global transaction identifier (`gid` column) of in-doubt transactions. In-doubt transactions will contain "rollback" in the column "state".

Example

The example below retrieves the global transaction identifier (`gid`) of in-doubt transactions performed by the database role `myrole` and that used table `tbl`. The retrieved global transaction identifiers `pgx_loader:9589` and `pgx_loader:9590` identify in-doubt transactions.

```
postgres=# SELECT gid, state FROM pgx_loader.pgx_loader_state WHERE
postgres=# role_oid IN (SELECT oid FROM pg_roles WHERE rolname = 'myrole') AND
postgres=# relation_oid IN (SELECT relid FROM pg_stat_all_tables WHERE
postgres=# relname = 'tbl');
   gid          | state
-----+-----
pgx_loader:9590 | rollback
pgx_loader:9591 | commit
pgx_loader:9589 | rollback
(3 rows)
```

2. Refer to the `pg_prepared_xacts` system view.

Check if the in-doubt transactions retrieved above exist.

Example

The example below checks if in-doubt transactions with the global transaction identifiers `pgx_loader:9589` and `pgx_loader:9590` exist.

```
postgres=# SELECT gid FROM pg_prepared_xacts WHERE gid IN ('pgx_loader:9589', 'pgx_loader:9590');
gid
-----
pgx_loader:9590
pgx_loader:9589
(2 rows)
```

See

Refer to "[E.1 pgx_loader_state](#)" for information on the `pgx_loader_state` table.

Resolving in-doubt transactions

Execute the `pgx_loader` command in recovery mode to resolve in-doubt transactions.

After executing the `pgx_loader` command in recovery mode, perform the procedure described in "[Checking for in-doubt transactions](#)" to check if the in-doubt transactions have been resolved.

Example

The example below completes the in-doubt transactions prepared for table `tbl`.

```
$ pgx_loader recovery -t tbl
```

Point

The recovery mode of the `pgx_loader` command only resolves transactions prepared by high-speed data load. For transactions prepared by an application using distributed transactions other than this feature, follow the procedure described in "[14.13 Actions in Response to Error in a Distributed Transaction](#)".

11.3 Removing High-Speed Data Load

This section describes how to remove high-speed data load.

11.3.1 Removing the Extension

Execute `DROP EXTENSION` to remove the high-speed data load extension. The extension needs to be removed on each database.

Example

The example below removes the extension on the "postgres" database.

```
postgres=# DROP EXTENSION pgx_loader;
DROP EXTENSION
```

 Note

- The information required for operation of high-speed data load is stored in the `pgx_loader_state` table of the `pgx_loader` schema. Do not remove the high-speed data load extension if the `pgx_loader_state` table is not empty.
- Only superusers can remove the high-speed data load extension.
- The high-speed data load extension can only be removed on the public schema.

Chapter 12 Global Meta Cache

The Global Meta Cache (GMC) feature loads a meta cache into shared memory using the `pgx_global_metacache` parameter. This reduces the amount of memory required throughout the system.

12.1 Usage

Describes how to use the Global Meta Cache feature.

12.1.1 Deciding Whether to Enable the Global Meta Cache Feature

Global Meta Cache is a mechanism for sharing meta caches between processes, so it works well on systems with a high number of resources accessed and SQL connections. The number of resources is primarily the number of tables accessed by a process, the number of indexes, or the total number of all columns in all tables accessed.

In particular, consider using Global Meta Cache if the total size of the meta cache for each process exceeds the amount of installed memory, or takes up a large portion of that memory, thereby squeezing memory allocations to the database cache or the Operating system file cache. Using Global Meta Cache may slightly increase the time it takes to execute a single SQL to reference a meta cache on shared memory (For example, it will not exceed 5% of the execution time in a situation where all the data is located in the database cache), but you can expect a greater benefit from being able to allocate more memory, such as for the database cache.

If performance degradation using Global Meta Cache is not acceptable, you may want to limit the number of tables accessed by a process.

12.1.2 Estimating Memory for Global Meta Cache

To enable the Global Meta Cache feature, the `pgx_global_metacache` parameter must specify an upper limit on the size of the shared memory (Hereinafter, the GMC area) dedicated to Global Meta Cache. Ideally, this upper limit should be the size estimated in "[Appendix A Parameters](#)". Values lower than this can still work, but refer to "[12.1.3 How the GMC Memory Area Is Used](#)" on using the GMC area to understand the disadvantages.

12.1.3 How the GMC Memory Area Is Used

At startup, the memory for the GMC area is not used much, but the GMC area grows as new meta caches are placed in the GMC area. If it does, it discards any meta caches that the system determines are not heavily used and places a new one in the GMC area.

Therefore, the GMC area will work even if it is smaller than the estimate, but the meta cache will be regenerated if the discarded meta cache needs to be reused. Note that if this happens frequently, it will degrade overall performance.

With this in mind, it may not be a problem if, for example, the tables to be accessed are different depending on the time zone, and the degradation of the time zone immediately after the change is acceptable.

In any case, be sure to test and tune the system thoroughly before running it.

12.1.4 Enabling the Global Meta Cache Feature

To Enable the Global Meta Cache feature edit the `postgresql.conf` file and set the `pgx_global_metacache` parameter. Restarting the instance after editing the `postgresql.conf` file is required. Refer to "[Appendix A Parameters](#)" for information on the parameters.

Parameter Name	Description
<code>pgx_global_metacache</code>	Specify the maximum amount of memory for the GMC area on shared memory. When it's set to 0 (default value), the Global Meta Cache feature is disabled. When enabled, the minimum value allowed is 10MB.

When the cache is created, if the total amount of meta caches on shared memory exceeds the value specified by `pgx_global_metacache`, the inactive, unreferenced meta caches are removed from the GMC area. Note that if all GMC are in use and the cache cannot be created in the GMC area, the cache is temporarily created in the local memory of the backend process.

Example

Here is an example postgresql.conf configuration:

```
pgx_global_metacache = 800 MB
```

Wait Events

The Global Meta Cache feature may cause wait events. Wait events are identified in the wait_event column of the pg_stat_activity view. GMC specific wait events are described below.

[GMC Feature Wait Events]

Wait Event Type	Wait Event Name	Description
LWLock	global_metacache	Waiting to find, add, and remove meta caches in the GMC area.
	global_metacache_sweep	Waiting to select a meta cache that can be deleted when GMC space is low. If the GMC is fully referencing and there is no deletable meta cache, it is waiting for the reference to be removed and a deletable meta cache to be selected.

Note

If global_metacache_sweep is happened frequently, increase the pgx_global_metacache setting.

See

Refer to "Viewing Statistics" in the PostgreSQL Documentation for information on the pg_stat_activity view.

12.1.5 Estimating Resources

Refer to "Global Meta Cache Memory Requirements" in the Installation and Setup Guide for Server for formulas to estimate the amount of memory used by the Global Meta Cache feature.

12.2 Statistics

Describes the statistics for the Global Meta Cache feature.

12.2.1 System View

You can check the cache hit ratio and size of the GMC area in the system view pgx_stat_gmc. Refer to "C.6 pgx_stat_gmc" for information on the columns.

If the cache hit ratio is low and the current memory usage is close to pgx_global_metacache, increase the pgx_global_metacache setting because performance may be degraded.

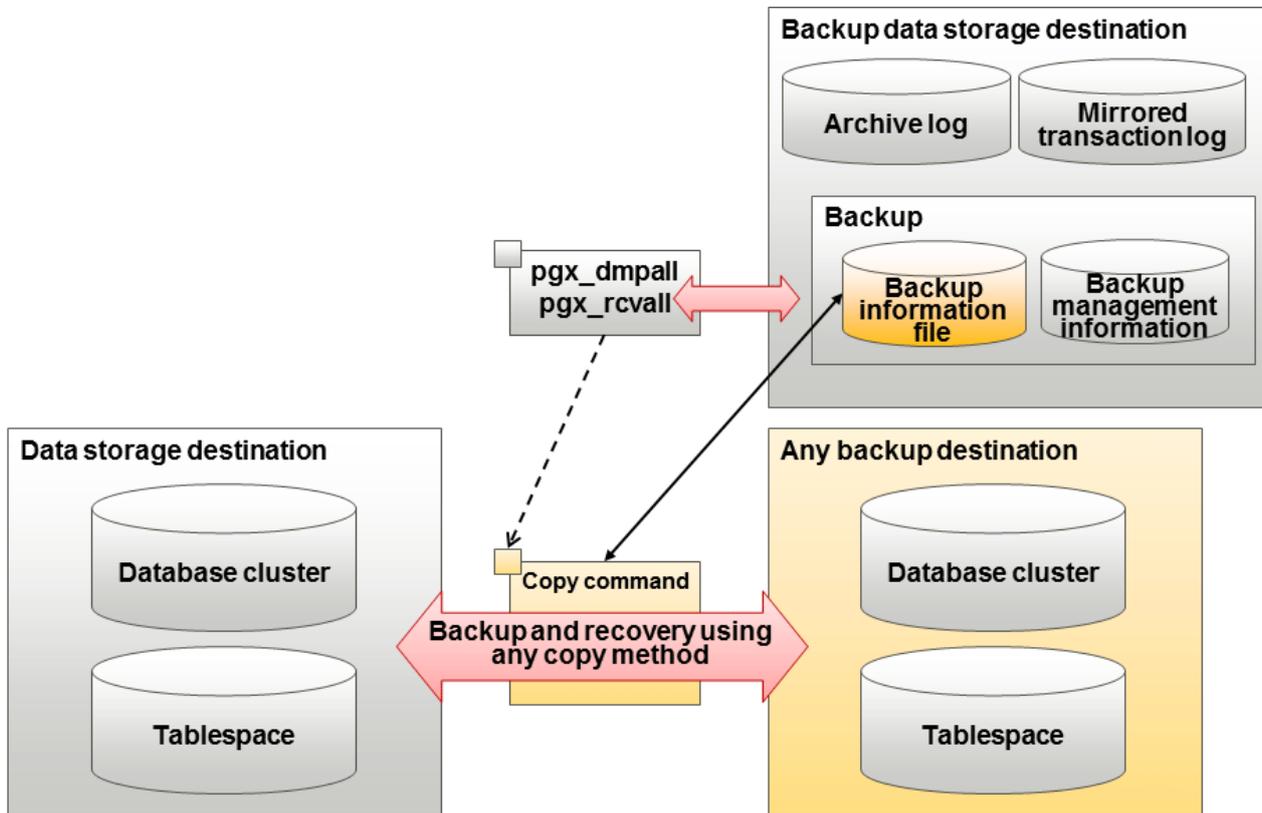
Refer to "7.6 Monitoring Database Activity" in the Operations Guide for information on the statistics.

Chapter 13 Backup/Recovery Using the Copy Command

By using a copy command created by the user, the `pgx_dmpall` command and the `pgx_rcvall` command can perform backup to any destination and can perform recovery from any destination using any copy method.

Copy commands must be created in advance as executable scripts for the user to implement the copy process on database clusters and tablespaces, and are called when executing the `pgx_dmpall` and `pgx_rcvall` commands.

This appendix describes backup/recovery using the copy command.



Point

It is also possible to back up only some tablespaces using the copy command. However, database resources not backed up using the copy command are still backed up to the backup data storage destination.

Note

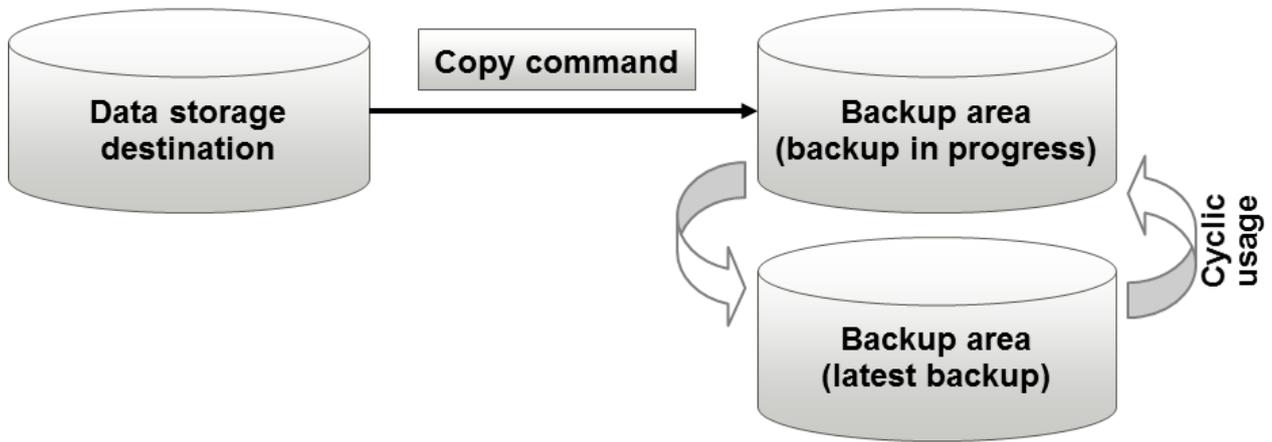
Both the backup data storage destination and the optional backup destination are necessary for recovery - if they are located in secondary media, combined management of these is necessary.

13.1 Configuration of the Copy Command

This section describes the configuration of the copy command for backup and recovery.

Cyclic usage of the backup area

Prepare two backup areas for the copy command in case an issue affects the data storage destination during backup. The copy command performs backup while cyclically using these backup areas.

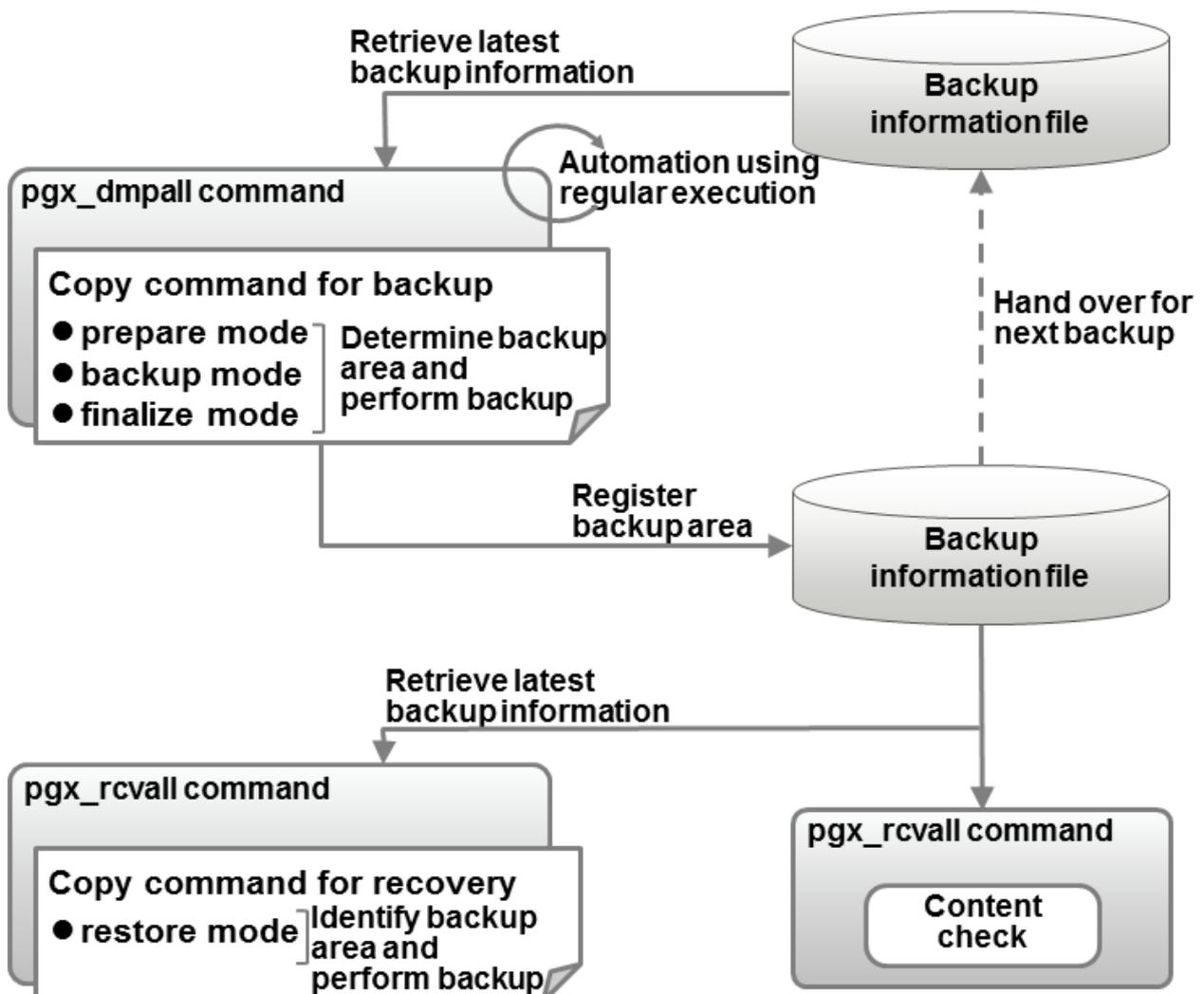


 **Note**

The backup data storage destination cannot be used as these backup areas used by the copy command.

Backup using the backup information file

The copy command must determine the backup destination on each backup, as it is necessary to cycle through the backup areas. Backup can be automated by using the backup information file, which contains information about the backup destination.



Information

The backup information file is prepared in the backup data storage destination by the `pgx_dmpall` command, and contains information that can be read or updated by the copy command. This file is managed by associating it with the latest backup successfully completed by the `pgx_dmpall` command, so the latest backup information relating to the copy command registered by the user can be retrieved. Additionally, the content of the backup information file can be displayed using the `pgx_rcvall` command.

Configuration of the copy command for backup

The `pgx_dmpall` command calls the copy command for backup after execution for the three modes below. It is therefore necessary for the copy command for backup to implement the required processing for each of the modes.

- prepare mode

Determines which of the two backup areas will be used for the current backup.

The backup area to be used for the current backup is determined by reading the information relating to the latest backup destination where the backup information file was written to during the previous backup.

- backup mode

Performs backup on the backup area determined by prepare mode, using any copy method.

- finalize mode

Writes information relating to the destination of the current backup to the backup information file.

This enables the prepare mode to check the destination of the previous backup during the next backup.

Note

The user can use any method to hand over backup information between modes within the copy command, such as creating temporary files.

Configuration of the copy command for recovery

The `pgx_rcvall` command calls the copy command for recovery for the mode below. It is therefore necessary for the copy command for recovery to implement the required processing for the mode.

- restore mode

Any copy method can be used to implement restore from the backup destination retrieved using the copy command for backup.

Point

By referring to the mode assigned to the copy command as an argument, backup and recovery can be implemented using a single copy command.

Example

Using a bash script

```
case $1 in
  prepare)
    processingRequiredForPrepareMode
    ;;
  backup)
    processingRequiredForBackupMode
    ;;
  finalize)
    processingRequiredForFinalizeMode
```

```
;;
restore)
    processingRequiredForRestoreMode
;;
esac
```

Point

A sample batch file that backs up the database cluster and tablespace directory to a specific directory is supplied to demonstrate how to write a copy command.

The sample is stored in the directory below:

```
/installDir/share/copy_command.archive.sh.sample
```

13.2 Backup Using the Copy Command

To perform backup using the copy command, in addition to performing the standard backup procedure, it is also necessary to create a copy command, and then execute the `pgx_dmpall` command specifying it. This section describes the procedure specific to using the copy command.

Preparing for backup

You must prepare for backup before actually starting the backup process.

Perform the following procedure:

1. Determine the database resources to be backed up

Determine the database resources to be backed up using the copy command. The copy command can back up the following resources:

- Database cluster
- Tablespace

To back up only some tablespaces, create a file listing them. This file is not necessary to back up all tablespaces.

Example

To back up only tablespaces `tblspc1` and `tblspc2`

```
tblspc1
tblspc2
```

2. Prepare a backup area

Prepare a backup area to save the database resources to be backed up, as determined in step 1.

3. Create the copy command

Create the copy commands for backup and recovery. Refer to "[13.4 Copy Command Interface](#)" for details.

Performing backup

Execute the `pgx_dmpall` command with the `-Y` option specifying the full path of the copy command for backup created in step 3 of preparation for backup.

The example below backs up only some tablespaces, but not the database cluster, using the copy command.

Example

```
$ pgx_dmpall -D /database/inst1 -Y '/database/command/backup.sh'  
--exclude-copy-cluster -P '/database/command/tablespace_list.txt'
```

Point

- To exclude up the database cluster from backup using the copy command, specify the --exclude-copy-cluster option.
- To back up only some tablespaces using the copy command, use the -P option specifying the full path of the file created in step 1 of preparation for backup.

See

- Refer to "pgx_dmpall" in the Reference for information on the command.

Checking backup status

Use the pgx_rcvall command to check the backup status.

Execute the pgx_rcvall command with the -l option specified to output backup data information. If backup was performed using the copy command, the resources backed up using the copy command will also be output.

Example

```
$ pgx_rcvall -l -D /database/inst1  
Date                Status   Dir                                     Resources backed up by the copy command  
2020-05-01 13:30:40 COMPLETE /backup/inst1/2020-05-01_13-30-40 pg_data,dbspace,indexspace
```

13.3 Recovery Using the Copy Command

To perform recovery using the copy command, in addition to performing the standard recovery procedure, it is also necessary to create a copy command, and then execute the pgx_rcvall command specifying it. This section describes the procedure specific to using the copy command.

Determining the backup area of the latest backup

Check the backup information file to determine the backup area used for the latest backup, and confirm that it is in a recoverable state.

Execute the pgx_rcvall command with the --view-results-of-copying option to output the content of the backup information file.

Example

```
$ pgx_rcvall -D /database/inst1 --view-results-of-copying
```

Perform recovery

Execute the pgx_rcvall command with the -Y option specifying the full path of the copy command for recovery created in step 3 of the preparation for backup described in "13.2 Backup Using the Copy Command".

The example below recover only some tablespaces, but not the database cluster, using the copy command.

Example

```
$ pgx_rcvall -D /database/inst1 -B /backup/inst1 -Y '/database/command/recovery.sh'
```

Point

If the latest backup was performed using the copy command, the `pgx_rcvall` command automatically recognizes which database resources were backed up using the copy command, or whether resources were backed up to the backup data storage destination. Therefore, recovery can be performed by simply executing the `pgx_rcvall` command specifying the copy command for recovery.

See

Refer to "pgx_rcvall" in the Reference for information on the command.

13.4 Copy Command Interface

The following types of copy command are available:

- Copy command for backup
- Copy command for recovery

This appendix describes the interface of each copy command.

13.4.1 Copy Command for Backup

Feature

User command called from the `pgx_dmpall` command.

Format

The syntax for calling the copy command from the `pgx_dmpall` command is described below.

If the operation mode is "prepare"

```
copyCommandName prepare 'pathOfBackupInfoFile' 'pathOfBackupTargetListFile'
```

If the operation mode is "backup"

```
copyCommandName backup
```

If the operation mode is "finalize"

```
copyCommandName finalize 'pathOfBackupInfoFile'
```

Argument

- Operation mode

Mode	Description
prepare	Implements the preparation process for backing up using the copy command. Called before the PostgreSQL online backup mode is started.
backup	Implements the backup process. Called during the PostgreSQL online backup mode.

Mode	Description
finalize	Implements the backup completion process. Called after the PostgreSQL online backup mode is completed.

- Full path of the backup information file

Full path of the backup information file of the latest backup, enclosed in single quotation marks. If a backup has not been performed, specify ''.

- Full path of the backup target list file

Full path of the file containing the resources to be backed up using the copy command, enclosed in single quotation marks. One of the following is described in each resource name.

Resource	Description
Database cluster	pg_data
Tablespace	Tablespace name

Example

To back up the database cluster and the tablespaces dbspace and indexspace using the copy command, the file should contain the following:

```
pg_data
dbspace
indexspace
```

Information

The encoding of resource names output to the backup target list file by the pgx_dmpall command is the encoding used when this command connects to the database with auto specified for the client_encoding parameter, and is dependent on the locale at the time of command execution.

The number of arguments vary depending on operation mode. The argument of each operation mode is as follows.

Operation mode	First argument	Second argument	Third argument
prepare	Operation mode	Backup information file path name	Backup target list file path name
backup		None	None
finalize		Backup information file path name	

Additionally, the access permissions for the backup information file and backup target list file are different depending on the operation mode. The access permissions of each operation mode are as follows.

Operation mode	Backup information file	Backup target list file
prepare	Can be viewed by the instance administrator only	Can be viewed by the instance administrator only
backup	-	-
finalize	Can be viewed and updated by the instance administrator only	-

Return value

Return value	Description
0	Normal end The pgx_dmpall command continues processing.
Other than 0	Abnormal end The pgx_dmpall command terminates in error.

Description

- The copy command operates with the privileges of the operating system user who executed the pgx_dmpall command. Therefore, grant copy command execution privileges to users who will execute the pgx_dmpall command. Additionally, have the copy command change users as necessary.
- To write to the backup information file, use a method such as redirection from the copy command.
- Because the copy command is called for each mode, implement all processing for each one.
- To copy multiple resources simultaneously, have the copy command copy them in parallel.

Note

- The backup information file and backup target list file cannot be deleted. Additionally, the privileges cannot be changed.
- Standard output and standard error output of the copy command are output to the terminal where the pgx_dmpall command was executed.
- If the copy command becomes unresponsive, the pgx_dmpall command will also become unresponsive. If the copy command is deemed to be unresponsive by the operating system, use an operating system command to forcibly stop it.
- Output the copy command execution trace and the result to a temporary file, so that if it terminates in error, the cause can be investigated at a later time.
- For prepare mode only, it is possible to use the PostgreSQL client application to access the database using the copy command. For all other modes, do not execute FUJITSU Enterprise Postgres commands or PostgreSQL applications.
- Enable the fsync parameter in postgresql.conf, because data on the shared memory buffer needs to have been already written to disk when backup starts.

13.4.2 Copy Command for Recovery

Feature

User command called from the pgx_rcvall command.

Format

The syntax for calling the copy command from the pgx_rcvall command is described below.

```
copyCommandName restore 'pathOfBackupInfoFile' 'pathOfBackupTargetListFile'
```

Argument

- Operation mode

Mode	Description
restore	Performs restore.

- Full path of the backup information file

Full path of the backup information file, enclosed in single quotation marks.

- Full path of the backup target list file

Full path of the file containing the resources to be restored using the copy command, enclosed in single quotation marks.

The access permissions for the backup information file and backup target list file are as below.

Backup information file	Backup target list file
Can be viewed by the instance administrator only	Can be viewed by the instance administrator only

Return value

Return value	Description
0	Normal end The pgx_rcvall command continues processing.
Other than 0	Abnormal end The pgx_rcvall command terminates in error.

Description

- The copy command operates with the privileges of the operating system user who executed the pgx_rcvall command. Therefore, grant copy command execution privileges to users who will execute the pgx_rcvall command. Additionally, have the copy command change users as necessary.
- The copy command is called once only in restore mode.
- To copy multiple resources simultaneously, have the copy command copy them in parallel.

Note

- The backup information file and backup target list file cannot be deleted. Additionally, the privileges cannot be changed.
- Standard output and standard error output of the copy command are output to the terminal where the pgx_rcvall command was executed.
- If the copy command becomes unresponsive, the pgx_rcvall command will also become unresponsive. If the status of the copy command is deemed to be unresponsive by the operating system, use an operating system command to forcibly stop it.
- Output the copy command execution trace and the result to a temporary file, so that if it terminates in error, the cause can be investigated at a later time.
- Do not execute FUJITSU Enterprise Postgres commands or PostgreSQL applications in the copy command.
- There may be files and directories not required for recovery using the archive log included in the backup, such as postmaster.pid, pg_wal/*subdirectory* and pg_replslot in the database cluster. If such unnecessary files and directories exist, have the copy command delete them after the restore.

Chapter 14 Actions when an Error Occurs

This chapter describes the actions to take when an error occurs in the database or an application, while FUJITSU Enterprise Postgres is operating.

Depending on the type of error, it may be necessary to recover the database cluster. The recovery process recovers the following resources:

- Data storage destination
- Transaction log storage destination (if the transaction log is stored in a separate disk from the data storage destination)
- Backup data storage destination



Even if a disk is not defective, the same input-output error messages, as those generated when the disk is defective, may be output. The recovery actions differ for these error messages.

Check the status of the disk, and select one of the following actions:

- If the disk is defective

Refer to "[14.1 Recovering from Disk Failure \(Hardware\)](#)", and take actions accordingly.

- If the disk is not defective

Refer to "[14.14 I/O Errors Other than Disk Failure](#)", and take actions accordingly.

A few examples of errors generated even if the disk is not defective include:

- Network error with an external disk
- Errors caused by power failure or mounting issues

Determining the cause of an error

If an error occurs, refer to the WebAdmin message and the server log, and determine the cause of the error.



Refer to "Configuring Parameters" in the Installation and Setup Guide for Server for information on server logs.

Approximate recovery time

The formulas for deriving the approximate recovery time of resources in each directory are given below.

If using the copy command with the `pgx_rcvall` command, the recovery time will depend on the implementation of the copy command.

- Data storage destination or transaction log storage destination

$$\text{Recovery time} = (\text{usageByTheDataStorageDestination} + \text{usageByTheTransactionLogStorageDestination}) / \text{diskWritePerformance} \times 1.5$$

- *usageByTheDataStorageDestination*: Disk space used by the database cluster
- *usageByTheTransactionLogStorageDestination*: Disk space used by the transaction log stored outside the database cluster
- *diskWritePerformance*: Measured maximum data volume (bytes/second) that can be written per second in the system environment where the operation is performed
- 1.5: Coefficient assuming the time excluding disk write, which is the most time-consuming step

- Backup data storage destination

$$\text{Recovery time} = \frac{\text{usageByTheBackupDataStorageDestination}}{\text{diskWritePerformance}} \times 1.5 \times \text{EffectOfCompression}$$

- *usageByTheBackupDataStorageDestination*: Disk space used by the backup data (If compressed, the amount of disk space when decompressed. If you do not know the decompression size, calculate it by the disk space of the database cluster.)
- *diskWritePerformance*: Measured maximum data volume (bytes/second) that can be written per second in the system environment where the operation is performed
- 1.5: Coefficient assuming the time excluding disk write, which is the most time-consuming step
- *EffectOfCompression*: Specify 0.6 for compression or 1 for no compression

14.1 Recovering from Disk Failure (Hardware)

This section describes how to recover database clusters to a point immediately before failure, if a hardware failure occurs in the data storage disk or the backup data storage disk.

There are two methods of recovery:

- [14.1.1 Using WebAdmin](#)
- [14.1.2 Using Server Command](#)

Point

Back up the database cluster after recovering it. Backup deletes obsolete archive logs (transaction logs copied to the backup data storage destination), freeing up disk space and reducing the recovery time.

14.1.1 Using WebAdmin

Recover the database cluster by following the appropriate recovery procedure below for the disk where the failure occurred.

Note

Recovery operation cannot be performed on an instance that is part of a streaming replication cluster in standby mode.

If disk failure occurs on a standby instance, it may be necessary to delete and re-create the instance.

Recovery operation can be performed on an instance that is part of a streaming replication cluster in "Master" mode. If a recovery operation is performed on a master instance, it will break the replication cluster and streaming replication will stop between the master instance and all its standby instances. In such an event, the standby instances can be promoted to standalone instances or can be deleted and re-created.

If failure occurred in the data storage disk or the transaction log storage disk

Follow the procedure below to recover the data storage disk or the transaction log storage disk.

1. Stop applications
 - Stop applications that are using the database.
2. Stop the instance
 - Stop the instance. Refer to "[2.1.1 Using WebAdmin](#)" for information on how to stop an instance. WebAdmin automatically stops instances if recovery of the database cluster is performed without stopping the instance.
3. Recover the failed disk
 - Replace the disk, and then recover the volume configuration information.

4. Create a tablespace directory

If a tablespace was defined after backup, create a directory for it.

5. Recover the keystore, and enable automatic opening of the keystore

Do the following if the data in the database has been encrypted:

- Restore the keystore to its state at the time of the database backup.
- Enable automatic opening of the keystore.

6. Recover the database cluster

Log in to WebAdmin, and in the [Instances] tab, click [Solution] for the error message in the lower-right corner.

7. Run recovery

In the [Restore Instance] dialog box, click [Yes].

Instance restore is performed. An instance is automatically started when recovery is successful.

 Note

WebAdmin does not support recovery of hash index. If you are using a hash index, then after recovery, execute the REINDEX command to rebuild it. Use of hash indexes is not recommended.

8. Resume applications

Resume applications that are using the database.

 Point

WebAdmin may be unable to detect disk errors, depending on how the error occurred.

If this happens, refer to "[14.10.3 Other Errors](#)" to perform recovery.

If failure occurred on the backup data storage disk

Follow the procedure below to recover the backup data storage disk.

1. Recover the failed disk

Replace the disk, and then recover the volume configuration information.

2. Recover the backup data

Log in to WebAdmin, and in the [Instances] tab, click [Solution] for the error message.

3. Run backup

Perform backup to enable recovery of the backup data. In the [Backup] dialog box, click [Yes]. The backup is performed. An instance is automatically started when backup is performed.

 Point

If you click [Recheck the status], the resources in the data storage destination and the backup data storage destination are reconfirmed. As a result, the following occurs:

- If an error is not detected

The status of the data storage destination and the backup data storage destination returns to normal, and it is possible to perform operations as usual.

- If an error is detected

An error message is displayed in the message list again. Click [Solution], and resolve the problem by following the resolution for the cause of the error displayed in the dialog box.

14.1.2 Using Server Command

Recover the database cluster by following the appropriate recovery procedure below for the disk where the failure occurred.

If failure occurred on the data storage disk or the transaction log storage directory

Follow the procedure below to recover the data storage disk or the transaction log storage directory.

1. Stop applications

Stop applications that are using the database.

2. Stop the instance

Stop the instance, refer to "2.1.2 Using Server Commands" for details.

If the instance fails to stop, refer to "14.11 Actions in Response to Failure to Stop an Instance".

3. Recover the failed disk

Replace the disk, and then recover the volume configuration information.

4. Create a storage destination directory

- If failure occurred on the data storage disk

Create a data storage destination directory. If a tablespace was defined, also create a directory for it.

- If failure occurred on the transaction log storage disk

Create a transaction log storage destination directory.

Example

To create a data storage destination directory:

```
$ mkdir /database/inst1
$ chown fsepuser:fsepuser /database/inst1
$ chmod 700 /database/inst1
```



Refer to "Preparing Directories to Deploy Resources" under "Setup" in the Installation and Setup Guide for Server for information on how to create a storage directory.

5. Recover the keystore, and enable automatic opening of the keystore

When the data in the database has been encrypted, restore the keystore to its state at the time of the database backup. Configure automatic opening of the keystore as necessary.

6. Recover the database cluster

Recover the database cluster using the backup data.

Specify the following in the `pgx_rcvall` command:

- Specify the data storage location in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup data storage location in the `-B` option.

Example

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1
```

Note

If recovery fails, remove the cause of the error in accordance with the displayed error message and then re-execute the `pgx_rcvall` command.

If the message "pgx_rcvall: an error occurred during recovery" is displayed, then the log recorded when recovery was executed is output after this message. The cause of the error is output in around the last fifteen lines of the log, so remove the cause of the error in accordance with the message and then re-execute the `pgx_rcvall` command.

The following message displayed during recovery is output as part of normal operation of `pgx_rcvall` command (therefore the user does not need not be concerned).

```
FATAL: The database system is starting
```

7. Start the instance

Start the instance.

Refer to "[2.1.2 Using Server Commands](#)" for information on how to start an instance.

8. Resume applications

Resume applications that are using the database.

If failure occurred on the backup data storage disk

The procedure for recovering the backup data storage disk is described below.

There are two methods of taking action:

- Performing recovery while the instance is active
- Stopping the instance before performing recovery

The following table shows the different steps to be performed depending on whether you stop the instance.

No	Step	Instance stopped	
		No	Yes
1	Confirm that transaction log mirroring has stopped	Y	N
2	Stop output of archive logs	Y	N
3	Stop applications	N	Y
4	Stop the instance	N	Y
5	Recover the failed disk	Y	Y
6	Create a backup data storage destination directory	Y	Y
7	Resume output of archive logs	Y	N
8	Resume transaction log mirroring	Y	N
9	Start the instance	N	Y
10	Run backup	Y	Y
11	Resume applications	N	Y

Y: Required

N: Not required

The procedure is as follows:

If an instance has not been stopped

1. Confirm that transaction log mirroring has stopped

Use the following SQL function to confirm that transaction log mirroring has stopped.

```
postgres=# SELECT pgx_is_wal_multiplexing_paused();
pgx_is_wal_multiplexing_paused
-----
t
(1 row)
```

If transaction log mirroring has not stopped, then stop it using the following SQL function.

```
postgres=# SELECT pgx_pause_wal_multiplexing();
LOG:  multiplexing of transaction log files has been stopped
pgx_pause_wal_multiplexing
-----
(1 row)
```

2. Stop output of archive logs

Transaction logs may accumulate during replacement of backup storage disk, and if the data storage disk or the transaction log storage disk becomes full, there is a risk that operations may not be able to continue.

To prevent this, use the following methods to stop output of archive logs.

- Changing archive_command

Specify a command that will surely complete normally, such as "echo skipped archiving WAL file %f" or "/bin/true", so that archive logs will be regarded as having been output.

If you specify echo, a message is output to the server log, so it may be used as a reference when you conduct investigations.

- Reload the configuration file

Execute the pg_ctl reload command or the pg_reload_conf SQL function to reload the configuration file.

If you simply want to stop output of errors without the risk that operations will not be able to continue, specify an empty string ("") in archive_command and reload the configuration file.

3. Recover the failed disk

Replace the disk, and then recover the volume configuration information.

4. Create a backup data storage destination

Create a backup data storage destination.

Example

```
$ mkdir /database/inst1
$ chown fsepuser:fsepuser /database/inst1
$ chmod 700 /database/inst1
```

Refer to "[3.2.2 Using Server Commands](#)" for information on how to create a backup data storage destination.

5. Resume output of archive logs

Return the archive_command setting to its original value, and reload the configuration file.

6. Resume transaction log mirroring

Execute the pgx_resume_wal_multiplexing SQL function.

Example

```
SELECT pgx_resume_wal_multiplexing()
```

7. Run backup

Use the `pgx_dmpall` command to back up the database cluster.

Specify the following value in the `pgx_dmpall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

Example

```
> pgx_dmpall -D /database/inst1
```

If an instance has been stopped

1. Stop applications

Stop applications that are using the database.

2. Stop the instance

Stop the instance. Refer to "[2.1.2 Using Server Commands](#)" for details.

If the instance fails to stop, refer to "[14.11 Actions in Response to Failure to Stop an Instance](#)".

3. Recover the failed disk

Replace the disk, and then recover the volume configuration information.

4. Create a backup data storage destination

Create a backup data storage destination.

Example

```
# mkdir /backup/inst1
# chown fsepuser:fsepuser /backup/inst1
# chmod 700 /backup/inst1
```

Refer to "[3.2.2 Using Server Commands](#)" for details.

5. Start the instance

Start the instance. Refer to "[2.1.2 Using Server Commands](#)" for information on how to start an instance.

6. Run backup

Use the `pgx_dmpall` command to back up the database cluster.

Specify the following value in the `pgx_dmpall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

Example

```
> pgx_dmpall -D /database/inst1
```

7. Resume applications

Resume applications that are using the database.



See

- Refer to "`pgx_rcvall`" and "`pgx_dmpall`" in the Reference for information on the `pgx_rcvall` command and `pgx_dmpall` command.
- Refer to "Write Ahead Log" under "Server Administration" in the PostgreSQL Documentation for information on `archive_command`.
- Refer to "[B.1 WAL Mirroring Control Functions](#)" for information on `pgx_resume_wal_multiplexing`.

14.2 Recovering from Data Corruption

If data in a disk is logically corrupted and the database does not operate properly, you can recover the database cluster to its state at the time of backup.

There are two methods of recovery:

- [14.2.1 Using WebAdmin](#)
- [14.2.2 Using the `pgx_rcvall` Command](#)



- Back up the database cluster after recovering it. Backup deletes obsolete archive logs (transaction logs copied to the backup data storage destination), freeing up disk space and reducing the recovery time.
 - If you recover data to a point in the past, a new time series (database update history) will start from that recovery point. When recovery is complete, the recovery point is the latest point in the new time series. When you subsequently recover data to the latest state, the database update is re-executed on the new time series.
-

14.2.1 Using WebAdmin

If using WebAdmin, recover the data to the point immediately prior to data corruption by using the backup data.

Refer to "[14.1.1 Using WebAdmin](#)" for details.

14.2.2 Using the `pgx_rcvall` Command

Recover the database cluster by specifying in the `pgx_rcvall` command the date and time of the backup you want to read from. Then re-execute the transaction as required to recover the data.

Follow the procedure below to recover the data storage disk.

1. Stop applications

Stop applications that are using the database.

2. Stop the instance

Stop the instance. Refer to "[2.1.2 Using Server Commands](#)" for information on how to stop an instance.

If the instance fails to stop, refer to "[14.11 Actions in Response to Failure to Stop an Instance](#)".

3. Confirm the backup date and time

Execute the `pgx_rcvall` command to confirm the backup data saved in the backup data storage destination, and determine a date and time prior to data corruption.

Specify the following values in the `pgx_rcvall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup storage directory in the `-B` option.
- The `-l` option displays the backup data information.

Example

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1 -l
Date           Status          Dir
2020-05-20 10:00:00  COMPLETE      /backup/inst1/2020-05-20_10-00-00
```

4. Recover the keystore, and enable automatic opening of the keystore

When the data in the database has been encrypted, restore the keystore to its state at the time of the database backup. Configure automatic opening of the keystore as necessary.

5. Recover the database cluster

Use the `pgx_rcvall` command to recover the database cluster.

Specify the following values in the `pgx_rcvall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup storage directory in the `-B` option.
- Specify the recovery date and time in the `-e` option.

Example

In the following examples, "May 20, 2020 10:00:00" is specified as the recovery time.

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1 -e '2020-05-20 10:00:00'
```

Note

If recovery fails, remove the cause of the error in accordance with the displayed error message and then re-execute the `pgx_rcvall` command.

If the message "`pgx_rcvall: an error occurred during recovery`" is displayed, then the log recorded when recovery was executed is output after this message. The cause of the error is output in around the last fifteen lines of the log, so remove the cause of the error in accordance with the message and then re-execute the `pgx_rcvall` command.

The following message displayed during recovery is output as part of normal operation of `pgx_rcvall` command (therefore the user does not need not be concerned).

```
FATAL: The database system is starting
```

6. Start the instance

Start the instance. Refer to "[2.1.2 Using Server Commands](#)" for information on how to start an instance.

If necessary, re-execute transaction processing from the specified recovery time, and then resume database operations.

Note

The `pgx_rcvall` command cannot accurately recover a hash index. If you are using a hash index, wait for the instance to start and then execute the `REINDEX` command for the appropriate index.

7. Resume applications

Resume applications that are using the database.

See

Refer to "`pgx_rcvall`" in the Reference for information on the `pgx_rcvall` command.

14.3 Recovering from an Incorrect User Operation

This section describes how to recover database clusters when data has been corrupted due to erroneous user operations.

There are two methods of recovery:

- [14.3.1 Using WebAdmin](#)
- [14.3.2 Using the `pgx_rcvall` Command](#)

Note

- Back up the database cluster after recovering it. Backup deletes obsolete archive logs (transaction logs copied to the backup data storage destination), freeing up disk space and reducing the recovery time.
- If you recover data to a point in the past, a new time series (database update history) will start from that recovery point. When recovery is complete, the recovery point is the latest point in the new time series. When you subsequently recover data to the latest state, the database update is re-executed on the new time series.
- An effective restore point is one created on a time series for which you have made a backup. That is, if you recover data to a point in the past, you cannot use any restore points set after that recovery point. Therefore, once you manage to recover your target past data, make a backup.

14.3.1 Using WebAdmin

You can use WebAdmin to recover data to a backup point.

Note

Recovery operation cannot be performed on an instance that is part of a streaming replication cluster in standby mode.

If disk failure occurs on a standby instance, it may be necessary to delete and re-create the instance.

Recovery operation can be performed on an instance that is part of a streaming replication cluster in "Master" mode. If a recovery operation is performed on a master instance, it will break the replication cluster and streaming replication will stop between the master instance and all its standby instances. In such an event, the standby instances can be promoted to standalone instances or can be deleted and re-created.

Follow the procedure below to recover the data in the data storage disk.

1. Stop applications

Stop applications that are using the database.

2. Stop the instance

Stop the instance. Refer to "[2.1.1 Using WebAdmin](#)" for information on how to stop an instance.

3. Recover the keystore, and enable automatic opening of the keystore

Do the following if the data in the database has been encrypted:

- Restore the keystore to its state at the time of the database backup.
- Enable automatic opening of the keystore.

4. Recover the database cluster

Log in to WebAdmin, and in the [Instances] tab, select the instance to be recovered and click .

5. Recover to the backup point

In the [Restore Instance] dialog box, click [Yes].

Recovery is performed. An instance is automatically started when recovery is successful.

Note

WebAdmin cannot accurately recover a hash index. If you are using a hash index, then after recovery, execute the REINDEX command for the appropriate index.

6. Resume database operations

If necessary, re-execute transaction processing from the backup point to when an erroneous operation was performed, and then resume database operations.

14.3.2 Using the pgx_rcvall Command

The `pgx_rcvall` command recovers database clusters to the restore point created with the server command. Refer to "Setting a restore point" in "3.2.2 Using Server Commands" for information on how to create a restore point.

Follow the procedure below to recover the data in the data storage disk.

1. Stop applications

Stop applications that are using the database.

2. Stop the instance

Stop the instance. Refer to "2.1.2 Using Server Commands" for information on how to stop an instance.

If the instance fails to stop, refer to "14.11 Actions in Response to Failure to Stop an Instance".

3. Confirm the restore point

Execute the `pgx_rcvall` command to confirm the backup data saved in the backup data storage destination, and use a restore point recorded in an arbitrary file, as explained in "3.2.2 Using Server Commands", to determine a restore point prior to the erroneous operation.

Specify the following values in the `pgx_rcvall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup data storage destination in the `-B` option.
- The `-l` option displays the backup data information.

Example

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1 -l
Date                Status            Dir
2020-05-01 10:00:00 COMPLETE         /backup/inst1/2020-05-01_10-00-00
```

4. Recover the keystore, and enable automatic opening of the keystore

When the data in the database has been encrypted, restore the keystore to its state at the time of the database backup. Configure automatic opening of the keystore as necessary.

5. Recover the database cluster

Use the `pgx_rcvall` command to recover the database cluster.

Specify the following values in the `pgx_rcvall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup data storage destination in the `-B` option.
- The `-n` option recovers the data to the specified restore point.

Example

The following example executes the `pgx_rcvall` command with the restore point "batch_20200503_1".

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1 -n batch_20200503_1
```

Note

If recovery fails, remove the cause of the error in accordance with the displayed error message and then re-execute the `pgx_rcvall` command.

If the message "pgx_rcvall: an error occurred during recovery" is displayed, then the log recorded when recovery was executed is output after this message. The cause of the error is output in around the last fifteen lines of the log, so remove the cause of the error in accordance with the message and then re-execute the `pgx_rcvall` command.

The following message displayed during recovery is output as part of normal operation of `pgx_rcvall` (therefore the user does not need not be concerned).

```
FATAL: The database system is starting
```

6. Start the instance

Start the instance.

Refer to "2.1.2 Using Server Commands" for information on how to start an instance.

Note

The `pgx_rcvall` command cannot accurately recover a hash index. If you are using a hash index, wait for the instance to start and then execute the `REINDEX` command for the appropriate index.

7. Restart operation of the database

If necessary, re-execute transaction processing from the specified recovery time to the point when an erroneous operation was performed, and then resume database operations.

See

Refer to "pgx_rcvall" in the Reference for information on the `pgx_rcvall` command.

14.4 Actions in Response to an Application Error

If there is a connection from a client that has been in the waiting state for an extended period, you can minimize performance degradation of the database by closing the problematic connection.

The following methods are available for identifying a connection to be closed:

- `view(pg_stat_activity)` (refer to "14.4.1 When using the view (`pg_stat_activity`)")
- `ps` command (refer to "14.4.2 Using the `ps` Command")

Use the system management function (`pg_terminate_backend`) to disconnect connections.

14.4.1 When using the view (`pg_stat_activity`)

When using the view (`pg_stat_activity`), follow the procedure below to close a connection.

1. Use `psql` command to connect to the postgres database.

```
> psql postgres
psql (12.1)
Type "help" for help.
```

2. Close connections from clients that have been in the waiting state for an extended period.

Use `pg_terminate_backend()` to close connections that have been trying to connect for an extended period.

However, when considering continued compatibility of applications, do not reference or use system catalogs and functions directly in SQL statements. Refer to "Notes on Application Compatibility" in the Application Development Guide for details.

Example

The following example closes connections where the client has been in the waiting state for at least 60 minutes.

```
select pid,username,application_name,client_hostname,pg_terminate_backend(pid) from
pg_stat_activity where state='idle in transaction' and current_timestamp > cast(query_start +
interval '60 minutes' as timestamp);
-[ RECORD 1 ]-----+-----
```

```
pid                | 4684
username           | fsepuser
application_name   | apl1
client_addr        | 192.11.11.1
pg_terminate_backend | t
```



See

- Refer to "System Administration Functions" under "The SQL Language" in the PostgreSQL Documentation for information on `pg_terminate_backend`.
- Refer to "Notes on Application Compatibility" in the Application Development Guide for information on how to maintain application compatibility.

14.4.2 Using the ps Command

Follow the procedure below to close a connection using a standard Unix tool (`ps` command).

1. Execute the `ps` command.

Note that "<x>" indicates the product version.

```
> ps axwfo user,pid,ppid,TTY,command | grep postgres
fsepuser 19174 18027 pts/1                \_ grep postgres
fsepuser 20517      1 ?                /opt/fsepv<x>server64/bin/postgres -D /disk01/data
fsepuser 20518 20517 ?                \_ postgres: logger process
fsepuser 20520 20517 ?                \_ postgres: checkpointer process
fsepuser 20521 20517 ?                \_ postgres: writer process
fsepuser 20522 20517 ?                \_ postgres: wal writer process
fsepuser 20523 20517 ?                \_ postgres: autovacuum launcher process
fsepuser 20524 20517 ?                \_ postgres: archiver process
fsepuser 20525 20517 ?                \_ postgres: stats collector process
fsepuser 18673 20517 ?                \_ postgres: fsepuser postgres 192.168.100.1(49448) idle
fsepuser 16643 20517 ?                \_ postgres: fsepuser db01 192.168.100.11(49449) UPDATE waiting
fsepuser 16644 20517 ?                \_ postgres: fsepuser db01 192.168.100.12(49450) idle in transaction
```

Process ID 16643 may be a connection that was established a considerable time ago by the UPDATE statement, or a connection that has occupied resources (waiting).

2. Close connections from clients that have been in the waiting state for an extended period.

Use `pg_terminate_backend()` to close the connection with the process ID identified in step 1 above.

The example below disconnects the process with ID 16643.

However, when considering continued compatibility of applications, do not reference or use system catalogs and functions directly in SQL statements.

```
postgres=# SELECT pg_terminate_backend (16643);
pg_terminate_backend
-----
t
(1 row)
```



See

- Refer to "System Administration Functions" under "The SQL Language" in the PostgreSQL Documentation for information on `pg_terminate_backend`.

- Refer to "Notes on Application Compatibility" in the Application Development Guide for information on how to maintain application compatibility.

14.5 Actions in Response to an Access Error

If access is denied, grant privileges allowing the instance administrator to operate the following directories, and then re-execute the operation. Also, refer to the event log and the server log, and confirm that the file system has not been mounted as read-only due to a disk error. If the file system has been mounted as read-only, mount it properly and then re-execute the operation.

- Data storage destination
- Tablespace storage destination
- Transaction log storage destination
- Backup data storage destination



Refer to "Preparing Directories to Deploy Resources" under "Setup" in the Installation and Setup Guide for Server for information on the privileges required for the directory.

14.6 Actions in Response to Insufficient Space on the Data Storage Destination

If the data storage destination runs out of space, check if the disk contains any unnecessary files and delete them so that operations can continue.

If deleting unnecessary files does not solve the problem, you must migrate data to a disk with larger capacity.

There are two methods of migrating data:

- [14.6.1 Using a Tablespace](#)
- [14.6.2 Replacing the Disk with a Larger Capacity Disk](#)

14.6.1 Using a Tablespace

FUJITSU Enterprise Postgres enables you to use a tablespace to change the storage destination of database objects, such as tables and indexes, to a different disk.

The procedure is as follows:

1. Create a tablespace
Use the CREATE TABLESPACE command to create a new tablespace in the prepared disk.
2. Modify the tablespace
Use the ALTER TABLE command to modify tables for the newly defined tablespace.



Refer to "SQL Commands" under "Reference" in the PostgreSQL Documentation for information on the CREATE TABLESPACE command and ALTER TABLE command.

14.6.2 Replacing the Disk with a Larger Capacity Disk

Before replacing the disk with a larger capacity disk, migrate resources at the data storage destination using the backup and recovery features.

There are two methods of performing backup and recovery:

- [14.6.2.1 Using WebAdmin](#)
- [14.6.2.2 Using Server Commands](#)

The following sections describe procedures that use each of these methods to replace the disk and migrate resources at the data storage destination.



Note

- Before replacing the disk, stop applications and instances that are using the database.
- It is recommended that you back up the database cluster following recovery. Backup deletes obsolete archive logs (transaction logs copied to the backup data storage destination), freeing up disk space and reducing the recovery time.

14.6.2.1 Using WebAdmin

Follow the procedure below to replace the disk and migrate resources at the data storage destination by using WebAdmin.

1. Back up files

If the disk at the data storage destination contains any required files, back up the files. It is not necessary to back up the data storage destination.

2. Stop applications

Stop applications that are using the database.

3. Back up the database cluster

Back up the latest resources at the data storage destination. Refer to "[3.2.1 Using WebAdmin](#)" for details.

4. Stop the instance

Stop the instance. Refer to "[2.1.1 Using WebAdmin](#)" for information on how to stop an instance.

5. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

6. Recover the database cluster

Log in to WebAdmin, and perform recovery operations. Refer to steps 4 ("Create a tablespace directory") to 7 ("Run recovery") under "If failure occurred in the data storage disk or the transaction log storage disk" in "[14.1.1 Using WebAdmin](#)" for information on the procedure. An instance is automatically started when recovery is successful.

7. Resume applications

Resume applications that are using the database.

8. Restore the files

Restore the files backed up in step 1.

14.6.2.2 Using Server Commands

Follow the procedure below to replace the disk and migrate resources at the data storage destination by using server commands.

1. Back up files

If the disk at the data storage destination contains any required files, back up the files. It is not necessary to back up the data storage destination.

2. Stop applications

Stop applications that are using the database.

3. Back up the database cluster

Back up the latest resources at the data storage destination. Refer to "3.2.2 Using Server Commands" for details.

4. Stop the instance

After backup is complete, stop the instance. Refer to "2.1.2 Using Server Commands" for information on how to stop an instance.

If the instance fails to stop, refer to "14.11 Actions in Response to Failure to Stop an Instance".

5. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

6. Create a data storage destination

Create a data storage destination. If a tablespace was defined, also create a directory for it.

Example

```
$ mkdir /database/inst1
$ chown fsepuser:fsepuser /database/inst1
$ chmod 700 /database/inst1
```

7. Recover the keystore, and enable automatic opening of the keystore

When the data in the database has been encrypted, restore the keystore to its state at the time of the database backup. Configure automatic opening of the keystore as necessary.

8. Recover the database cluster

Use the `pgx_rcvall` command to recover the database cluster.

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup storage directory in the `-B` option.

Example

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1
```

 Note

If recovery fails, remove the cause of the error in accordance with the displayed error message and then re-execute the `pgx_rcvall` command.

If the message "pgx_rcvall: an error occurred during recovery" is displayed, then the log recorded when recovery was executed is output after this message. The cause of the error is output in around the last fifteen lines of the log, so remove the cause of the error in accordance with the message and then re-execute the `pgx_rcvall` command.

The following message displayed during recovery is output as part of normal operation of `pgx_rcvall` (therefore the user does not need not be concerned).

```
FATAL: The database system is starting
```

 See

Refer to "pgx_rcvall" in the Reference for information on the `pgx_rcvall` command.

9. Start the instance

Start the instance.

Refer to "2.1.2 Using Server Commands" for information on how to start an instance.



Note

The `pgx_rcvall` command cannot accurately recover a hash index. If you are using a hash index, wait for the `pgx_rcvall` command to end and then execute the `REINDEX` command for the appropriate index.

10. Resume applications

Resume applications that are using the database.

11. Restore files

Restore the files backed up in step 1.

14.7 Actions in Response to Insufficient Space on the Backup Data Storage Destination

If space runs out on the backup data storage destination, check if the disk contains any unnecessary files and delete them, and then make a backup as required.

If deleting unnecessary files does not solve the problem, take the following action:

- [14.7.1 Temporarily Saving Backup Data](#)
- [14.7.2 Replacing the Disk with a Larger Capacity Disk](#)

14.7.1 Temporarily Saving Backup Data

This method involves temporarily moving backup data to a different directory, saving it there, and securing disk space on the backup data storage destination so that a backup can be made normally.

Use this method if you need time to prepare a larger capacity disk.

If space runs out on the backup data storage destination, archive logs can no longer be stored in the backup data storage destination. As a result, transaction logs continue to accumulate in the data storage destination or the transaction log storage destination.

If action is not taken soon, the transaction log storage destination will become full, and operations may not be able to continue.

To prevent this, secure space in the backup data storage destination, so that archive logs can be stored.

There are two methods of taking action:

- [14.7.1.1 Using WebAdmin](#)
- [14.7.1.2 Using Server Commands](#)

14.7.1.1 Using WebAdmin

Follow the procedure below to recover the backup data storage disk.

1. Temporarily save backup data

Move backup data to a different directory and temporarily save it, and secure space in the backup data storage destination directory.

The reason for saving the backup data is so that the data in the data storage destination can be recovered even if it is corrupted before you perform recovery. If there is no disk at the save destination and you consider that there is no risk of corruption at the data storage destination, delete the backup data.

The following example saves backup data from the backup data storage destination directory (`/backup/inst1`) under `/mnt/usb/backup`.

Example

```
> mkdir /mnt/usb/backup/  
> mv /backup/inst1/* /mnt/usb/backup/
```

2. Back up the database cluster

Back up the latest resources at the data storage destination. Refer to "3.2.1 Using WebAdmin" for details.

3. Delete temporarily saved backup data

If backup completes normally, the temporarily saved backup data becomes unnecessary and is deleted.

The following example deletes backup data that was temporarily saved in /mnt/usb.

Example

```
> rm -rf /mnt/usb/backup
```

14.7.1.2 Using Server Commands

The following describes the procedure for recovering the backup storage disk.

There are two methods of taking action:

- Performing recovery while the instance is active
- Stopping the instance before performing recovery

The following table shows the different steps to be performed depending on whether you stop the instance.

No	Step	Instance stopped	
		No	Yes
1	Stop transaction log mirroring	Y	N
2	Stop output of archive logs	Y	N
3	Stop applications	N	Y
4	Stop the instance	N	Y
5	Temporarily save backup data	Y	Y
6	Resume output of archive logs	Y	N
7	Resume transaction log mirroring	Y	N
8	Start an instance	N	Y
9	Run backup	Y	Y
10	Resume applications	N	Y
11	Delete temporarily saved backup data	Y	Y

Y: Required

N: Not required

The procedure is as follows:

Performing recovery while the instance is active

1. Stop transaction log mirroring

Stop transaction log mirroring.

```
postgres=# SELECT pgx_pause_wal_multiplexing();
LOG:  multiplexing of transaction log files has been stopped
pgx_pause_wal_multiplexing
-----
(1 row)
```

2. Stop output of archive logs

Transaction logs may accumulate during replacement of backup storage disk, and if the data storage disk or the transaction log storage disk becomes full, there is a risk that operations may not be able to continue.

To prevent this, use the following methods to stop output of archive logs.

- Changing the `archive_command` parameter

Specify a command that will surely complete normally, such as "echo skipped archiving WAL file %f" or "/bin/true", so that archive logs will be regarded as having been output.

If you specify echo, a message is output to the server log, so it may be used as a reference when you conduct investigations.

- Reloading the configuration file

Run the `pg_ctl reload` command or the `pg_reload_conf` SQL function.

If you simply want to stop output of errors without the risk that operations will not be able to continue, specify an empty string (") in `archive_command` and reload the configuration file.

3. Temporarily save backup data

Move backup data to a different directory and temporarily save it, and secure space in the backup data storage destination directory.

The reason for saving the backup data is so that the data in the data storage destination can be recovered even if it is corrupted before you perform the next step. If there is no disk at the save destination and you consider that there is no risk of corruption at the data storage destination, delete the backup data.

The following example saves backup data from the backup data storage destination directory (`/backup/inst1`) under `/mnt/usb/backup`.

Example

```
> mkdir /mnt/usb/backup/  
> mv /backup/inst1/* /mnt/usb/backup/
```

4. Resume output of archive logs

Return the `archive_command` setting to its original value, and reload the configuration file.

5. Resume transaction log mirroring

Execute the `pgx_resume_wal_multiplexing` SQL function.

Example

```
SELECT pgx_resume_wal_multiplexing()
```

6. Run backup

Use the `pgx_dmpall` command to back up the database cluster.

Specify the following option in the `pgx_dmpall` command:

- Specify the directory of the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

Example

```
> pgx_dmpall -D /database/inst1
```

7. Delete temporarily saved backup data

If backup completes normally, the temporarily saved backup data becomes unnecessary and is deleted.

The following example deletes backup data that was temporarily saved in `/mnt/usb`.

Example

```
> rm -rf /mnt/usb/backup
```

If an instance has been stopped

1. Stop applications

Stop applications that are using the database.

2. Stop the instance

Stop the instance. Refer to ["2.1.2 Using Server Commands"](#) for details.

If the instance fails to stop, refer to ["14.11 Actions in Response to Failure to Stop an Instance"](#).

3. Temporarily save backup data

Move backup data to a different directory and temporarily save it, and secure space in the backup data storage destination directory.

The reason for saving the backup data is so that the data in the data storage destination can be recovered even if it is corrupted before you perform recovery. If there is no disk at the save destination and you consider that there is no risk of corruption at the data storage destination, delete the backup data.

The following example saves backup data from the backup data storage destination directory (/backup/inst1) under /mnt/usb/backup.

Example

```
> mkdir /mnt/usb/backup/  
> mv /backup/inst1/* /mnt/usb/backup/
```

4. Start the instance

Start the instance. Refer to ["2.1.2 Using Server Commands"](#) for information on how to start an instance.

5. Run backup

Use the `pgx_dmpall` command to back up the database cluster.

Specify the following value in the `pgx_dmpall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

Example

```
> pgx_dmpall -D /database/inst1
```

6. Resume applications

Resume applications that are using the database.

7. Delete temporarily saved backup data

If backup completes normally, the temporarily saved backup data becomes unnecessary and is deleted.

The following example deletes backup data that was temporarily saved in /mnt/usb.

Example

```
> rm -rf /mnt/usb/backup
```



See

- Refer to `"pgx_rcvall"` and `"pgx_dmpall"` in the Reference for information on the `pgx_rcvall` command and `pgx_dmpall` command.
- Refer to `"Write Ahead Log"` under `"Server Administration"` in the PostgreSQL Documentation for information on `archive_command`.
- Refer to ["B.1 WAL Mirroring Control Functions"](#) for information on the `pgx_is_wal_multiplexing_paused` and `pgx_resume_wal_multiplexing`.

14.7.2 Replacing the Disk with a Larger Capacity Disk

This method involves replacing the disk at the backup data storage destination with a larger capacity disk, so that it does not run out of free space again. After replacing the disk, back up data to obtain a proper backup.

There are two methods of performing backup:

- [14.7.2.1 Using WebAdmin](#)
- [14.7.2.2 Using Server Commands](#)



Before replacing the disk, stop applications that are using the database.

14.7.2.1 Using WebAdmin

Follow the procedure below to recover the backup storage disk.

1. Back up files

If the disk at the backup data storage destination contains any required files, back up the files. It is not necessary to back up the backup data storage destination.

2. Temporarily save backup data

Save the backup data to a different directory.

The reason for saving the backup data is so that the data in the data storage destination can be recovered even if it is corrupted before you perform the next step. If there is no disk at the save destination and you consider that there is no risk of corruption at the data storage destination, delete the backup data.

The following example saves backup data from the backup data storage destination directory (/backup/inst1) under /mnt/usb/backup.

Example

```
> mkdir /mnt/usb/backup/  
> mv /backup/inst1/* /mnt/usb/backup/
```

3. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

4. Run backup

Log in to WebAdmin, and perform recovery operations. Refer to steps 2 ("Recover the backup data") and 3 ("Run backup") under "If failure occurred on the backup storage disk" in "[14.1.1 Using WebAdmin](#)".

5. Restore files

Restore the files backed up in step 1.

6. Delete temporarily saved backup data

If backup completes normally, the temporarily saved backup data becomes unnecessary and is deleted.

The following example deletes backup data that was temporarily saved in /mnt/usb.

Example

```
> rm -rf /mnt/usb/backup
```

14.7.2.2 Using Server Commands

The procedure for recovering the backup data storage disk is described below.

There are two methods of taking action:

- Performing recovery while the instance is active
- Stopping the instance before performing recovery

The following table shows the different steps to be performed depending on whether you stop the instance.

No	Step	Instance stopped	
		No	Yes
1	Back up files	Y	Y
2	Temporarily save backup data	Y	Y
3	Confirm that transaction log mirroring has stopped	Y	N
4	Stop output of archive logs	Y	N
5	Stop applications	N	Y
6	Stop the instance	N	Y
7	Replace with a larger capacity disk	Y	Y
8	Create a backup storage directory	Y	Y
9	Resume output of archive logs	Y	N
10	Resume transaction log mirroring	Y	N
11	Start the instance	N	Y
12	Run backup	Y	Y
13	Resume applications	N	Y
14	Restore files	Y	Y
15	Delete temporarily saved backup data	Y	Y

Y: Required

N: Not required

The procedure is as follows:

If an instance has not been stopped

1. Back up files

If the disk at the backup data storage destination contains any required files, back up the files. It is not necessary to back up the backup data storage destination.

2. Temporarily save backup data

Save the backup data to a different directory.

The reason for saving the backup data is so that the data in the data storage destination can be recovered even if it is corrupted before you perform the next step. If there is no disk at the save destination and you consider that there is no risk of corruption at the data storage destination, delete the backup data.

The following example saves backup data from the backup data storage destination directory (/backup/inst1) under /mnt/usb/backup.

Example

```
> mkdir /mnt/usb/backup/
> mv /backup/inst1/* /mnt/usb/backup/
```

3. Confirm that transaction log mirroring has stopped

Use the following SQL function to confirm that transaction log mirroring has stopped.

```

postgres=# SELECT pgx_is_wal_multiplexing_paused();
pgx_is_wal_multiplexing_paused
-----
t
(1 row)

```

If transaction log mirroring has not stopped, then stop it using the following SQL function.

```

postgres=# SELECT pgx_pause_wal_multiplexing();
LOG:  multiplexing of transaction log files has been stopped
pgx_pause_wal_multiplexing
-----
(1 row)

```

4. Stop output of archive logs

Transaction logs may accumulate during replacement of backup storage disk, and if the data storage destination disk or the transaction log storage destination disk becomes full, there is a risk that operations may not be able to continue.

To prevent this, use the following methods to stop output of archive logs.

- Changing the `archive_command` parameter

Specify a command that will surely complete normally, such as "echo skipped archiving WAL file %f" or "/bin/true", so that archive logs will be regarded as having been output.

If you specify echo, a message is output to the server log, so it may be used as a reference when you conduct investigations.

- Reloading the configuration file

Run the `pg_ctl reload` command or the `pg_reload_conf` SQL function.

If you simply want to stop output of errors without the risk that operations will not be able to continue, specify an empty string ("") in `archive_command` and reload the configuration file.

5. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

6. Create a backup data storage destination

Create a backup data storage destination.

Example

```

# mkdir /backup/inst1
# chown fsepuser:fsepuser /backup/inst1
# chmod 700 /backup/inst1

```

Refer to "[3.2.2 Using Server Commands](#)" for details.

7. Resume output of archive logs

Return the `archive_command` setting to its original value, and reload the configuration file.

8. Resume transaction log mirroring

Execute the `pgx_resume_wal_multiplexing` SQL function.

Example

```

SELECT pgx_resume_wal_multiplexing()

```

9. Run backup

Use the `pgx_dmpall` command to back up the database cluster.

Specify the following value in the `pgx_dmpall` command:

- Specify the data storage destination in the -D option. If the -D option is omitted, the value of the PGDATA environment variable is used by default.

Example

```
> pgx_dmpall -D /database/inst1
```

10. Restore files

Restore the files backed up in step 1.

11. Delete temporarily saved backup data

If backup completes normally, the temporarily saved backup data becomes unnecessary and is deleted.

The following example deletes backup data that was temporarily saved in /mnt/usb.

Example

```
> rm -rf /mnt/usb/backup
```

If an instance has been stopped

1. Back up files

If the disk at the backup data storage destination contains any required files, back up the files. It is not necessary to back up the backup data storage destination.

2. Temporarily save backup data

Save the backup data to a different directory.

The reason for saving the backup data is so that the data in the data storage destination can be recovered even if it is corrupted before you perform the next step. If there is no disk at the save destination and you consider that there is no risk of corruption at the data storage destination, delete the backup data.

The following example saves backup data from the backup data storage destination directory (/backup/inst1) under /mnt/usb/backup.

Example

```
> mkdir /mnt/usb/backup/  
> mv /backup/inst1/* /mnt/usb/backup/
```

3. Stop applications

Stop applications that are using the database.

4. Stop the instance

Stop the instance. Refer to "[2.1.2 Using Server Commands](#)" for information on how to stop an instance.

If the instance fails to stop, refer to "[14.11 Actions in Response to Failure to Stop an Instance](#)".

5. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

6. Create a backup data storage destination

Create a backup data storage destination.

Example

```
# mkdir /backup/inst1  
# chown fsepuser:fsepuser /backup/inst1  
# chmod 700 /backup/inst1
```

Refer to "[3.2.2 Using Server Commands](#)" for details.

7. Start the instance

Start the instance. Refer to "[2.1.2 Using Server Commands](#)" for information on how to start an instance.

8. Run backup

Use the `pgx_dmpall` command to back up the database cluster.

Specify the following value in the `pgx_dmpall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

Example

```
> pgx_dmpall -D /database/inst1
```

9. Resume applications

Resume applications that are using the database.

10. Restore files

Restore the files backed up in step 1.

11. Delete temporarily saved backup data

If backup completes normally, the temporarily saved backup data becomes unnecessary and is deleted.

The following example deletes backup data that was temporarily saved in `/mnt/usb`.

Example

```
> rm -rf /mnt/usb/backup
```



See

- Refer to "`pgx_rcvall`" and "`pgx_dmpall`" in the Reference for information on the `pgx_rcvall` command and `pgx_dmpall` command.
- Refer to "Write Ahead Log" under "Server Administration" in the PostgreSQL Documentation for information on `archive_command`.
- Refer to "[B.1 WAL Mirroring Control Functions](#)" for information on the `pgx_is_wal_multiplexing_paused` and `pgx_resume_wal_multiplexing`.

14.8 Actions in Response to Insufficient Space on the Transaction Log Storage Destination

If the transaction log storage destination runs out of space, check if the disk contains any unnecessary files and delete them so that operations can continue.

If deleting unnecessary files does not solve the problem, you must migrate data to a disk with larger capacity.

14.8.1 Replacing the Disk with a Larger Capacity Disk

Before replacing the disk with a larger capacity disk, migrate resources at the transaction log storage destination using the backup and recovery features.

There are two methods of performing backup and recovery:

- [14.8.1.1 Using WebAdmin](#)
- [14.8.1.2 Using Server Commands](#)

The following sections describe procedures that use each of these methods to replace the disk and migrate resources at the transaction log storage destination.



Note

- Before replacing the disk, stop applications that are using the database.
- It is recommended that you back up the database cluster following recovery. Backup deletes obsolete archive logs (transaction logs copied to the backup data storage destination), freeing up disk space and reducing the recovery time.

14.8.1.1 Using WebAdmin

Follow the procedure below to replace the disk and migrate resources at the transaction log storage destination by using WebAdmin.

1. Back up files

If the disk at the transaction log storage destination contains any required files, back up the files. It is not necessary to back up the transaction log storage destination.

2. Back up the database cluster

Back up the latest data storage destination resources and transaction log storage destination resources (refer to "[3.2.1 Using WebAdmin](#)" for details).

3. Stop applications

Stop applications that are using the database.

4. Stop the instance

Stop the instance. Refer to "[2.1.1 Using WebAdmin](#)" for information on how to stop an instance. WebAdmin automatically stops instances if recovery of the database cluster is performed without stopping the instance.

5. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

6. Create a tablespace directory

If a tablespace was defined after backing up, create a directory for it.

7. Recover the keystore, and enable automatic opening of the keystore

Do the following if the data in the database has been encrypted:

- Restore the keystore to its state at the time of the database backup.
- Enable automatic opening of the keystore.

8. Recover the database cluster

Log in to WebAdmin, and perform recovery operations. Refer to steps 4 ("Create a tablespace directory ") to 7 ("Run Recovery") under "If failure occurred in the data storage disk or the transaction log storage disk " in "[14.1.1 Using WebAdmin](#)" for information on the procedure. An instance is automatically started when recovery is successful.

9. Resume applications

Resume applications that are using the database.

10. Restore files

Restore the files backed up in step 1.

14.8.1.2 Using Server Commands

Follow the procedure below to replace the disk and migrate resources at the transaction log storage destination by using server commands.

1. Back up files

If the disk at the transaction log storage destination contains any required files, back up the files. It is not necessary to back up the transaction log storage destination.

2. Back up the database cluster

Use server commands to back up the latest data storage destination resources and transaction log storage destination resources. Refer to "[3.2.2 Using Server Commands](#)" for information on how to perform backup.

3. Stop applications

Stop applications that are using the database.

4. Stop the instance

After backup is complete, stop the instance. Refer to "[2.1.2 Using Server Commands](#)" for information on how to stop an instance.

If the instance fails to stop, refer to "[14.11 Actions in Response to Failure to Stop an Instance](#)".

5. Replace with a larger capacity disk

Replace the disk. Then, recover the volume configuration information.

6. Create a transaction log storage destination

Create a transaction log storage destination. If a tablespace was defined, also create a directory for it.

Example

```
# mkdir /tranlog/inst1
# chown fsepuser:fsepuser /tranlog/inst1
# chmod 700 /tranlog/inst1
```

7. Recover the keystore, and enable automatic opening of the keystore

When the data in the database has been encrypted, restore the keystore to its state at the time of the database backup. Configure automatic opening of the keystore as necessary.

8. Recover the database cluster

Use the `pgx_rcvall` command to recover the database cluster.

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the backup storage directory in the `-B` option.

Example

```
> pgx_rcvall -D /database/inst1 -B /backup/inst1
```

Note

If recovery fails, remove the cause of the error in accordance with the displayed error message and then re-execute the `pgx_rcvall` command.

If the message "`pgx_rcvall: an error occurred during recovery`" is displayed, then the log recorded when recovery was executed is output after this message. The cause of the error is output in around the last fifteen lines of the log, so remove the cause of the error in accordance with the message and then re-execute the `pgx_rcvall` command.

The following message displayed during recovery is output as part of normal operation of `pgx_rcvall` command (therefore the user does not need not be concerned).

```
FATAL: The database system is starting
```

See

Refer to "`pgx_rcvall`" in the Reference for information on the `pgx_rcvall` command.

9. Start the instance

Start the instance.

Refer to "2.1.2 Using Server Commands" for information on how to start an instance.

 Note

The `pgx_rcvall` command cannot accurately recover a hash index. If you are using a hash index, wait for the instance to start and then execute the `REINDEX` command for the appropriate index.

10. Resume applications

Resume applications that are using the database.

11. Restore files

Restore the files backed up in step 1.

14.9 Errors in More Than One Storage Disk

If an error occurs in the storage destination disks or resources are corrupted, determine the cause of the error from system logs and server logs and remove the cause.

If errors occur in either of the following combinations, you cannot recover the database.

Recreate the instance, and rebuild the runtime environment.

Data storage disk	Transaction log storage disk	Backup data storage disk
Error	-	Error
-	Error	Error

 See

Refer to "Setup" in the Installation and Setup Guide for Server for information on how to create an instance and build the runtime environment.

14.10 Actions in Response to Instance Startup Failure

If an instance fails to start, refer to the system log and the server log, and determine the cause of the failure.

If using WebAdmin, remove the cause of the error. Then, click [Solution] and [Recheck the status] and confirm that the instance is in the normal state.

The following sections describe common causes of errors and the actions to take.

14.10.1 Errors in the Configuration File

If you have directly edited the configuration file using a text editor or changed the settings using WebAdmin, refer to the system log and the server log, confirm that no messages relating to the files below have been output.

- postgresql.conf
- pg_hba.conf

 See

Refer to the following for information on the parameters in the configuration file:

- "Configuring Parameters" in the Installation and Setup Guide for Server
 - ["Appendix A Parameters"](#)
 - "Server Configuration" and "Client Authentication" under "Server Administration" in the PostgreSQL Documentation
-

14.10.2 Errors Caused by Power Failure or Mounting Issues

If mounting is cancelled after restarting the server, for example, because the disk device for each storage destination disk was not turned on, or because automatic mounting has not been set, then starting an instance will fail.

Refer to "[14.14.2 Errors Caused by Power Failure or Mounting Issues](#)", and take actions accordingly.

14.10.3 Other Errors

This section describes the recovery procedure to be used if you cannot take any action or the instance cannot start even after you have referred to the system log and the server log.

There are two methods of recovery:

- [14.10.3.1 Using WebAdmin](#)
- [14.10.3.2 Using Server Commands](#)

Note that recovery will not be possible if there is an error at the backup data storage destination. If the problem cannot be resolved, contact Fujitsu technical support.

14.10.3.1 Using WebAdmin

Follow the procedure below to perform recovery.

1. Delete the data storage destination directory and the transaction log storage destination directory
Back up the data storage destination directory and the transaction log storage destination directory before deleting them.
2. Reconfirm the status
Log in to WebAdmin, and in the [Instances] tab, click [Solution] for the error message.
Click [Recheck the status] to reconfirm the storage destination resources.
3. Run recovery
Restore the database cluster after WebAdmin detects an error.
Refer to "[14.2.1 Using WebAdmin](#)" for details.

14.10.3.2 Using Server Commands

Follow the procedure below to recover the database.

1. Delete the data storage destination directory and the transaction log storage destination directory
Save the data storage destination directory and the transaction log storage destination directory, and then delete them.
2. Execute recovery
Use the `pgx_rcvall` command to recover the database cluster.
Refer to "[14.2.2 Using the pgx_rcvall Command](#)" for details.

14.11 Actions in Response to Failure to Stop an Instance

If an instance fails to stop, refer to the system log and the server log, and determine the cause of the failure.

If the instance cannot stop despite taking action, perform the following operation to stop the instance.

There are two methods of recovery:

- [14.11.1 Using WebAdmin](#)
- [14.11.2 Using Server Commands](#)

14.11.1 Using WebAdmin

In the [Instances] tab, click  and select the Fast stop mode or the Immediate stop mode to stop the instance. Forcibly terminate the server process from WebAdmin if the instance cannot be stopped.

Refer to "[2.1.1 Using WebAdmin](#)" for information on the stop modes.

14.11.2 Using Server Commands

There are three methods:

- Stopping the Instance Using the Fast Mode

If backup is in progress, then terminate it, roll back all executing transactions, forcibly close client connections, and then stop the instance.
- Stopping the Instance Using the Immediate Mode

Forcibly terminate the instance immediately. A crash recovery is run when the instance is restarted.
- Forcibly Stopping the Server Process

Reliably stops the server process when the other methods are unsuccessful.

14.11.2.1 Stopping the Instance Using the Fast Mode

Specify "-m fast" in the pg_ctl command to stop the instance.

If the instance fails to stop when you use this method, stop the instance as described in "[14.11.2.2 Stopping the Instance Using the Immediate Mode](#)" or "[14.11.2.3 Forcibly Stopping the Server Process](#)".



Example

```
> pg_ctl stop -D /database/inst1 -m fast
```

14.11.2.2 Stopping the Instance Using the Immediate Mode

Specify "-m immediate" in the pg_ctl command to stop the instance.

If the instance fails to stop when you use this method, stop the instance as described in "[14.11.2.3 Forcibly Stopping the Server Process](#)".



Example

```
> pg_ctl stop -D /database/inst1 -m immediate
```

14.11.2.3 Forcibly Stopping the Server Process

If both the Fast mode and the Immediate mode fail to stop the instance, use the kill command or the kill parameter of the pg_ctl command to forcibly stop the server process.

The procedure is as follows:

1. Execute the ps command

Note that "<x>" indicates the product version.

```
> ps axwfo user,pid,ppid,TTY,command | grep postgres
fsepuser 19174 18027 pts/1          \_ grep postgres
fsepuser 20517      1 ?          /opt/fsepv<x>server64/bin/postgres -D /database/inst1
```

```
fsepuser 20518 20517 ?      \_ postgres: logger process
fsepuser 20520 20517 ?      \_ postgres: checkpointer process
fsepuser 20521 20517 ?      \_ postgres: writer process
fsepuser 20522 20517 ?      \_ postgres: wal writer process
fsepuser 20523 20517 ?      \_ postgres: autovacuum launcher process
fsepuser 20524 20517 ?      \_ postgres: archiver process
fsepuser 20525 20517 ?      \_ postgres: stats collector process
```

The process ID (20517) indicates the server process.

2. Forcibly stop the server process

As instance manager, forcibly stop the server process.

Using the `pg_ctl` command

```
> pg_ctl kill SIGQUIT 20517
```

Using the `kill` command

```
> kill -s SIGQUIT 20517
```

14.12 Actions in Response to Failure to Create a Streaming Replication Standby Instance

When creating a streaming replication standby instance using WebAdmin, if the instance creation fails, refer to the system log and the server log, and determine the cause of the failure.

When an error occurs in the creation of the standby instance using WebAdmin, it is unlikely that the partially created standby instance can be resumed to complete the operation.

In such a scenario, fix the cause of the error, delete the partially created standby instance, and then create a new standby instance. This recommendation is based on the following assumptions:

- As the instance is yet to be created completely, there are no applications connecting to the database.
- The standby instance is in error state and is not running.
- There are no backups for the standby instance and as a result, it cannot be recovered.



See

Refer to "Deleting Instances" in the Installation and Setup Guide for details on how to delete an instance.

14.13 Actions in Response to Error in a Distributed Transaction

If a system failure (such as server failure) occurs in an application that uses distributed transactions, then transactions may be changed to the in-doubt state.

At that point, resources accessed by the transaction will be locked, and rendered unusable by other transactions.

The following describes how to check for in-doubt transactions, and how to resolve them.

How to check for in-doubt transactions

The following shows how to check for them:

If the server fails

1. An in-doubt transaction will have occurred if a message similar to the one below is output to the log when the server is restarted.

Example

```
LOG: Restoring prepared transaction 2103.
```

2. Refer to system view `pg_prepared_xacts` to obtain information about the prepared transaction.

If the transaction identifier of the prepared transaction in the list (in the `transaction` column of `pg_prepared_xacts`) is the same as the identifier of the in-doubt transaction obtained from the log output when the server was restarted, then that row is the information about the in-doubt transaction.

Example

```
postgres=# select * from pg_prepared_xacts;
 transaction | gid          | prepared | owner  | database
-----+-----+-----+-----+-----
 2103 | 374cc221-f6dc-4b73-9d62-d4fec9b430cd | 2020-05-06 16:28:48.471+08 | postgres |
postgres (1 row)
```

Information about the in-doubt transaction is output to the row with the transaction ID 2103 in the `transaction` column.

If the client fails

If there are no clients connected and there is a prepared transaction in `pg_prepared_xacts`, then you can determine that the transaction is in the in-doubt state.

If at least one client is connected and there is a prepared transaction in `pg_prepared_xacts`, you cannot determine whether there is a transaction in the in-doubt state. In this case, use the following query to determine the in-doubt transaction from the acquired database name, user name, the time `PREPARE TRANSACTION` was executed, and the information about the table name accessed.

```
select gid,x.database,owner,prepared,l.relation::regclass as relation from pg_prepared_xacts x
left join pg_locks l on l.virtualtransaction = '-1/'||x.transaction and l.locktype='relation';
```

If it still cannot be determined from this information, wait a few moments and then check `pg_prepared_xacts` again.

If there is a transaction that has continued since the last time you checked, then it is likely that it is the one in the in-doubt state.

Point

As you can see from the explanations in this section, there is no one way to definitively determine in-doubt transactions.

Consider collecting other supplementary information (for example, logging on the client) or performing other operations (for example, allocating database users per job).

How to resolve in-doubt transactions

From the system view `pg_prepared_xacts` mentioned above, obtain the global transaction identifier (in the `gid` column of `pg_prepared_xacts`) for the in-doubt transaction, and issue either a `ROLLBACK PREPARED` statement or `COMMIT PREPARED` statement to resolve the in-doubt transaction.

Example

- Rolling back in-doubt transactions

```
postgres=# rollback prepared '374cc221-f6dc-4b73-9d62-d4fec9b430cd';
ROLLBACK PREPARED
```

- Committing in-doubt transactions

```
postgres=# commit prepared '374cc221-f6dc-4b73-9d62-d4fec9b430cd';
COMMIT PREPARED
```

14.14 I/O Errors Other than Disk Failure

Even if a disk is not defective, the same input-output error messages, as those generated when the disk is defective, may be output.

A few examples of such errors are given below. The appropriate action for each error is explained respectively.

- [14.14.1 Network Error with an External Disk](#)
- [14.14.2 Errors Caused by Power Failure or Mounting Issues](#)

14.14.1 Network Error with an External Disk

This is an error that occurs in the network path to/from an external disk.

Determine the cause of the error by checking the information in the system log and the server log, the disk access LED, network wiring, and network card status. Take appropriate action to remove the cause of the error, for example, replace problematic devices.

14.14.2 Errors Caused by Power Failure or Mounting Issues

These are errors that occur when the disk device is not turned on, automatic mounting of the disk was not set, or mounting was accidentally cancelled.

In this case, check the information in the system log and the server log, the disk access LED, and whether the disk is mounted correctly. If problems are detected, take appropriate action.

If mounting has been cancelled, it is possible that mounting was accidentally cancelled, or automatic mounting at the time of starting the operating system is not set. In this case, set the mounting to be performed automatically.

14.15 Anomaly Detection and Resolution

The following operations performed via the command line interface will result in an anomaly in WebAdmin:

- Changes to the port and backup_destination parameters in postgresql.conf
- Changes to Mirroring Controller configuration of cluster replication added via WebAdmin

This section describes when WebAdmin checks for such anomalies, and what takes place when an anomaly is detected.

14.15.1 Port Number and Backup Storage Path Anomalies

An anomaly occurs when the value of [Port number] and/or [Backup storage path] in WebAdmin is different from the value of its corresponding parameter in postgresql.conf - port and backup_destination, respectively.

WebAdmin checks for anomalies when an instance is selected for viewing or any instance operation is performed. Anomalies will be identified for the selected instance only.

The following occurs when an anomaly is detected in port number and/or backup storage path:

- All instance operation buttons are disabled, except for "Edit instance", "Refresh instance", and "Delete Mirroring Controller"
- A red error status indicator is displayed on the instance icon
- For an anomaly specific to backup storage path, a red error status indicator is displayed on the [Backup storage] disk icon, and [Backup storage status] is set to "Error"
- The message, "WebAdmin has detected an anomaly with...", is displayed in the [Message] section along with an associated [Solution] button

Click [Solution]. The [Anomaly Error] dialog box is displayed.

Anomaly Error

WebAdmin has detected an anomaly due to change of Port number in postgresql.conf. The instance operations are disabled and will be available only after addressing this anomaly.

The instance may be restarted as part of the anomaly resolution.

Select one of the following options to resolve this anomaly:

- Recheck** the status of the anomaly condition
- Navigate** to the "Edit instance" page
- Reset** to override Port number in postgresql.conf
- Override** Port number in WebAdmin

Select the required option, click [OK], and then resolve the anomaly error.

Refer to "Editing instance information" in the Installation and Setup Guide for Server for information on the [Edit instance] page.



Note

Critical errors encountered during anomaly resolution will be displayed, however, rollback of the instance to its previous state is not supported.

14.15.2 Mirroring Controller Anomalies

The following conditions will cause a Mirroring Controller anomaly:

- The Mirroring Controller management folder or configuration files have been deleted
- The permissions to the Mirroring Controller management folder or configuration files have been changed such that:
 - The instance administrator's access to Mirroring Controller configuration is denied
 - Users other than an instance administrator have access privileges to Mirroring Controller configuration files

WebAdmin checks for anomalies when Mirroring Controller status check is performed.

The following occurs when a Mirroring Controller anomaly is detected:

- All Mirroring Controller functionality is disabled for the replication cluster, except for "Delete Mirroring Controller"
- [Mirroring Controller status] is set to "Error"
- Either of the following messages is displayed in the [Message] section

"Failed to access the Mirroring Controller management folder or configuration files '*path*'. Mirroring Controller functionality has been disabled. Consider deleting Mirroring Controller and adding it again."

"Failed to find the Mirroring Controller management folder or configuration files '*path*'. Mirroring Controller functionality has been disabled. Consider deleting Mirroring Controller and adding it again."

Appendix A Parameters

This appendix describes the parameters to be set in the postgresql.conf file of FUJITSU Enterprise Postgres.

The postgresql.conf file is located in the data storage destination.

- core_directory (string)

This parameter specifies the directory where the corefile is to be output. If this parameter is omitted, the data storage destination is used by default. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

- core_contents (string)

This parameter specifies the contents to be included in the corefile.

- full: Outputs all contents of the server process memory to the corefile.
- none: Does not output a corefile.
- minimum: Outputs only non-shared memory server processes to the corefile. This reduces the size of the corefile. However, in some cases, this file may not contain sufficient information for examining the factor that caused the corefile to be output.

If this parameter is omitted, "minimum" is used by default. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

- keystore_location (string)

This parameter specifies the directory that stores the keystore file. Specify a different location from other database clusters. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

- tde_z.IBM_CCA_CSU_DEFAULT_ADAPTER (string)

This parameter specifies the value of the environment variable CSU_DEFAULT_ADAPTER for IBM Common Cryptographic Architecture (CCA) configuration. If this parameter is omitted, will follow the current CCA configuration. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

Information

.....
Refer to IBM documentaion for the environment variable CSU_DEFAULT_ADAPTER.
.....

- tde_z.IBM_CCA_CSU_DEFAULT_DOMAIN (string)

This parameter specifies the value of the environment variable CSU_DEFAULT_DOMAIN for IBM Common Cryptographic Architecture (CCA) configuration. If this parameter is omitted, will follow the current CCA configuration. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

Information

.....
Refer to IBM documentaion for the environment variable CSU_DEFAULT_DOMAIN.
.....

- tde_z.SLOT_ID (string)

Specifies the slot ID assigned to the instance of FUJITSU Enterprise Postgres. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

- tde_z.USER_PIN (string)

User PIN to open a keystore. Specifies the user PIN set to the slot ID assigned to the instance of FUJITSU Enterprise Postgres. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

- tablespace_encryption_algorithm (string)

This parameter specifies the encryption algorithm for tablespaces that will be created. Valid values are "AES128", "AES256", and "none". If you specify "none", encryption is not performed. The default value is "none". To perform encryption, it is recommended that you specify "AES256". Only superusers can change this setting.

- backup_destination (string)

This parameter specifies the absolute path of the directory where pgx_dmpall will store the backup data. Specify a different location from other database clusters. This parameter can only be set when specified on starting an instance. It cannot be changed dynamically, while an instance is active.

Place this directory on a different disk from the data directory to be backed up and the tablespace directory. Ensure that users do not store arbitrary files in this directory, because the contents of this directory are managed by the database system.

- search_path (string)

When using the SUBSTR function compatible with Oracle databases, set "oracle" and "pg_catalog" in the search_path parameter. You must specify "oracle" before "pg_catalog".



Example

```
search_path = '$user', public, oracle, pg_catalog'
```



Information

- The search_path feature specifies the priority of the schema search path. The SUBSTR function in Oracle database is defined in the oracle schema.
- Refer to "Statement Behavior" under "Server Administration" in the PostgreSQL Documentation for information on search_path.

- track_waits (string)

This parameter enables collection of statistics for pgx_stat_lwlock and pgx_stat_latch.

- on: Enables collection of statistics.
- off: Disables collection of statistics.

If this parameter is omitted, "on" is assumed.

Only superusers can change this setting.

- track_sql (string)

This parameter enables collection of statistics for pgx_stat_sql.

- on: Enables collection of statistics.
- off: Disables collection of statistics.

If this parameter is omitted, "on" is assumed.

Only superusers can change this setting.

Parameters for the in-memory feature

- reserve_buffer_ratio (numerical value)

This parameter specifies the proportion of shared memory to be used for a stable buffer table.

- Minimum value: 0
- Maximum value: 80

If this parameter is omitted, 0 will be used.

- vci.cost_threshold (numerical value)

This parameter specifies the lowest cost that selects an execution plan that uses a VCI. If the cost of the best execution plan that does not use a VCI is lower than this value, that execution plan will be selected.

- Minimum value: 0
- Maximum value: Maximum value that can be expressed as a 4-byte signed integer

If this parameter is omitted or a value outside this range is specified, 18000 will be used.

- vci.control_max_workers (numerical value)

This parameter specifies the number of background workers that manage VCI. The number of workers for the entire instance is limited by max_worker_processes, so add the value specified here to max_worker_processes.

- Minimum value: 1
- Maximum value: 8388607

If this parameter is omitted or a value outside this range is specified, 8 will be used.

- vci.enable (string)

This parameter enables or disables VCI.

- on: Enables VCI.
- off: Disables VCI.

If this parameter is omitted, "on" will be used.

- vci.log_query (string)

This parameter enables or disables log output when VCI is not used due to insufficient memory specified by vci.max_local_ros.

- on: Enables log output.
- off: Disables log output.

If this parameter is omitted, "off" will be used.

- vci.maintenance_work_mem (numerical value)

This parameter specifies the maximum memory size used for maintenance of VCI (when executing CREATE INDEX, for example).

- Minimum value: 1 MB
- Maximum value: Maximum value that can be expressed as a 4-byte signed integer

If this parameter is omitted or a value outside this range is specified, 256 MB will be used.

- vci.max_local_ros (numerical value)

This parameter specifies the maximum memory size used for VCI scan.

- Minimum value: 64 MB
- Maximum value: Maximum value that can be expressed as a 4-byte signed integer

If this parameter is omitted or a value outside this range is specified, 64 MB will be used.



Information

.....
 The maximum value that can be expressed as a 4-byte signed integer changes according to the operating system. Follow the definition of the operating system in use.

- vci.max_parallel_degree (numerical value)

This parameter specifies the maximum number of background workers used for parallel scan. The number of workers for the entire instance is limited by max_worker_processes, so add the value specified here to max_worker_processes.

A value from -8388607 to 8388607 can be specified.

- Integer (1 or greater): Parallel scan is performed using the specified degree of parallelism.
- 0: Stops the parallel scan process.

- Negative number: The specified value minus the maximum number of CPUs obtained from the environment is used as the degree of parallelism and parallel scan is performed.

If this parameter is omitted or a value outside this range is specified, 0 will be used.

- vci.shared_work_mem (numerical value)

This parameter specifies the maximum memory size used for VCI parallel scan.

- Minimum value: 32 MB
- Maximum value: Maximum value that can be expressed as a 4-byte signed integer

If this parameter is omitted or a value outside this range is specified, 1 GB will be used.

Parameters for the Global Meta Cache

- pgx_global_metacache (numerical value)

Specifies the memory size of the GMC area.

Specify a value calculated by the formula below.

A value lower than the calculated value will still work, but the meta cache may not be able to fit into the GMC area.

In this case, the system will discard the meta cache it thinks it is no longer needed, but if it is needed again, the meta cache will need to be expanded and will not perform well.

If the value is less than 10 MB and is set to a nonzero value that disables the feature, the database startup fails because the Global Meta Cache feature cannot operate.

A setting of 0 disables the Global Meta Cache feature. The default is 0.

Changing this setting requires restarting the database.

```
Size of GMC area
= Max(10MB,
      (All user table x 0.4 KB
       + All user Indexes x 0.3 KB
       + All user columns x 0.8 KB) x 1.5 (*1) )
```

*1) Safety Factor (1.5)

This value takes into account the case where both GMC before and after the change temporarily exist at the same time in shared memory when the table definition is changed or the row of the system catalog is changed.

- track_gmc (string)

This parameter enables collection of statistics for pgx_stat_gmc.

- on: Enables collection of statistics.
- off: Disables collection of statistics.

If this parameter is omitted, "on" is used.

Only superusers can change this setting.



See

Refer to "Server Configuration" under "Server Administration" in the PostgreSQL Documentation for information on other postgresql.conf parameters.

Appendix B System Administration Functions

This appendix describes the system administration functions of FUJITSU Enterprise Postgres.



Refer to "System Administration Functions" under "The SQL Language" in the PostgreSQL Documentation for information on other system administration functions.

B.1 WAL Mirroring Control Functions

The following table lists the functions that can be used for backup and recovery based on WAL mirroring.

Table B.1 WAL mirroring control functions

Name	Return type	Description
<code>pgx_pause_wal_multiplexing()</code>	void	Stops WAL multiplexing
<code>pgx_resume_wal_multiplexing()</code>	void	Resumes WAL multiplexing
<code>pgx_is_wal_multiplexing_paused()</code>	boolean	Returns true if WAL multiplexing has stopped

If WAL multiplexing has not been configured, these functions return an error. Setting the `backup_destination` parameter in `postgresql.conf` configures WAL multiplexing.

Only superusers can execute these functions.

B.2 Transparent Data Encryption Control Functions

The following table lists the functions that can be used for transparent data encryption.

Table B.2 Transparent data encryption control functions

Name	Return type	Description
<code>pgx_open_keystore(<i>user pin</i> <i>passphrase</i>)</code>	void	Opens the keystore
<code>pgx_set_master_key(<i>user pin</i> <i>passphrase</i>)</code>	void	Sets the master encryption key
<code>pgx_set_keystore_passphrase(<i>oldPassphrase</i>, <i>newPassphrase</i>)</code>	void	Changes the keystore passphrase

The `pgx_open_keystore` function uses the specified user pin or passphrase to open the keystore. When the keystore is opened, it enables access to the master encryption key. In this way, you can access the encrypted data and create encrypted tablespaces. If you are using a file-based key store, and the keystore is already open, this function returns an error.

Only superusers can execute this function. Also, this function cannot be executed within a transaction block.

The `pgx_set_master_key` function generates a master encryption key and stores it in the keystore. If the keystore does not exist, this function creates a keystore. If the keystore already exists, this function modifies the master encryption key. If the keystore has not been opened, this function opens it.

The user pin is a string of 4 to 8 bytes.

The passphrase is a string of 8 to 200 bytes.

Only superusers can execute this function. Also, this function cannot be executed within a transaction block. Processing is not affected by whether the keystore is open.

The `pgx_set_keystore_passphrase` function changes the keystore passphrase. Specify the current passphrase in *oldPassphrase*, and a new passphrase in *newPassphrase*.

The passphrase is a string of 8 to 200 bytes.

Only superusers can execute this function. Also, this function cannot be executed within a transaction block. Processing is not affected by whether the keystore is open.

B.3 Data Masking Control Functions

The table below lists the functions that can be used for data masking.

Table B.3 Data masking control functions

Name	Return type	Description
pgx_alter_confidential_policy	boolean	Changes masking policies
pgx_create_confidential_policy	boolean	Creates masking policies
pgx_drop_confidential_policy	boolean	Deletes masking policies
pgx_enable_confidential_policy	boolean	Enables or disables masking policies
pgx_update_confidential_values	boolean	Changes replacement characters when full masking is specified for masking type

B.3.1 `pgx_alter_confidential_policy`

Description

Changes masking policies

Format

The format varies depending on the content to be changed. The format is shown below.

- Common format

```
common_arg:
[schema_name      := 'schemaName', ]


```

- Add a masking target to a masking policy

```
pgx_alter_confidential_policy(
  commonArg,
  [action           := 'ADD_COLUMN', ]
  column_name      := 'colName'
  [, function_type  := 'FULL'] |
  [, function_type  := 'PARTIAL', partialOpt] |
  [, function_type  := 'REGEXP', regexpOpt]
)
```

```
partialOpt:
function_parameters := 'maskingFmt'
```

```
regexpOpt:
regexp_pattern     := 'regexpPattern',
```

```
regexp_replacement := 'regexpReplacementChar',  
[, regexp_flags := 'regexpFlags']
```

- Delete a masking target from a masking policy

```
pgx_alter_confidential_policy(  
commonArg,  
action := 'DROP_COLUMN',  
column_name := 'colName'  
)
```

- Change the masking condition

```
pgx_alter_confidential_policy(  
commonArg,  
action := 'MODIFY_EXPRESSION',  
expression := 'expr'  
)
```

- Change the content of a masking policy set for a masking target

```
pgx_alter_confidential_policy(  
commonArg,  
action := 'MODIFY_COLUMN',  
column_name := 'colName'  
[, function_type := 'FULL'] |  
[, function_type := 'PARTIAL', partialOpt] |  
[, function_type := 'REGEXP', regexpOpt]  
)
```

```
partialOpt:  
function_parameters := 'maskingFmt'
```

```
regexpOpt:  
regexp_pattern := 'regexpPattern',  
regexp_replacement := 'regexpReplacementChar',  
[, regexp_flags := 'regexpFlags']
```

- Change the masking policy description

```
pgx_alter_confidential_policy(  
commonArg,  
action := 'SET_POLICY_DESCRIPTION',  
policy_description := 'policyDesc'  
)
```

- Change the masking target description

```
pgx_alter_confidential_policy(  
commonArg,  
action := 'SET_COLUMN_DESCRIPTION',  
column_name := 'colName',  
column_description := 'colDesc'  
)
```

Argument

The argument varies depending on the content to be changed. Details are as follows.

- Common arguments

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	schema_name	varchar(63)	Schema name of table for which a masking policy is applied	'public'
	table_name	varchar(63)	Name of table for which a masking policy is applied	Mandatory
	policy_name	varchar(63)	Masking policy name	Mandatory

- Add a masking target to a masking policy

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	action	varchar(63)	'ADD_COLUMN'	'ADD_COLUMN'
	column_name	varchar(63)	Masking target name	Mandatory
	function_type	varchar(63)	Masking type - 'FULL': Full masking - 'PARTIAL': Partial masking - 'REGEXP': Regular expression masking	'FULL'
Partial masking	function_parameters	varchar(1024)	Masking format for partial masking	Mandatory
Regular expression masking	regexp_pattern	varchar(1024)	Search pattern for regular expression masking	Mandatory
	regexp_replacement	varchar(1024)	Replacement character/string for regular expression masking	Mandatory
	regexp_flags	varchar(20)	Regular expression flags	NULL

- Delete a masking target from a masking policy

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	action	varchar(63)	'DROP_COLUMN'	Mandatory
	column_name	varchar(63)	Masking target name	Mandatory

- Change the masking condition

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	action	varchar(63)	'MODIFY_EXPRESSION'	Mandatory
	expression	varchar(1024)	Masking condition to be changed	Mandatory

- Change the content of a masking policy set for a masking target

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	action	varchar(63)	'MODIFY_COLUMN'	Mandatory
	column_name	varchar(63)	Masking target name	Mandatory
	function_type	varchar(63)	Masking type - 'FULL': Full masking - 'PARTIAL': Partial masking - 'REGEXP': Regular expression masking	'FULL'
Partial masking	function_parameters	varchar(1024)	Masking format for partial masking	Mandatory
Regular expression masking	regexp_pattern	varchar(1024)	Search pattern for regular expression masking	Mandatory
	regexp_replacement	varchar(1024)	Replacement character/string for regular expression masking	Mandatory
	regexp_flags	varchar(20)	Regular expression flags	NULL

- Change the masking policy description

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	action	varchar(63)	'SET_POLICY_DESCRIPTION'	Mandatory
	policy_description	varchar(1024)	Masking policy description	Mandatory

- Change the masking target description

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	action	varchar(63)	'SET_COLUMN_DESCRIPTION'	Mandatory
	column_name	varchar(63)	Masking target name	Mandatory
	column_description	varchar(1024)	Masking target description	Mandatory

Details about whether arguments can be omitted are as follows.

Argument	Mandatory or optional									
	ADD_COLUMN			DROP_COLUMN	MODIFY_EXPRESSION	MODIFY_COLUMN			SET_POLICY_DESCRIPTION	SET_COLUMN_DESCRIPTION
	Full masking	Partial masking	Regular expression masking			Full masking	Partial masking	Regular expression masking		
schema_name	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
table_name	N	N	N	N	N	N	N	N	N	N

Argument	Mandatory or optional									
	ADD_COLUMN			DROP_COLUMN	MODIFY_EXPRESSION	MODIFY_COLUMN			SET_POLICY_DESCRIPTION	SET_COLUMN_DESCRIPTION
	Full masking	Partial masking	Regular expression masking			Full masking	Partial masking	Regular expression masking		
policy_name	N	N	N	N	N	N	N	N	N	N
action	Y	Y	Y	N	N	N	N	N	N	N
column_name	N	N	N	N	-	N	N	N	-	N
function_type	Y	N	N	-	-	Y	N	N	-	-
expression	-	-	-	-	N	-	-	-	-	-
policy_description	-	-	-	-	-	-	-	-	N	-
column_description	-	-	-	-	-	-	-	-	-	N
function_parameters	-	N	-	-	-	-	N	-	-	-
regexp_pattern	-	-	N	-	-	-	-	N	-	-
regexp_replacement	-	-	N	-	-	-	-	N	-	-
regexp_flags	-	-	Y	-	-	-	-	Y	-	-

Y: Can be omitted; N: Cannot be omitted; -: Ignored when specified

Return value

Return value	Description
TRUE	Ended normally
FALSE	Ended abnormally

Execution example 1

Adding masking policy p1 to masking target c2

```
postgres=# select pgx_alter_confidential_policy(table_name := 't1', policy_name := 'p1', action :=
'ADD_COLUMN', column_name := 'c2', function_type := 'PARTIAL', function_parameters := 'VVVFVVVFVVVV,
VVV-VVVV-VVVV, *, 4, 11');
pgx_alter_confidential_policy
-----
t
(1 row)
```

Execution example 2

Deleting masking target c1 from masking policy p1

```
postgres=# select pgx_alter_confidential_policy(table_name := 't1', policy_name := 'p1', action :=
'DROP_COLUMN', column_name := 'c1');
pgx_alter_confidential_policy
-----
t
(1 row)
```

Execution example 3

Changing the masking condition for masking policy p1

```
postgres=# select pgx_alter_confidential_policy(table_name := 't1', policy_name := 'p1', action :=
'MODIFY_EXPRESSION', expression := 'false');
pgx_alter_confidential_policy
-----
t
(1 row)
```

Execution example 4

Changing the content of masking policy p1 set for masking target c2

```
postgres=# select pgx_alter_confidential_policy(table_name := 't1', policy_name := 'p1', action :=
'MODIFY_COLUMN', column_name := 'c2', function_type := 'FULL');
pgx_alter_confidential_policy
-----
t
(1 row)
```

Execution example 5

Changing the description of masking policy p1

```
postgres=# select pgx_alter_confidential_policy(table_name := 't1', policy_name := 'p1', action :=
'SET_POLICY_DESCRIPTION', policy_description := 'this policy is an example. ');
pgx_alter_confidential_policy
-----
t
(1 row)
```

Execution example 6

Changing the description of masking target c2

```
postgres=# select pgx_alter_confidential_policy(table_name := 't1', policy_name := 'p1', action :=
'SET_COLUMN_DESCRIPTION', column_name := 'c2', column_description := 'c2 column is FULL. ');
pgx_alter_confidential_policy
-----
t
(1 row)
```

Description

- The arguments for the `pgx_alter_confidential_policy` system management function can be specified in any order.
- The action parameters below can be specified. When action parameters are omitted, `ADD_COLUMN` is applied.

Parameter	Description
<code>ADD_COLUMN</code>	Adds a masking target to a masking policy.
<code>DROP_COLUMN</code>	Deletes a masking target from a masking policy.
<code>MODIFY_EXPRESSION</code>	Changes expression.
<code>MODIFY_COLUMN</code>	Changes the content of a masking policy set for a masking target.
<code>SET_POLICY_DESCRIPTION</code>	Changes <code>policy_description</code> .
<code>SET_COLUMN_DESCRIPTION</code>	Changes <code>column_description</code> .

- The `function_parameters` argument is enabled when the `function_type` is `PARTIAL`. If the `function_type` is other than `PARTIAL`, it will be ignored.

- The arguments below are enabled when the `function_type` is REGEXP. If the `function_type` is other than REGEXP, these arguments will be ignored.
 - `regexp_pattern`
 - `regexp_replacement`
 - `regexp_flags`



- Refer to "String Constants" in the PostgreSQL Documentation for information on the strings to specify for arguments.
- Refer to "POSIX Regular Expressions" in the PostgreSQL Documentation and check `pattern`, `replacement`, and `flags` for information on the values that can be specified for `regexp_pattern`, `regexp_replacement`, and `regexp_flags`.

B.3.2 pgx_create_confidential_policy

Description

Creates masking policies

Format

The format varies depending on the masking type. The format is shown below.

```
pgx_create_confidential_policy(
[schema_name      := 'schemaName',]
table_name       := 'tableName',
policy_name      := 'policyName',
expression       := 'expr'
[, enable        := 'policyStatus']
[, policy_description := 'policyDesc']
[, column_name    := 'colName'
  [, function_type := 'FULL'] |
  [, function_type := 'PARTIAL', partialOpt] |
  [, function_type := 'REGEXP', regexpOpt]
[, column_description := 'colDesc']
])
```

```
partialOpt:
function_parameters := 'maskingFmt'
```

```
regexpOpt:
regexp_pattern      := 'regexpPattern',
regexp_replacement  := 'regexpReplacementChar',
[, regexp_flags     := 'regexpFlags']
```

Argument

Details are as follows.

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
All	<code>schema_name</code>	<code>varchar(63)</code>	Schema name of table for which the masking policy is created	'public'
	<code>table_name</code>	<code>varchar(63)</code>	Name of table for which the masking policy is created	Mandatory

Masking type for which an argument can be specified	Argument	Data type	Description	Default value
	policy_name	varchar(63)	Masking policy name	Mandatory
	expression	varchar(1024)	Masking condition	Mandatory
	enable	boolean	Masking policy status - 't': Enabled - 'f': Disabled	't'
	policy_description	varchar(1024)	Masking policy description	NULL
	column_name	varchar(63)	Masking target name	NULL
	function_type	varchar(63)	Masking type - 'FULL': Full masking - 'PARTIAL': Partial masking - 'REGEXP': Regular expression masking	'FULL'
	column_description	varchar(1024)	Masking target description	NULL
Partial masking	function_parameters	varchar(1024)	Masking format for partial masking	Mandatory
Regular expression masking	regexp_pattern	varchar(1024)	Search pattern for regular expression masking	Mandatory
	regexp_replacement	varchar(1024)	Replacement character/string for regular expression masking	Mandatory
	regexp_flags	varchar(20)	Regular expression flags	NULL

Details about whether arguments can be omitted are as follows.

Argument	Mandatory or optional		
	Full masking	Partial masking	Regular expression masking
schema_name	Y	Y	Y
table_name	N	N	N
policy_name	N	N	N
expression	N	N	N
enable	Y	Y	Y
policy_description	Y	Y	Y
column_name	Y	Y	Y
function_type	Y	Y	Y
column_description	Y	Y	Y
function_parameters	-	N	-
regexp_pattern	-	-	N
regexp_replacement	-	-	N
regexp_flags	-	-	Y

Y: Can be omitted; N: Cannot be omitted; -: Ignored when specified

Return value

Return value	Description
TRUE	Ended normally
FALSE	Ended abnormally

Execution example 1

Creating masking policy p1 that does not contain a masking target

```
postgres=# select pgx_create_confidential_policy(table_name := 't1', policy_name := 'p1',
expression := 'l=1');
pgx_create_confidential_policy
-----
t
(1 row)
```

Execution example 2

Creating masking policy p1 that contains masking target c1 of which the masking type is full masking

```
postgres=# select pgx_create_confidential_policy(schema_name := 'public', table_name := 't1',
policy_name := 'p1', expression := 'l=1', enable := 't', policy_description := 'this policy is an
example.', column_name := 'c1', function_type := 'FULL', column_description := 'c1 column is FULL.');
```

```
pgx_create_confidential_policy
-----
t
(1 row)
```

Execution example 3

Creating masking policy p1 that contains masking target c2 of which the masking type is partial masking

```
postgres=# select pgx_create_confidential_policy( table_name := 't1', policy_name := 'p1',
expression := 'l=1', column_name := 'c2', function_type := 'PARTIAL', function_parameters :=
'VVVFVVVFVVVFVVV, VVV-VVVV-VVVV, *, 4, 11');
```

```
pgx_create_confidential_policy
-----
t
(1 row)
```

Execution example 4

Creating masking policy p1 that contains masking target c3 of which the masking type is regular expression masking

```
postgres=# select pgx_create_confidential_policy( table_name := 't1', policy_name := 'p1',
expression := 'l=1', column_name := 'c3', function_type := 'REGEXP', regexp_pattern := '(.*)(@.*)',
regexp_replacement := 'xxx\2', regexp_flags := 'g');
```

```
pgx_create_confidential_policy
-----
t
(1 row)
```

Description

- The arguments for the `pgx_create_confidential_policy` system management function can be specified in any order.
- If `column_name` is omitted, only masking policies that do not contain masking target will be created.
- One masking policy can be created for each table. Use the `pgx_alter_confidential_policy` system management function to add a masking target to a masking policy.

- The `function_parameters` argument is enabled when the `function_type` is `PARTIAL`. If the `function_type` is other than `PARTIAL`, it will be ignored.
- The arguments below are enabled when the `function_type` is `REGEXP`. If the `function_type` is other than `REGEXP`, these arguments will be ignored.
 - `regexp_pattern`
 - `regexp_replacement`
 - `regexp_flags`

Note

If a table for which a masking policy is to be applied is deleted, delete the masking policy as well.

See

- Refer to "String Constants" in the PostgreSQL Documentation for information on the strings to specify for arguments.
- Refer to "POSIX Regular Expressions" in the PostgreSQL Documentation and check `pattern`, `replacement`, and `flags` for information on the values that can be specified for `regexp_pattern`, `regexp_replacement`, and `regexp_flags`.

B.3.3 `pgx_drop_confidential_policy`

Description

Deletes masking policies

Format

```
pgx_drop_confidential_policy(
[schema_name      := 'schemaName', ]


```

Argument

Details are as follows.

Argument	Data type	Description	Default value
<code>schema_name</code>	<code>varchar(63)</code>	Schema name of table for which a masking policy is deleted	'public'
<code>table_name</code>	<code>varchar(63)</code>	Name of table for which a masking policy is deleted	Mandatory
<code>policy_name</code>	<code>varchar(63)</code>	Masking policy name	Mandatory

Details about whether arguments can be omitted are as follows.

Argument	Mandatory or optional
<code>schema_name</code>	Y
<code>table_name</code>	N
<code>policy_name</code>	N

Y: Can be omitted; N: Cannot be omitted

Return value

Return value	Description
TRUE	Ended normally
FALSE	Ended abnormally

Execution example

Deleting masking policy p1

```
postgres=# select pgx_drop_confidential_policy(table_name := 't1', policy_name := 'p1');
pgx_drop_confidential_policy
-----
t
(1 row)
```

Description

The arguments for the `pgx_drop_confidential_policy` system management function can be specified in any order.



Note

If a table for which a masking policy is to be applied is deleted, delete the masking policy as well.



See

Refer to "String Constants" in the PostgreSQL Documentation for information on the strings to specify for arguments.

B.3.4 pgx_enable_confidential_policy

Description

Enables or disables masking policies

Format

```
pgx_enable_confidential_policy(  
[schema_name      := 'schemaName', ]  
table_name       := 'tableName',  
policy_name      := 'policyName',  
enable           := 'policyStatus'  
)
```

Argument

Details are as follows.

Argument	Data type	Description	Default value
<code>schema_name</code>	<code>varchar(63)</code>	Schema name of table for which a masking policy is enabled or disabled	'public'
<code>table_name</code>	<code>varchar(63)</code>	Name of table for which a masking policy is enabled or disabled	Mandatory
<code>policy_name</code>	<code>varchar(63)</code>	Masking policy name	Mandatory
<code>enable</code>	<code>boolean</code>	Masking policy status - 't': Enabled	Mandatory

Argument	Data type	Description	Default value
		- 'f': Disabled	

Details about whether arguments can be omitted are as follows.

Argument	Mandatory or optional
schema_name	Y
table_name	N
policy_name	N
enable	N

Y: Can be omitted; N: Cannot be omitted

Return value

Return value	Description
TRUE	Ended normally
FALSE	Ended abnormally

Execution example

Enabling masking policy p1

```
postgres=# select pgx_enable_confidential_policy(table_name := 't1', policy_name := 'p1', enable :=
't');
 pgx_enable_confidential_policy
-----
 t
(1 row)
```

Description

The arguments for the `pgx_enable_confidential_policy` system management function can be specified in any order.



See

Refer to "String Constants" in the PostgreSQL Documentation for information on the strings to specify for arguments.

B.3.5 `pgx_update_confidential_values`

Description

Changes replacement characters when full masking is specified for masking type

Format

```
pgx_update_confidential_values(
[number_value := 'numberValue']
[, char_value := 'charValue']
[, varchar_value := 'varcharValue']
[, date_value := 'dateValue']
[, ts_value := 'tsValue']
)
```

Argument

Details are as follows.

Argument	Data type	Description
number_value	integer	Replacement character in numeric type
char_value	varchar(1)	Replacement character in char type
varchar_value	varchar(1)	Replacement character in varchar type
date_value	date	Replacement character in date type
ts_value	timestamp	Replacement character in timestamp type

Return value

Return value	Description
TRUE	Ended normally
FALSE	Ended abnormally

Execution example

Using '*' as a replacement character in char type and varchar type

```
postgres=# select pgx_update_confidential_values(char_value := '*', varchar_value := '*');
pgx_update_confidential_values
-----
t
(1 row)
```

Description

- The arguments for the pgx_update_confidential_values system management function can be specified in any order.
- Specify one or more arguments for the pgx_update_confidential_values system management function. A replacement character is not changed for an omitted argument.



See

Refer to "String Constants" in the PostgreSQL Documentation for information on the strings to specify for arguments.

B.4 VCI Data Load Control Function

The table below lists the function that loads VCI data to buffer cache.

Table B.4 VCI data load control function

Name	Return type	Description
pgx_prewarm_vci(vci_index regclass)	int8	Loads the VCI data to buffer cache.

pgx_prewarm_vci loads the specified VCI data to buffer cache and returns the number of blocks of the loaded VCI data.

The aggregation process using VCI may take time immediately after an instance is started, because the VCI data has not been loaded to buffer cache. Therefore, the first aggregation process can be sped up by executing pgx_prewarm_vci after an instance is started.

The amount of memory required for preloading is the number of blocks returned by pgx_prewarm_vci multiplied by the size of one block.

This function can only be executed if the user has reference privilege to the VCI index and execution privilege to the pg_prewarm function.

B.5 High-Speed Data Load Control Functions

The table below lists the functions that can be used for high-speed data load.

Table B.5 High-speed data load control functions

Name	Return type	Description
pgx_loader	bigint	Creates dynamic shared memory, starts parallel workers and loads data
pgx_loader_recovery	smallint	Resolves in-doubt transactions

The `pgx_loader` command executes the above functions internally.

Appendix C System Views

This appendix describes how to use the system views in FUJITSU Enterprise Postgres.



See

Refer to "System Views" under "Internals" in the PostgreSQL Documentation for information on other system views.

C.1 pgx_tablespaces

The `pgx_tablespaces` catalog provides information related to the encryption of tablespaces.

Column	Type	References	Description
<code>spctablespace</code>	<code>oid</code>	<code>pg_tablespace.oid</code>	Tablespace OID
<code>spcencalgo</code>	<code>text</code>		Tablespace encryption algorithm

The `spcencalgo` string displays one of the following values:

- none: Tablespace is not encrypted
- AES128: AES with key length of 128 bits
- AES256: AES with key length of 256 bits

C.2 pgx_stat_lwlock

The `pgx_stat_lwlock` view displays statistics related to lightweight locks, with each type of content displayed on a separate line.

Table C.1 `pgx_stat_lwlock` view

Column	Type	Description
<code>lwlock_name</code>	<code>name</code>	Name of the lightweight lock
<code>total_waits</code>	<code>bigint</code>	Number of waits caused by the lightweight lock
<code>total_wait_time</code>	<code>double precision</code>	Number of milliseconds spent in waits caused by the lightweight lock
<code>stats_reset</code>	<code>timestamp with timezone</code>	Last time at which this statistics was reset

C.3 pgx_stat_latch

The `pgx_stat_latch` view displays statistics related to latches, with each type of wait information within FUJITSU Enterprise Postgres displayed on a separate line.

Table C.2 `pgx_stat_latch` view

Column	Type	Description
<code>latch_name</code>	<code>name</code>	Name of the latch
<code>total_waits</code>	<code>bigint</code>	Number of waits caused a wait
<code>total_wait_time</code>	<code>double precision</code>	Number of milliseconds spent in waits caused by the latch
<code>stats_reset</code>	<code>timestamp with timezone</code>	Last time at which this statistic was reset

C.4 pgx_stat_walwriter

The `pgx_stat_walwriter` view displays statistics related to WAL writing, in a single line.

Table C.3 pgx_stat_walwriter view

Column	Type	Description
dirty_writes	bigint	Number of times old WAL buffers were written to the disk because the WAL buffer was full when WAL records were added
writes	bigint	Number of WAL writes
write_blocks	bigint	Number of WAL write blocks
total_write_time	double precision	Number of milliseconds spent on WAL writing
stats_reset	timestamp with timezone	Last time at which this statistic was reset

C.5 pgx_stat_sql

The pgx_stat_sql view displays statistics related to SQL statement executions, with each type of SQL statement displayed on a separate line.

Table C.4 pgx_stat_sql view

Column	Type	Description
selects	bigint	Number of SELECT statements executed In database multiplexing mode, this number includes the SELECT statements executed in Mirroring Controller. Mirroring Controller executes the SELECT statement using the interval specified for the heartbeat_interval of the server definition file (milliseconds).
inserts	bigint	Number of INSERT statements executed
deletes	bigint	Number of DELETE statements executed
updates	bigint	Number of UPDATE statements executed
selects_with_parallelism	bigint	Number of times parallel scan was used in SELECT statements
inserts_with_parallelism	bigint	Not used
deletes_with_parallelism	bigint	Not used
updates_with_parallelism	bigint	Not used
copies_with_parallelism	bigint	Not used
declares	bigint	Number of DECLARE statements executed (number of cursor OPENS)
fetches	bigint	Number of FETCH statements executed
checkpoints	bigint	Number of CHECKPOINT statements executed
clusters	bigint	Number of CLUSTER statements executed
copies	bigint	Number of COPY statements executed
reindexes	bigint	Number of REINDEX statements executed
truncates	bigint	Number of TRUNCATE statements executed
locks	bigint	Number of times a lock occurred
stats_reset	timestamp with timezone	Last time at which this statistic was reset

C.6 pgx_stat_gmc

The pgx_stat_gmc view provides information about the GMC areas.

Table C.5 pgx_stat_gmc view

Column	Type	Description
searches	bigint	Number of times the cache table is searched.
hits	bigint	Number of times the cache table is hit.
size	bigint	The current amount of memory (bytes) used in the GMC area.
stats_reset	timestamp with timezone	Last time these statistics were reset.

Column	Type	Description
table_name	varchar(63)	Name of table for which a masking policy is applied
policy_name	varchar(63)	Masking policy name
expression	varchar(1024)	Masking condition
enable	boolean	Masking policy status - 't': Enabled - 'f': Disabled
policy_description	varchar(1024)	Masking policy description

Execution example

```
postgres=# select * from pgx_confidential_policies;
 schema_name | table_name | policy_name | expression | enable | policy_description
-----+-----+-----+-----+-----+-----
 public      | t1         | p1          | 1=1        | t      |
(1 row)
```

D.3 pgx_confidential_values

This table provides information on replacement characters when full masking is specified for masking type.

Column	Data type	Description	Default value
number_value	integer	Numeric	0
char_value	varchar(1)	char type	Spaces
varchar_value	varchar(1)	varchar type	Spaces
date_value	date	date type	'1970-01-01'
timestamp_value	timestamp	timestamp type	'1970-01-01 00:00:00'

Execution example

```
postgres=# select * from pgx_confidential_values;
 number_value | char_value | varchar_value | date_value | ts_value
-----+-----+-----+-----+-----
          0 |           |              | 1970-01-01 | 1970-01-01 00:00:00
(1 row)
```

Appendix E Tables Used by High-Speed Data Load

This appendix describes the tables used by high-speed data load.

E.1 pgx_loader_state

The `pgx_loader_state` table provides information about transactions prepared by high-speed data load.

Column	Type	Description
<code>id</code>	serial	Unique identifier. This value is assigned from the <code>pgx_loader_state_id_seq</code> sequence.
<code>gid</code>	text	Global transaction identifier assigned to a transaction.
<code>state</code>	text	State of the transaction. The value can be one of the following: <ul style="list-style-type: none">- commit: The prepared transaction has been committed.- rollback: The prepared transaction is in in-doubt state.
<code>master_pid</code>	integer	Process ID of the backend process (master process) that executed the <code>pgx_loader</code> control function.
<code>role_oid</code>	integer	Role identifier (OID). A prepared transaction can only be completed by the same user who executed the original transaction or by a superuser.
<code>relation_oid</code>	integer	Object identifier (OID).

Note

The `pgx_loader_state` table and `pgx_loader_state_id_seq` sequence are updated by high-speed data load. Do not update these database objects directly using SQL.

Appendix F Starting and Stopping the Web Server Feature of WebAdmin

To use WebAdmin for creating and managing a FUJITSU Enterprise Postgres instance on a server where FUJITSU Enterprise Postgres is installed, you must first start the Web server feature of WebAdmin.

- Using WebAdmin in a single-server configuration

You must start the Web server on the server on which FUJITSU Enterprise Postgres and WebAdmin are installed.

- Using WebAdmin in a multiserver configuration

You must start the Web server on all servers on which WebAdmin has been installed.

This appendix describes how to start and stop the Web server feature of WebAdmin.

Note that "<x>" in paths indicates the product version.



Refer to "Installing WebAdmin in a Multiserver Configuration" in the Installation and Setup Guide for Server for information on multiserver installation.

F.1 Starting the Web Server Feature of WebAdmin

Follow the procedure below to start the Web server feature of WebAdmin.

1. Change to superuser

Acquire superuser privileges on the system.

Example

```
$ su -  
Password:*****
```

2. Start the Web server feature of WebAdmin

Execute the WebAdminStart command to start the Web server feature of WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin  
# ./WebAdminStart
```

F.2 Stopping the Web Server Feature of WebAdmin

This section describes how to stop the Web server feature of WebAdmin.

Follow the procedure below to stop the Web server feature of WebAdmin.

1. Change to superuser

Acquire superuser privileges on the system.

Example

```
$ su -  
Password:*****
```

2. Stop the Web server feature of WebAdmin

Execute the WebAdminStop command to stop the Web server feature of WebAdmin.

Example

If WebAdmin is installed in /opt/fsepv<x>webadmin:

```
# cd /opt/fsepv<x>webadmin/sbin  
# ./WebAdminStop
```

Appendix G WebAdmin Wallet

This appendix describes how to use the Wallet feature of WebAdmin.

When a remote instance or a standby instance is created, it is necessary to provide user name and password for authentication with the remote machine or the database instance.

The Wallet feature in WebAdmin is a convenient way to create and store these credentials.

Once created, these credentials can be repeatedly used in one or more instances.

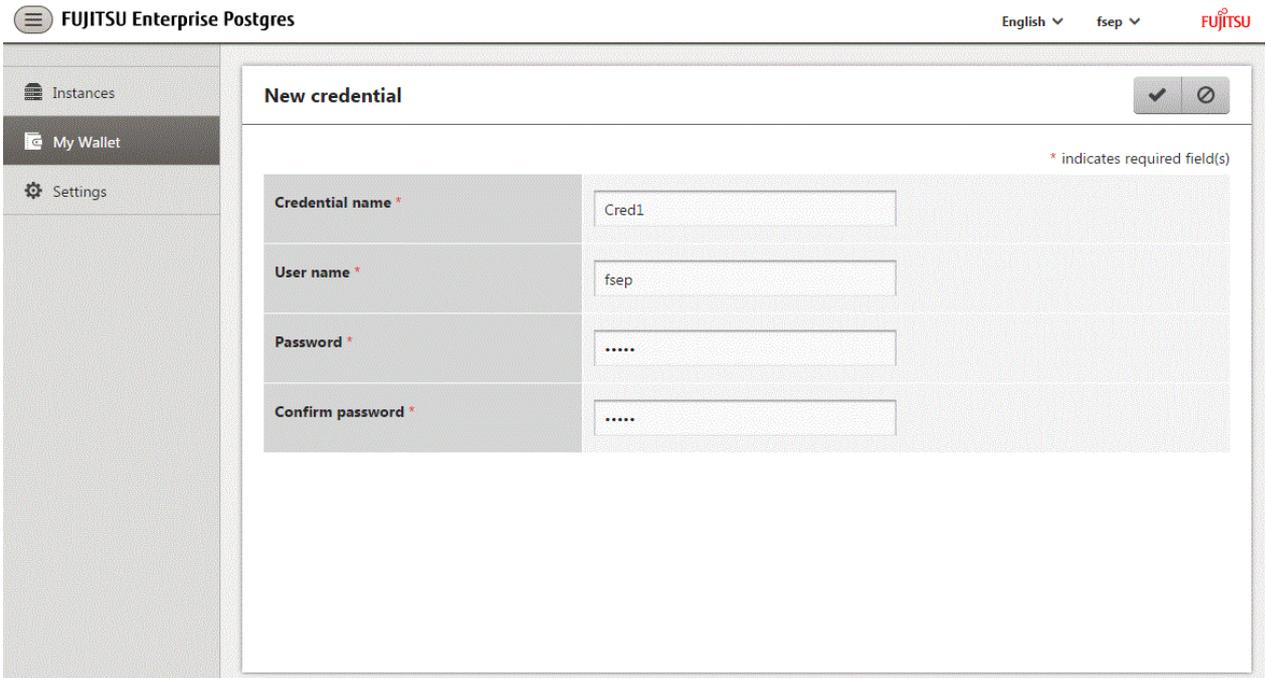
Note

It is not mandatory to create a credential in the Wallet. It is possible to create a remote instance or a standby instance without creating any credential in the Wallet.

If no credential is created beforehand, a user name and password can be entered in the instance creation page. When creating a "Remote" instance, if operating system credentials are entered without using a credential stored in the Wallet, WebAdmin automatically creates a credential with the given user name and password, and stores it in the user's wallet for future use.

G.1 Creating a Credential

1. In the [My Wallet] tab, click . The [New credential] page will be displayed.
2. Enter the information for the credentials.



The screenshot displays the 'New credential' page in the Fujitsu Enterprise Postgres WebAdmin interface. The page title is 'New credential'. On the left, there is a sidebar with three menu items: 'Instances', 'My Wallet', and 'Settings'. The 'My Wallet' menu item is currently selected. The main content area contains a form with four input fields, each with an asterisk indicating it is a required field. The fields are: 'Credential name' with the value 'Cred1', 'User name' with the value 'fsep', 'Password' with six dots, and 'Confirm password' with six dots. In the top right corner of the form area, there is a note: '* indicates required field(s)'. At the top of the page, the navigation bar includes the text 'FUJITSU Enterprise Postgres', a language dropdown set to 'English', a user dropdown set to 'fsep', and the 'FUJITSU' logo.

Enter the following items. Credential name, User name and Password should not contain hazardous characters. Refer to "[Appendix H WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".

- [Credential name]: Name of the credential

The name must meet the conditions below:

- Maximum of 16 characters
- The first character must be an ASCII alphabetic character
- The other characters must be ASCII alphanumeric characters

- [User name]: The operating system user name or database instance user name that will be used later
- [Password]: Password for the user
- [Confirm password]: Reenter the password.

3. Click to store the credential.

G.2 Using a Credential

Once a credential is created in the Wallet, it can be used during remote instance creation or standby instance creation.

The following page uses the credential that was created in the previous section.

The screenshot shows the 'Create instance' form in the Fujitsu Enterprise Postgres console. The form is for a standalone configuration and includes the following fields and values:

- Configuration type:** Standalone configuration
- Server product type:** FUJITSU Enterprise Postgres 12
- Standalone configuration:**
 - Location:** Remote
 - Instance name:** inst2
 - Instance port:** 27502
 - Host name:** StandbyHost
 - Operating system credential:** Cred1
 - User name:** fsep
 - Password:** ****
 - Data storage path:** /database/fsep/inst2/data
 - Backup:** Enabled
 - Backup storage path:** /database/fsep/inst2/backup
 - Transaction log path:** /database/fsep/inst2/transactionlog
 - Encoding:** UTF8
 - WAL file size (MB):** 8
- Remote WebAdmin port:**
 - Remote WebAdmin port for standalone:** 25515

When "Cred1" is selected in [Operating system credential], the user name and password are automatically populated from the credential.

Appendix H WebAdmin Disallow User Inputs Containing Hazardous Characters

WebAdmin considers the following as hazardous characters, which are not allowed in user inputs.

- | (pipe sign)
- & (ampersand sign)
- ; (semicolon sign)
- \$ (dollar sign)
- % (percent sign)
- @ (at sign)
- ' (single apostrophe)
- " (quotation mark)
- \ ' (backslash-escaped apostrophe)
- \ " (backslash-escaped quotation mark)
- <> (triangular parenthesis)
- () (parenthesis)
- + (plus sign)
- CR (Carriage return, ASCII 0x0d)
- LF (Line feed, ASCII 0x0a)
- ,
- \ (backslash)

Appendix I Collecting Failure Investigation Data

If the cause of an error that occurs while building the environment or during operations is unclear, data must be collected for initial investigation.

This appendix describes how to collect data for initial investigation.

Use the `pgx_fjqssinf` command to collect data for initial investigation.



See

.....
Refer to the Reference for information on the `pgx_fjqssinf` command.
.....

Appendix J Operation of Transparent data Encryption in File-based Keystores

This appendix explains about the operation of transparent data encryption in file-based.

J.1 Setting the Master Encryption Key

To use transparent data encryption, you must create a keystore and set the master encryption key.

1. In the `keystore_location` parameter of `postgresql.conf`, specify the directory to store the keystore.

Specify a different location for each database cluster.

```
keystore_location = '/key/store/location'
```

Refer to "[Appendix A Parameters](#)" for information on `postgresql.conf`.

After editing the `postgresql.conf` file, either start or restart the instance.

- Using WebAdmin

Refer to "[2.1.1 Using WebAdmin](#)", and restart the instance.

- Using the `pg_ctl` command

Specify the following in the `pg_ctl` command:

- Specify "restart" as the mode.
- Specify the data storage destination directory in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Specify the `-w` option. This means that the command returns after waiting for the instance to start. If the `-w` option is not specified, it may not be possible to determine if the starting of the instance completed successfully or if it failed.

Example

```
> pg_ctl restart -w -D /database/inst1
```

2. Execute an SQL function, such as the one below, to set the master encryption key. This must be performed by the superuser. Execute it as the database superuser.

```
SELECT pgx_set_master_key('passphrase');
```

The value "passphrase" is the passphrase that will be used to open the keystore. The master encryption key is protected by this passphrase, so avoid specifying a short simple string that is easy to guess.

Refer to "[B.2 Transparent Data Encryption Control Functions](#)" for information on the `pgx_set_master_key` function.



Note

Note that if you forget the passphrase, you will not be able to access the encrypted data. There is no method to retrieve a forgotten passphrase and decrypt data. Do not, under any circumstances, forget the passphrase.

The `pgx_set_master_key` function creates a file with the name `keystore.ks` in the keystore storage destination. It also creates a master encryption key from random bit strings, encrypts it with the specified passphrase, and stores it in `keystore.ks`. At this point, the keystore is open.

J.2 Opening the Keystore

To create encrypted tablespaces and access the encrypted data, you must first open the keystore. When you open the keystore, the master encryption key is loaded into the database server memory and becomes usable for encryption and decryption.

You need to open the keystore each time you start the instance. To open the keystore, the database superuser must execute the following SQL function.

```
SELECT pgx_open_keystore('passphrase');
```

The value "passphrase" is the passphrase specified during creation of the keystore.

Refer to "[B.2 Transparent Data Encryption Control Functions](#)" for information on the `pgx_open_keystore` function.

Note that, in the following cases, the passphrase must be entered when starting the instance, because the encrypted WAL must be decrypted for recovery. In this case, the above-mentioned `pgx_open_keystore` function cannot be executed.

- If performing crash recovery at the time of starting the instance
- If performing recovery using continuous archiving

For the above cases, specify the `--keystore-passphrase` option in the `pg_ctl` command, and then start the instance. This will display the prompt for the passphrase to be entered, as shown below.

```
> pg_ctl --keystore-passphrase start
Enter the passphrase:
The server is starting
>
```



Point

When using an automatically opening keystore, you do not need to enter the passphrase and you can automatically open the keystore when the database server starts. Refer to "[J.5.3 Enabling Automatic Opening of the Keystore](#)" for details.

J.3 Encrypting a Tablespace

Refer to "[5.5 Encrypting a Tablespace](#)".

J.4 Checking an Encrypted Tablespace

Refer to "[5.6 Checking an Encrypted Tablespace](#)".

J.5 Managing the Keystore

This section describes how to manage the keystore and the master encryption key to guard against the threat of theft.

J.5.1 Changing the Master Encryption Key

Using the same encryption key for an extended period gives attackers an opportunity to decipher the encrypted data. It is recommended that you change the key at regular intervals, or whenever the key is exposed to risk.

Adhere to the industry's best practices for encryption algorithms and key management when considering how often the key should be changed. For example, the NIST in the United States has published "NIST Special Publication 800-57". The PCI DSS also refers to this publication. This publication recommends changing the master encryption key once a year.

To change the master encryption key, execute the `pgx_set_master_key` function, which is the same function used for configuring the key. Refer to "[J.1 Setting the Master Encryption Key](#)" for details.

After changing the master encryption key, you must immediately back up the keystore.

J.5.2 Changing the Keystore Passphrase

In security policies for organizations, it is usually a requirement that the passphrase be changed whenever a security administrator who knows the passphrase is removed from duties due to transfer or retirement. It is also recommended that the passphrase be changed if it is ever exposed to risks due to deception such as social engineering.

To change the keystore passphrase, execute the following SQL function as a superuser.

```
SELECT pgx_set_keystore_passphrase('oldPassphrase', 'newPassphrase');
```

After changing the passphrase, you must immediately back up the keystore.

Refer to "[B.2 Transparent Data Encryption Control Functions](#)" for information on the `pgx_set_keystore_passphrase` function.

J.5.3 Enabling Automatic Opening of the Keystore

When using an automatically opening keystore, you do not need to enter the passphrase and you can automatically open the keystore when the instance starts. Execute the `pgx_keystore` command to enable automatic opening of the keystore.

```
> pgx_keystore --enable-auto-open /key/store/location/keystore.ks
Enter the passphrase:
Automatic opening of the keystore is now enabled
>
```



See

Refer to "`pgx_keystore`" in the Reference for information on `pgx_keystore` command.

When automatic opening is enabled, an automatically opening keystore is created in the same directory as the original keystore. The file name of the automatically opening keystore is `keystore.aks`. The file `keystore.aks` is an obfuscated copy of the decrypted content of the `keystore.ks` file. As long as this file exists, there is no need to enter the passphrase to open the keystore when starting the instance.

Do not delete the original keystore file, `keystore.ks`. It is required for changing the master encryption key and the passphrase. When you change the master encryption key and the passphrase, `keystore.aks` is recreated from the original keystore file, `keystore.ks`.

Protect `keystore.ks`, `keystore.aks`, and the directory that stores the keystore so that only the user who starts the instance can access them.

Configure the permission of the files so that only the user who starts the instance can access the SQL functions and commands that create these files. Accordingly, manually configure the same permission mode if the files are restored.



Example

```
# chown -R fsepuser:fsepuser /key/store/location
# chmod 700 /key/store/location
# chmod 600 /key/store/location/keystore.ks
# chmod 600 /key/store/location/keystore.aks
```

An automatically opening keystore will only open on the computer where it was created.

To disable automatic opening of the keystore, delete `keystore.aks`.



Note

- To use WebAdmin for recovery, you must enable automatic opening of the keystore.
- Refer to "[5.8 Backing Up and Restoring/Recovering the Database](#)" after enabling or reconfiguring encryption to back up the database.
- Specify a different directory from those below as the keystore storage destination:
 - Data storage destination
 - Tablespace storage destination
 - Transaction log storage destination
 - Backup data storage destination

J.5.4 Backing Up and Recovering the Keystore

Back up the keystore at the following times in case it is corrupted or lost. Note that you must store the database and the keystore on separate data storage media. Storing both on the same data storage medium risks the danger of the encrypted data being deciphered if the medium is stolen. A passphrase is not required to open an automatically opening keystore, so store this type of keystore in a safe location.

- When the master encryption key is first configured
- When the master encryption key is changed
- When the database is backed up
- When the keystore passphrase is changed

Point

Do not overwrite an old keystore when backing up a keystore. This is because during database recovery, you must restore the keystore to its state at the time of database backup. When the backup data of the database is no longer required, delete the corresponding keystore.

Example

- Back up the database and the keystore on May 1, 2020.

```
> pgx_dmpall -D /database/inst1
> cp -p /key/store/location/keystore.ks /keybackup/keystore_20200501.ks
```

Specify the following in the `pgx_dmpall` command:

- Specify the data storage destination in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.
- Change the master encryption key, and back up the keystore on May 5, 2020.

```
> psql -c "SELECT pgx_set_master_key('passphrase');" postgres
> cp -p /key/store/location/keystore.ks /keybackup/keystore_20200505.ks
```

Specify the following in the `psql` command:

- Specify the SQL function that sets the master encryption key in the `-c` option.
- Specify the name of the database to be connected to as the argument.

If the keystore is corrupted or lost, restore the keystore containing the latest master encryption key. If there is no keystore containing the latest master encryption key, restore the keystore to its state at the time of database backup, and recover the database from the database backup. This action recovers the keystore to its latest state.

Example

- Restore the keystore containing the latest master encryption key as of May 5, 2020.

```
> cp -p /keybackup/keystore_20200505.ks /key/store/location/keystore.ks
```

- If there is no backup of the keystore containing the latest master encryption key, recover the keystore by restoring the keystore that was backed up along with the database on 1 May 2020.

```
> cp -p /keybackup/keystore_20200501.ks /key/store/location/keystore.ks
> pgx_rcvall -B /backup/inst1 -D /database/inst1 --keystore-passphrase
```

Specify the following in the `pgx_rcvall` command:

- Specify the data storage directory in the `-D` option. If the `-D` option is omitted, the value of the `PGDATA` environment variable is used by default.

- Specify the backup data storage directory in the -B option.
- The --keystore-passphrase option prompts you to enter the passphrase to open the keystore.

.....

If you have restored the keystore, repeat the process of enabling automatic opening of the keystore. This ensures that the contents of the automatically opening keystore (keystore.aks) are identical to the contents of the restored keystore.

It is recommended that you do not back up the automatically opening keystore file, keystore.aks. If the database backup medium and the backup medium storing the automatically opening keystore are both stolen, the attacker will be able to read the data even without knowing the passphrase.

If the automatically opening keystore is corrupted or lost, you must again enable automatic opening. The keystore.aks file will be recreated from keystore.ks at this time.



See

.....

Refer to "pgx_rcvall" and "pgx_dmpall" in the Reference for information on the pgx_rcvall and pgx_dmpall commands.

Refer to "psql" under "Reference" in the PostgreSQL Documentation for information on the psql command.

Refer to "[B.2 Transparent Data Encryption Control Functions](#)" for information on the pgx_set_master_key function.

Refer to "[J.5.3 Enabling Automatic Opening of the Keystore](#)" for information on how to enable automatic opening of the keystore.

.....

J.6 Backing Up and Restoring/Recovering the Database

Refer to "[5.8 Backing Up and Restoring/Recovering the Database](#)".

You do not need to back up the Opencryptoki token directory.

J.7 Importing and Exporting the Database

Refer to "[5.9 Importing and Exporting the Database](#)".

J.8 Encrypting Existing Data

Refer to "[5.10 Encrypting Existing Data](#)".

J.9 Operations in Cluster Systems

This section describes how to use transparent data encryption on cluster systems such as high-availability systems, streaming replication, and database multiplexing.

J.9.1 HA Clusters that do not Use Database Multiplexing

Take the following points into account when using transparent data encryption in an HA cluster environment that does not use database multiplexing.

Placement and automatic opening of the keystore file

There are two alternatives for placing the keystore file:

- Sharing the keystore file
- Placing a copy of the keystore file

Sharing the keystore file

This involves using the same keystore file on the primary server and the standby server.

As the standby server is not active while the primary server is running, this file would not be accessed simultaneously, and therefore, it can be shared.

To manage the keystore file in a more secure manner, place it on the key management server or the key management storage isolated in a secure location.

Enable the automatic opening of the keystore on both the primary and standby servers.

Placing a copy of the keystore file

This involves placing a copy of the primary server keystore file on the standby server.

You can do this if you cannot prepare a shared server or disk device that can be accessed from both the primary and standby servers.

However, if you change the master encryption key and the passphrase on the primary server, you must copy the keystore file to the standby server again.

To manage the keystore file in a more secure manner, prepare the key management server or the key management storage isolated in a secure location for both the primary and standby servers, and place the keystore files there.

Enable the automatic opening of the keystore on both the primary and standby servers. Note that copying the automatically opening keystore file (keystore.aks) to the standby server does not enable the automatic opening of the keystore.

J.9.2 Database Multiplexing Mode

Note the following when using transparent data encryption in environments that use streaming replication, or database multiplexing with streaming replication.

Placing the keystore file

Place a copy of the primary server keystore file on the standby server.

This is required as the keystore file cannot be shared, and both servers may need to access it simultaneously.



Point

.....

To manage the keystore file in a more secure manner, place it on the key management server or the key management storage isolated in a secure location. A keystore used by both the primary and standby servers can be managed on the same key management server or key management storage.

However, create different directories for the keystores to be used by the primary server and the standby server. Then copy the keystore for the primary server to the directory used on the standby server.

.....

Automatically opening the keystore

You must enable automatic opening of the keystore.

To do this, enable automatic opening of the keystore in all servers that make up database multiplexing. The settings for automatic opening of the keystore include information unique to each server, so simply copying the file does not enable it.

Changing the passphrase

Changes to the passphrase are reflected in all servers that make up database multiplexing, so no special operation is required.

Building and starting a standby server

Before using the `pg_basebackup` command or `pgx_rcvall` command to build a standby server, copy the keystore file from the primary server to the standby server. When using an automatically opening keystore, use the copied keystore file to enable automatic opening on the standby server.

Open the keystore each time you start the standby server. This step is necessary for decrypting and restoring encrypted WAL received from the primary server. To open the keystore, specify the `--keystore-passphrase` option in the `pg_ctl` command or `pgx_rcvall` command and enter the passphrase, or use an automatically opening keystore.

Changing the master encryption key and the passphrase

Change the master encryption key and the passphrase on the primary server. You need not copy the keystore from the primary server to the standby server. You need not even restart the standby server or reopen the keystore. Changes to the master encryption key and the passphrase are reflected in the keystore on the standby server.



.....

Refer to "pgx_rcvall " in the Reference for information on pgx_rcvall command.

Refer to "pg_ctl" under "Reference" in the PostgreSQL Documentation for information on pg_ctl command.

Refer to "pg_basebackup" under "Reference" in the PostgreSQL Documentation for information on pg_basebackup command.

Refer to "High Availability, Load Balancing, and Replication" under "Server Administration" in the PostgreSQL Documentation for information on how to set up streaming replication.

.....

J.10 Security-Related Notes

Refer to "[5.12 Security-Related Notes](#)".

J.11 Tips for Installing Built Applications

Refer to "[5.13 Tips for Installing Built Applications](#)".

Appendix K Utilize zEnterprise Data Compression (zEDC)

In conjunction with a feature called zEDC, IBM Z enables faster compression and decompression. The functions of zEDC are available by using zlib library and gzip command corresponding to zEDC. This product can use zEDC because it also uses zlib and gzip.

Refer to IBM documentation for zEDC compression characteristics, required hardware, software requirements, and more.

The compression and decompression processes available with zEDC are as follows:

Feature	How to specify compression/decompression operations that enable zEDC	Target
pg_basebackup	The output format is tar and gzip compression is enabled with the -z, --gzip, -Z, and --compress option.	A base backup
pg_dump	Compression of custom-format archive or directory-format archive.	Custom-format archive or directory-format archive
pg_restore	Decompression of custom-format archive or directory-format archive.	Custom-format archive or directory-format archive
pg_receivewal	Compressed by -Z and -compress options.	Received WAL
pgcrypto	<p>The following functions compress with option compress-algo of 1 or 2:</p> <ul style="list-style-type: none"> - pgp_sym_encrypt(data text, psw text [, options text]) returns bytea - pgp_sym_encrypt_bytea(data bytea, psw text [, options text]) returns bytea - pgp_pub_encrypt(data text, key bytea [, options text]) returns bytea - pgp_pub_encrypt_bytea(data bytea, key bytea [, options text]) returns bytea <p>Further, the encrypted compressed data by the above functions is decrypted as follows:</p> <ul style="list-style-type: none"> - pgp_sym_decrypt(msg bytea, psw text [, options text]) returns text - pgp_sym_decrypt_bytea(msg bytea, psw text [, options text]) returns bytea - pgp_pub_decrypt(msg bytea, key bytea [, psw text [, options text]]) returns text - pgp_pub_decrypt_bytea(msg bytea, key bytea [, psw text [, options text]]) returns bytea 	<p>In the encrypt functions, the data argument</p> <p>In the decrypt functions, the msg argument</p>
pgx_dmpall	<p>Compressed by -Z and -compress options in pgx_dmpall command.</p> <p>Compressed by -Z in archive_command.</p>	<p>Backup data</p> <p>Archive logs</p>
pgx_rcvall	Decompression process when restoring compressed backup data.	<p>Backup data</p> <p>Archive logs</p>
pg_rman	<p>When the backup data is compressed with -z or --compress-data option.</p> <p>When restoring compressed backup data.</p>	Backup data

 Note

By default, zEDC is enabled only at compression level 1 of zlib and gzip. If necessary, change the compression level at which zEDC is enabled with the `DFLTCC_LEVEL_MASK` environment variable.

Refer to IBM documentation for more information on zEDC because IBM may change the specification of zEDC.

For `pgcrypto` functions, change the compression level with `compress-level` and specify whether to use zEDC.

For `pg_rman` compression, the default compression level is used. (In general, the default compression level is 6.)

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Security Operation Guide

Preface

Purpose of this document

This document describes security when building and operating a FUJITSU Software Enterprise Postgres (hereinafter referred to as "FUJITSU Enterprise Postgres") database system.

Intended readers

This document is intended for those who are:

- Considering installing FUJITSU Enterprise Postgres
- Designing, building, and operating the security operating environment in FUJITSU Enterprise Postgres
- Accessing FUJITSU Enterprise Postgres database systems

Readers of this document are assumed to have general knowledge of:

- Business operations
- FUJITSU Enterprise Postgres
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of Security](#)

Provides an overview of the security system, and explains the security features provided by FUJITSU Enterprise Postgres.

[Chapter 2 Overview of Security Operation](#)

Provides an overview of security operation.

[Chapter 3 Tasks of the Manager](#)

Explains the tasks for security measures to be implemented by the manager.

[Chapter 4 Tasks of Administrators](#)

Explains the tasks for security measures to be implemented by administrators.

[Chapter 5 Tasks of Users](#)

Explains the tasks for security measures to be implemented by users.

[Chapter 6 Audit Log Feature](#)

Explains the audit log feature provided by FUJITSU Enterprise Postgres.

References

This document contains abstracts from the following document:

- Database Security Guideline Version 2.0
(Database Security Consortium (DBSC))

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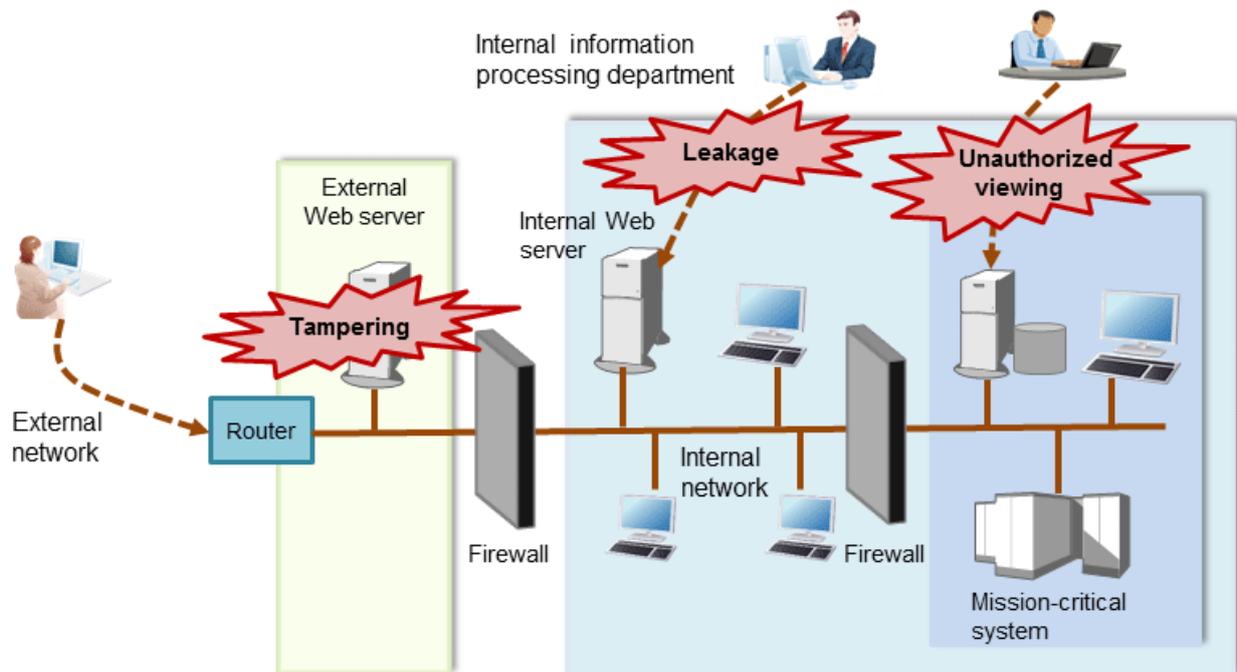
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Chapter 1 Overview of Security

1.1 What is Security?

Computer security is the protection of information systems and data from risks such as leakage or tampering of information, attacks, intrusions, eavesdropping from external sources, and interference with information services. Security measures are essential for the advance prevention of security threats in order for information systems to gain trust as social infrastructure.

Figure 1.1 Security threats



The security measures in information systems can be classified as follows:

- Network
- Web
- Application
- Database
- PC

This document focuses on database security measures when using FUJITSU Enterprise Postgres.

1.2 Security Requirements

Below are the necessary security requirements for information systems.

Maintenance of security policies

A security policy clarifies the approach the company should take in relation to information assets, and the actions employees should take.

It is necessary to undertake security of information systems while maintaining security policies.

Integrated security management

Security has the aspects below. It is necessary to manage information in an integrated manner based on these aspects.

Confidentiality

Access to the information is restricted to prevent leakage of information outside of the company

Example measures: Prevention of information leakage or setup of access privileges

Integrity

Integrity is guaranteed, ensuring information does not become corrupted or tampered with

Example measures: Prevention or detection of tampering

Availability

Failure is prevented and normal operation is maintained so that information can be used when needed

Example measures: Power supply measures, system mirroring

1.3 Security Threats

A security threat is defined as something that threatens the confidentiality, integrity, and availability indicated in "1.2 Security Requirements" in respect to information assets. This includes technical threats such as accessing a database, but does not include physical destruction.

Threats are considered to be a combination of type of user who is the source of the threat, information assets that need to be protected, techniques, and unauthorized actions. For example, a threat might be a general user exploiting a database vulnerability to obtain database management information, and then tampering with that information.

When considering security measures, it is firstly necessary to clarify what kind of threats there are. A list of possible threats is shown in the table below. Refer to "Types of user" and "Information assets" for details on the definition of each type of user and information assets that should be protected.

Possible threats

Type of user	Information asset	Technique	Unauthorized action
General user Internal user System manager System developer System administrator System operator	Database management information	Eavesdropping of packets Dictionary attack of passwords Unauthorized acquisition of IDs/ passwords through social engineering Unauthorized acquisition of information through misuse of settings Unauthorized acquisition of information through exploiting a database vulnerability Acquisition by an unauthorized route	Unauthorized acquisition (viewing) of information Unauthorized tampering or destruction (updating) of information
General user Internal user	General database information	Acquisition by a normal route SQL issued with the aim of obstructing a job	Misuse of information that can be acquired normally (taking data outside of the company) Obstructing a job (resource depletion)
General user Internal user	General database information	Eavesdropping of packets Dictionary attack of passwords Unauthorized acquisition of IDs/ passwords through social engineering	Unauthorized tampering or destruction (updating) of information

Type of user	Information asset	Technique	Unauthorized action
		Unauthorized acquisition of information through exploiting configuration errors	
		Unauthorized acquisition of information through exploiting a database vulnerability	
		Acquisition by an unauthorized route	
System manager System developer System administrator System operator	General database information	Eavesdropping of packets	Unauthorized acquisition (viewing) of information
		Dictionary attack of passwords	
		Unauthorized acquisition of IDs/ passwords through social engineering	Unauthorized tampering or destruction (updating) of information
		Unauthorized acquisition of information through exploiting configuration errors	
		Unauthorized acquisition of information through exploiting a database vulnerability	
		Acquisition by an unauthorized route	
System developer	Database management information	Creation of a backdoor	Unauthorized acquisition (viewing) of information
	General database information		Unauthorized tampering or destruction (updating) of information
System manager System administrator	Database management information	Unauthorized acquisition of information by creating an unauthorized database administrator account	Unauthorized acquisition (viewing) of information
	General database information		Unauthorized tampering or destruction (updating) of information
System manager System operator	Database management information	Unauthorized acquisition of information by tampering with database-related files (definition file, physical file, and so on)	Unauthorized acquisition (viewing) of information
	General database information		Unauthorized tampering or destruction (updating) of information
Database administrator	Database management information	Misuse of information (taking information outside of the company) after obtaining it through the normal route	Misuse of information that can be acquired normally (taking information outside of the company)
		Unauthorized use of IDs/ passwords from the management information	Tampering with or destroying information that can be acquired
		Unauthorized acquisition of information by tampering with management information	

Type of user	Information asset	Technique	Unauthorized action
		SQL issued with the aim of obstructing a job	Obstructing a job (resource depletion)
	General database information	Eavesdropping of packets	Unauthorized acquisition (viewing) of information
		Misuse of information (taking information outside of the company) after obtaining it through an unauthorized route	Unauthorized tampering or destruction (updating) of information
Database operator	Database management information	Eavesdropping of packets	Unauthorized acquisition (viewing) of information
		Dictionary attack of passwords	Unauthorized tampering or destruction (updating) of information
		Unauthorized acquisition of IDs/ passwords through social engineering	
		Unauthorized acquisition of information by exploiting configuration errors	
		Unauthorized acquisition of information through exploiting a database vulnerability	
		Acquisition by an unauthorized route	
	Acquisition by a normal route	Misuse of information that can be acquired normally (taking data outside of the company)	
	General database information	SQL issued with the aim of obstructing a job	Obstructing a job (resource depletion)

Types of user

In database security, the persons involved with databases and their roles are defined below.

Type of user	Role
System manager	Manages developers, administrators, and operators
System developer	Builds the network around the database server Builds the database server
System administrator	Operates devices of the surrounding database network Operates the database server
System operator	Operates the surrounding database network
Database administrator	Builds the database system Operates the database system
Database operator	Performs business operations
Internal user	End user inside the company
General user	End user outside the company

Information assets

In database security, it is necessary to protect the information assets to be stored on the database server.

Such assets are defined below.

Database management information

- Database configuration information (system catalog, user ID/password, and so on)
- Database logs (such as access logs)

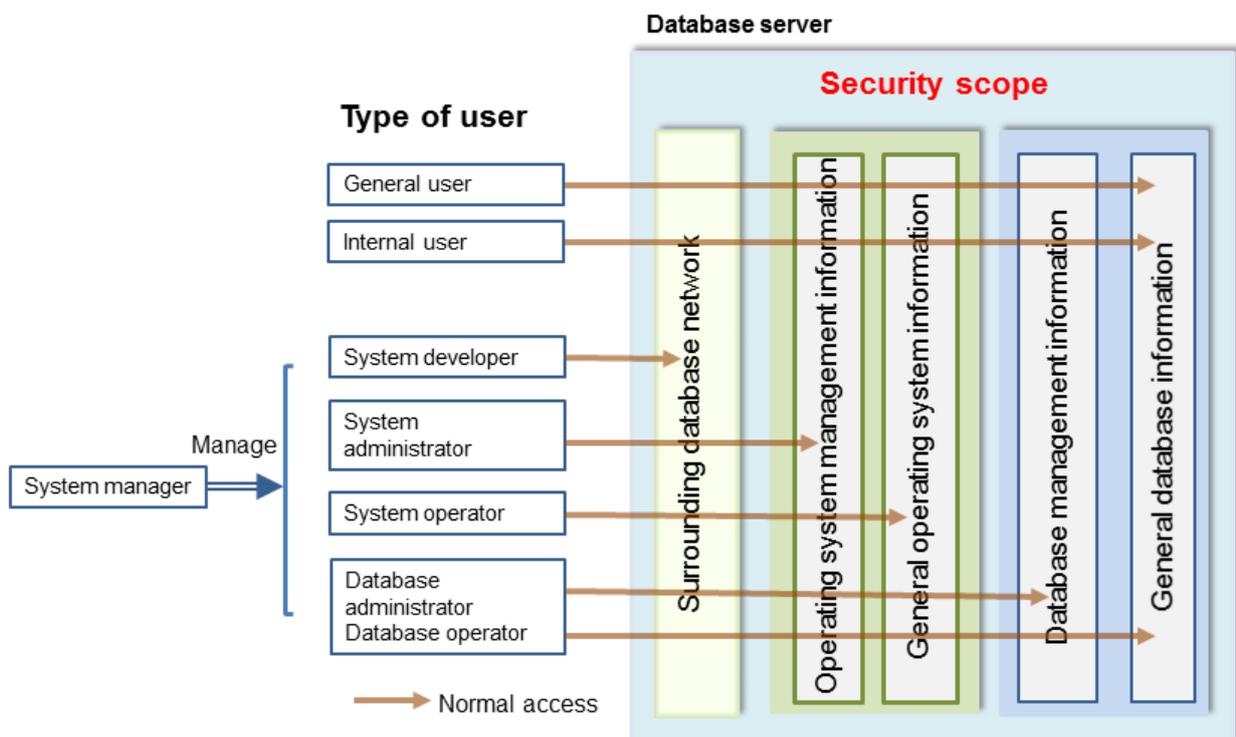
General database information

- Job data
- Applications

1.4 Security Scope

In database systems, both the database server and the surrounding database network are part of the security scope. It is necessary to clarify the extent of the security scope that each type of user is involved with, and consider security measures for the same.

The relationship of the security scope and the types of user is shown below.



1.5 Security Provided by FUJITSU Enterprise Postgres

FUJITSU Enterprise Postgres provides security features that satisfy the security requirements indicated in "[1.2 Security Requirements](#)".

This section describes security provided by FUJITSU Enterprise Postgres.

1.5.1 Roles Targeted For Security

In FUJITSU Enterprise Postgres database systems, the roles targeted in relation to security are "Manager", "Administrator", and "User". In order to build a robust security system, it is necessary to put security measures in place for each role.

The roles targeted for security and the mapping of [Types of user](#) indicated in "[1.3 Security Threats](#)" are shown in the table below.

Role targeted for security	Type of user
Manager	System manager
Administrator	System developer
	System administrator
	System operator
	Database administrator
	Database operator
User	General user
	Internal user

Manager

The manager establishes a security policy and decides on an operations policy for the organization as a whole.

Refer to "[Chapter 3 Tasks of the Manager](#)" for details.

Administrator

Administrators design, build and operate a system. While doing this, the administrators must implement the security measures in accordance with the security policy established by the manager.

Refer to "[Chapter 4 Tasks of Administrators](#)" for details.

User

A user is a person other than the manager or an administrator who accesses a database. There may be any number of users. It is necessary for users to be registered in the database system, and that access to the database is restricted according to the access privileges.

Refer to "[Chapter 5 Tasks of Users](#)" for details.

1.5.2 Security Features

FUJITSU Enterprise Postgres provides the following security features:

- Authentication
- Access control
- Encryption
- Audit log
- Data masking

This section describes each of these features.

Authentication

The databases that can be accessed can be restricted by authenticating the database users who access the database. Additionally, authentication of the server can be performed to prevent spoofing of the database server.

Refer to "Client Authentication" in "Server Administration" in the PostgreSQL Documentation for details on authentication.

Refer to "Secure TCP/IP Connections with SSL" in "Server Setup and Operation" in the PostgreSQL Documentation for details on server authentication.

Access control

Database objects can only be used by the object creator or database user who was specified as the owner when the object was created (both persons are hereinafter referred to as "owner"), or instance administrator, when objects are in their initial state. By having the object owner

or instance administrator control access privileges for database users, it is possible to control what kind of tables the database users who connect to the database can access, and what kind of operations they can perform.

Refer to "Privileges" in "The SQL Language" in the PostgreSQL Documentation for details on object access control.

Encryption

FUJITSU Enterprise Postgres provides a transparent data encryption feature that satisfies the requirements below.

- Confidential information can be changed into an unidentifiable state.
- The encryption key and data are managed separately.
- The encryption key is replaced at regular intervals.

PostgreSQL provides an encryption feature called "pgcrypto" that can also be used in FUJITSU Enterprise Postgres, however, it is recommended to use the transparent data encryption features because it will otherwise be necessary to modify the applications that consider encryption. Refer to "Protecting Storage Data Using Transparent Data Encryption" in the Operation Guide for details.

Additionally, if communication data transferred between a client and a server contains confidential information, it is necessary to encrypt the communication data to protect it against threats, such as eavesdropping on the network.

Refer to "Configuring Secure Communication Using Secure Sockets Layer" in the Operation Guide for details on encryption of communication data.

Audit log

A feature that addresses threats such as misuse of administrator privileges, unauthorized access to a database by a user, and other such threats. Information for tracing the processing of administrators and users is retrieved and stored as an audit log.

By periodically viewing and monitoring audit logs, the administrators can detect events that are impacting on the system in some way, or are depleting system resources as a result of incorrect operations by users, and can take appropriate measures to prevent information leakages or system failures in advance.

Refer to "[Chapter 6 Audit Log Feature](#)" for details.

Data masking

A feature that changes part of the data to make it available for reference in response to queries issued by an application.

For example, for a query of employee data, digits except the last four digits of an eight-digit employee number can be changed to "*" so that it can be used for reference without exposing the actual data.

Specifically, the data changed by the data masking feature can be transferred to a test database so that users who perform testing or development can reference the data. During testing, it is desirable to use the data that will be used on a production environment database. However, actual production data should not be used as is for testing because of the risk of leakage of confidential data. This feature enables data that is similar to actual production data to be safely used in test and development environments.

Refer to "Data Masking" in the Operation Guide for details on data masking.

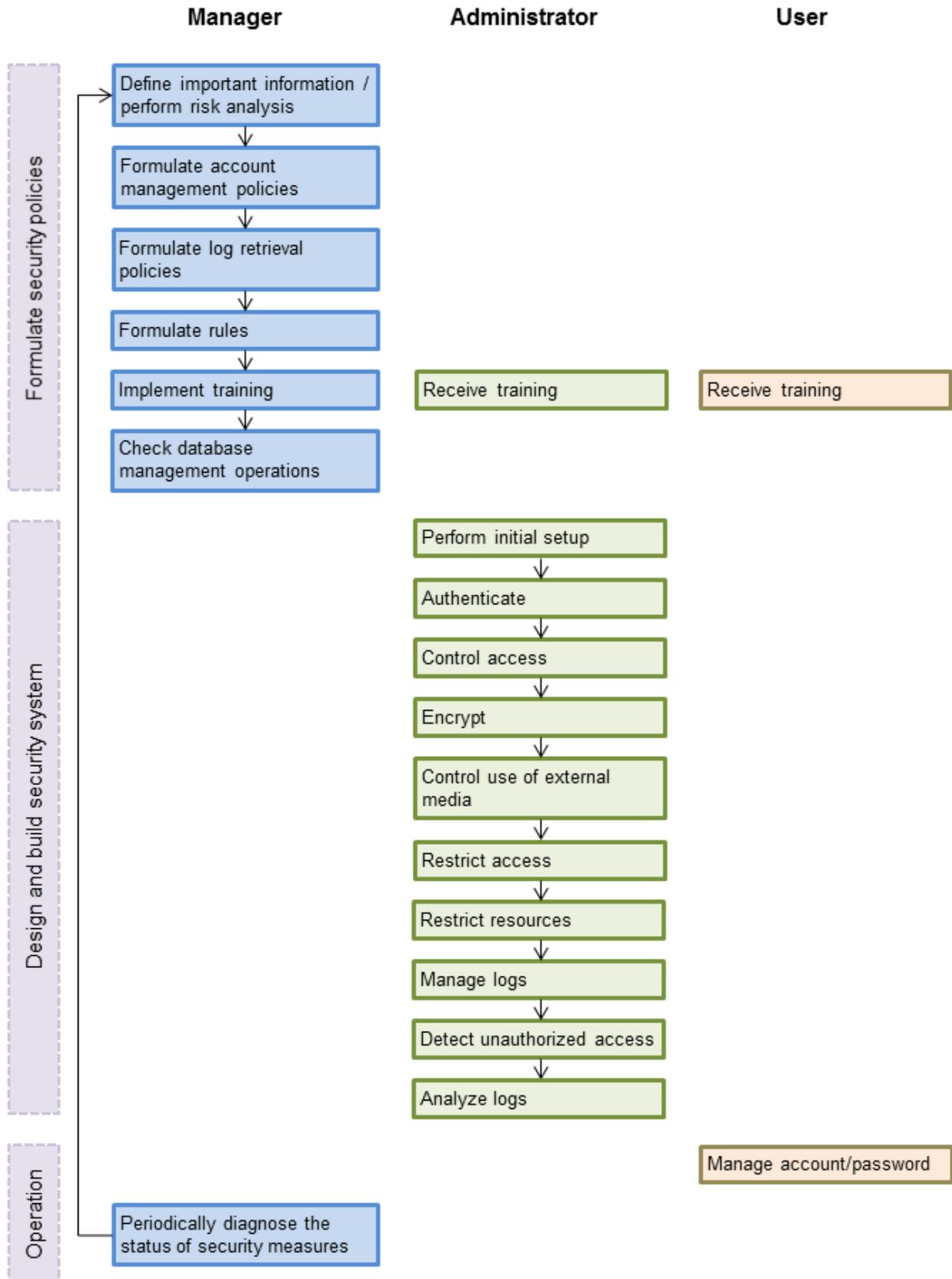
Chapter 2 Overview of Security Operation

2.1 Security Operation Flow

This section shows the flow of work when building a security environment and performing security operation in FUJITSU Enterprise Postgres.

When performing security operation, there are technical measures to be implemented to address security threats by equipping the system with security features, and manual work, such as the implementation of security guidelines, a training system, and the establishment of usage rules.

Figure 2.1 Security operation flow



Chapter 3 Tasks of the Manager

The manager formulates security policies, which become guidelines for security measures.

3.1 Defining Important Information and Risk Analysis

Before formulating security policies, define important information and perform risk analysis. Based on the importance of the information and the result of risk analysis, decide what kind of security measures to put in place.

In defining the important information, identify what should be protected and classify it by importance in order to effectively implement the security measures. Information that should be protected includes "database management information" and "general database information", as indicated in "[Information assets](#)". Examples of information classifications are "personal information" and "confidential information".

In the risk analysis, refer to "[Possible threats](#)" to identify threats that may arise, and analyze the risks in respect to such threats.

Additionally, by performing a risk analysis once annually as a guide, it is possible to identify threats that may adversely impact the business and related vulnerabilities.

3.2 Formulating Account Management Policies

In formulating an account management policy, implement the following and document the formulated policy.

Organize system users and roles

Identify the necessary roles of the relevant system based on "[Types of user](#)". Additionally, organize personnel for each role.

Organize accounts

Organize accounts with the appropriate privileges for each role, and decide on account policies.

- Database administrator account
 - Organize separate accounts for database administrators and database operators
 - Ensure that the database administrator account can only be used by specific persons
 - Perform tasks that do not require database administrator privileges using a separate account without database administrator privileges
- General account

Create an account for general users by application usage.

Review account management policy

Review the accounts in order to effectively implement security measures.

- Regularly check the accounts mentioned above and their privileges, and determine if they are still appropriate
- If there have been system or operational changes, review the accounts and privileges
- If unsuitable accounts and privileges are discovered, modify them as required

3.3 Formulating Log Retrieval Policies

In formulating a log retrieval policy, implement the following and document the formulated policy.

Organize the purpose of log retrieval

To clarify what logs will be retrieved for, define their reason for retrieval.

Examples of the purpose might include, "To use for investigation in the event of unauthorized access", and "To submit to investigating authorities as evidence if any issues arise".

Decide on the types of logs to be retrieved

In order to retrieve appropriate logs, organize the types of logs that can be retrieved in the target system, and decide on the logs to be retrieved.

Examples of log types are "operating system logs", "application run logs", and "database audit logs".

Organize log retrieval target access

In order to decide on access for log retrieval targets, organize what kind of access will take place.

For example, the following access is possible:

- Access related to important information
 - Access to personal information, confidential information, and database management information
 - Access outside of business hours
 - Login
 - Specific SQL
- Access suspected to be unauthorized
 - Large amount of search access
 - Access from different locations
 - Access outside of business hours

Decide on the log retrieval content

In order to effectively use retrieved logs, organize the required content as a log, and decide on the retrieval content.

For example, the following output content is possible:

- When (time)
- Who (database account, application user)
- What (object ID, table name)
- Where from (machine name, IP address)
- How (SQL type, SQL statement)
- Execution result (success/fail)

Formulate log maintenance policy

In order to use the logs as purposed, formulate the log maintenance policy.

For each log, define its location, storage medium, retention period, access control, and so on.

3.4 Formulating Rules

Formulate the rules that will become the standard for security measures of the target system. Additionally, prescribe penalties for security violations. For example, formulate rules and penalties as below:

- Rules
 - Applying security patches and update programs
 - Prohibiting unauthorized acquisition of information from the database
 - Prohibiting the saving of acquired information to media that is not permitted for use
- Penalties
 - Prescribe penalties in the company's employment policies and procedures

- Set fines

3.5 Implementing Training

In order to have administrators and users recognize the importance and necessity of information security, and to prevent unauthorized access due to operational omissions and mistakes, implement and promote security-related training for administrators and users.

For example, implement promotion of security policies, formulation of training schedules, and formulation of training materials.

3.6 Checking the Database Management Operations

In order to prevent operational errors and unauthorized actions by administrators, implement the measures below:

- Always collect the latest information on security incidents and vulnerabilities related to databases
- Implement management operations only after providing advance notice
- Retain records of management operations

3.7 Periodic Diagnosis of the Status of Security Measures

In order to check if the security measures are effective, periodically diagnose if the security measures have been put in place appropriately based on the security threats.

Additionally, evaluate if the current security measures and policies are effective for the threats and vulnerabilities, and if there are any issues, review the security policies and security measures.

Chapter 4 Tasks of Administrators

Administrators perform the actions below as security measures when designing, building, and operating the system in accordance with the security policies formulated by the manager.

Preparation

- Implement training

Measures to protect against unauthorized behavior

- Perform initial setup
- Authenticate
- Control access
- Encrypt
- Control use of external media
- Restrict access
- Restrict resources

Measures to detect and trace unauthorized behavior

- Manage logs
- Detect unauthorized access
- Analyze logs

4.1 Receiving Training

Administrators receive security-related training in accordance with the training schedule formulated by the manager. Additionally, administrators instruct users to receive training.

4.2 Initial Setup

To minimize database vulnerabilities and the possibility of unauthorized access, implement the security measures below in the initial stage of system building. Additionally, configure the database server so that it primarily operates the database system only.

Making the server more robust

Configure the operating system and network to prevent intrusion into or destruction of a database server, so that the system operates on a secure server.

- Remove unnecessary features or services on the operating system
- Enable only the necessary protocols
- Implement the security features for services, protocols, and daemons considered to have a relatively low security level, such as file sharing and FTP

Installing the latest version

Always download and apply the latest patches in order to reflect the latest security measures.

Installing the minimum necessary features

Install only the necessary features in order to prevent unauthorized use of the system.

Additionally, delete or disable features and services that will not be used.

Changing the port

To prevent unauthorized use of the system, change the default port that is set during installation.



Specify the port during setup of FUJITSU Enterprise Postgres. Refer to the Installation and Setup Guide for Server for details.

Access restrictions for communication features

To prevent unauthorized use of the system using the communication features, implement access restrictions for communication features.

Settings for prohibiting the access path to database configuration files

To prevent database destruction, implement the measures below:

- Restrict users who are permitted to access database configuration files, and periodically review the permissions
- Allow only administrators to access table or definition scripts

Restrictions on the access path to the database

To prevent unauthorized use or operating errors for the database, restrict the distribution range of applications used to access the database only to devices used by users who are permitted access.

Dealing with unauthorized programs

To prevent unauthorized intrusions into a system through a backdoor, such as by tampering with the program source code of an application, document the author of the program to be run and perform checking and testing so that the program will not be tampered with. Additionally, employ safe coding techniques so that issues with general coding vulnerabilities can be addressed.

System security settings

In cases where it is clear that the system security settings will impact security, set reliable security settings in the initial setup stage, such as setting appropriate security parameters.

4.3 Authentication

When accessing a database, authentication must always be performed in order to prevent tampering or information leakage from spoofing by a malicious user.

Password authentication is used when logging on to a database, and the account and password used for authentication are to be strictly managed by administrators.

Additionally, authentication must also be implemented reliably for connections to a database from clients, so that only permitted users can access the database.

4.3.1 Managing Accounts

For account management, perform the actions below.

Create the required accounts

To prevent unauthorized use of accounts, such as spoofing, implement the measures below when creating an account:

- Select the required account
- Specify the user privileges
- Create database administrator accounts and general user accounts separately according to the privileges



Accounts are created using the CREATE ROLE statement. Refer to "CREATE ROLE" in the PostgreSQL Documentation for details.

Delete unnecessary accounts

Remove accounts not used on a daily basis, such as unused accounts and accounts not needed for operations that are created by default during product installation.

Point

Accounts are deleted using the `DROP ROLE` statement. Refer to "DROP ROLE" in the PostgreSQL Documentation for details.

Set up account lockout

The usage frequency of accounts is to be checked periodically, and if there are any accounts that have not been used for a long period, lock those accounts. Set a limit for failed login attempts, and if this limit is exceeded, lock the account. Additionally, set the period until a locked account is reenabled.

Point

Account locking can be performed by using LDAP authentication. Refer to "LDAP Authentication" in the PostgreSQL Documentation for details.

Manage database administrator accounts

Manage database administrator accounts in accordance with the account management policy formulated by the manager.

Manage development environment and production environment accounts

To prevent unauthorized use of accounts used in a development environment, delete accounts used in the development environment before operation starts in the production environment. In cases where it is unavoidable to use an account used in the development environment in the production environment, use different passwords in each environment.

Set up a temporary use account

If a temporary user will use the system, either provide a shared account with a temporary password for each use, or create a temporary account.

4.3.2 Managing Passwords

Manage passwords as below.

Make strong passwords

The use of account passwords that can easily be guessed by others, such as a password that matches the ID, or the default password provided during installation, is prohibited. Set a complex and strong password.

Change passwords regularly

Change passwords regularly to prevent others from accessing the account in case the password is obtained by unauthorized means. Additionally, configure the settings to force a password change when prompted after the first use.

Set the password expiry period

To encourage regular changing of passwords, set a password expiry period.

Point

Password setting and changing is specified using the `CREATE ROLE` statement or `ALTER ROLE` statement. Refer to "CREATE ROLE" and "ALTER ROLE" in the PostgreSQL Documentation for details.

Additionally, by using `passwordcheck` and LDAP authentication, the actions below can be performed:

- The default password set during installation can be changed
- The password expiry period can be set
- The number and types of characters used for the password can be checked

Refer to "passwordcheck" and "LDAP Authentication" in the PostgreSQL Documentation for details.

4.3.3 Configuring Connections and Authentication

Configure connections and authentication so that the database can only be accessed by permitted users.

Point

Client authentication is configured in `pg_hba.conf`. Refer to "Client Authentication" in the PostgreSQL Documentation for details.

4.4 Access Control

If appropriate access privileges are not set for administrators and users, security incidents may occur, such as information leakage resulting from access to information by an unauthorized person. To minimize such incidents, it is necessary to implement the security measures below for the access privileges and perform rule-based access control.

Point

Notes when setting access privileges

- The creation of a special account that allows granting of privileges to all users is prohibited
- The creation of a general account that allows access to general information such as operations data is prohibited

Identifying the database access requirements

To set the appropriate access privileges for each usage purpose for the database, follow the procedure below to identify the access requirements:

1. Classify the usage purpose of the account, such as "For database management", "For object management", and "For data access".
2. Classify the required privileges for each usage purpose, such as "By feature" and "By object".
3. Categorize the accounts based on each privilege.
4. Identify the minimum necessary range of data and minimum necessary access content (view, update, create, delete) to be accessed for each categorized account, and decide on the database access requirements.

Setting the access privileges

Assign the minimum necessary privileges based on the database access requirements for each categorized account. Additionally, restrict accounts when assigning administrator privileges.

Reviewing access privileges

To reflect changes in access requirements in the system, periodically review the access privileges and check if there are any access privileges that are no longer needed. If any unnecessary access privileges have been set, promptly modify the access privileges.

Point

Access privileges are set using the `GRANT` statement or `REVOKE` statement. Refer to "GRANT" and "REVOKE" in the PostgreSQL Documentation for details.

4.5 Encryption

To prevent unauthorized usage of data in the event information leakage occurs due to data theft, eavesdropping of communication, and other such activities, implement the encryption measures below.

Encrypt communication

To protect data from eavesdropping over the network between a database server and clients, use the encryption feature to encrypt communications.

Refer to "Configuring Secure Communication Using Secure Sockets Layer" in the Operation Guide for details.

Encrypt data

To protect data from theft, use the encryption feature to encrypt the data. The data below is targeted for encryption:

- Data to be stored on the database
- Backup data
- Data files

Refer to "Protecting Storage Data Using Transparent Data Encryption" in the Operation Guide for details.

Manage encryption keys

Restrict the persons who can access the encryption key to a minimum number of database administrators.

Additionally, to ensure the encrypted information will not be easily decrypted, create a mechanism for appropriately managing the encryption key for the entire life cycle (generation, distribution, saving, and disposal), and strictly manage the encryption key.

Refer to "Configuring Secure Communication Using Secure Sockets Layer" and "Protecting Storage Data Using Transparent Data Encryption" in the Operation Guide for details.

4.6 Controlling Use of External Media

Information leakage can be prevented by controlling use of external media (such as CD/DVD, USB drive, and external hard disk) and PCs that are connected to the database, and restricting the removal of data from the database.

Restricting connection of external media

Remove external media and printers that will not be used in operations, and restrict connection of external media to which information may be written.

Restricting use of external media

Restrict connections for external media and printers to control the writing of information to these devices.

Controlling use of connected PCs

Prevent leakage of information from PCs connected to the database:

- Limit connections of external media to PCs
- Implement security measures to make the PC robust
- Implement individual authentication for access from the PC
- Manage the installed software and monitor the software usage status
- Limit connections to printers

4.7 Security Measures for Servers/Applications

An even more robust security system can be achieved by strengthening security for servers and applications in addition to the security measures for databases. Implement the security measures below for servers and applications:

Restrict access

Implement the measures below and restrict access to the database server:

- Install the database server inside the firewall to prevent direct access to the database server from many unspecified PCs.
- In the local network, implement measures such as using the router to restrict IP addresses, and restrict PCs and segments that can directly access the database server.

Restrict resources

Restrict excessive use of CPU resources by general users to prevent the disruption of service and extraction of large amounts of data.

4.8 Log Management

Logs are a feature that addresses threats such as misuse of administrator privileges, and unauthorized access to a database by a user. Information for investigating/tracing processes and operations performed for the database is retrieved and managed as logs for identifying the cause in the event information leakage or unauthorized access occurs.

FUJITSU Enterprise Postgres provides the audit log feature for retrieving and managing logs. Refer to "[Chapter 6 Audit Log Feature](#)" for details.

This section describes the information that should be obtained as logs and how to maintain logs, as a measure for managing information leakage and unauthorized access.

4.8.1 Retrieving Logs

The audit logs below are retrieved in accordance with the log retrieval policy formulated by the manager.

Login information

Retrieves logs during login and logout.

Database access information (view/update)

Retrieves all access relating to the information below:

- General database information (such as personal information and confidential information used in the business)
- Database management information (system catalog, user ID/password, and so on)

Changed information of database objects

Retrieves logs related to creating, changing, and deleting database objects such as database accounts and tables.

Operation logs for audit logs

To prevent suppression of retrieved audit logs, operations such as initialization of audit logs, and stoppage of the audit log feature are retrieved as logs.

4.8.2 Maintaining Logs

Logs are maintained in accordance with the log retrieval policy formulated by the manager.

Storing logs

Perform the actions below and store logs securely so that the retrieved logs will not be updated by others:

- Save logs to external media, and store the external media in a secure location, such as lockable storage
- Restrict the viewing of logs to administrators only, and set access restrictions for logs, such as not assigning update rights
- Decide on the log retention period, with consideration to cases where investigation tracing back to the time of discovery of an issue is required

Preventing tampering of logs

Implement measures to prevent tampering of logs, such as retaining multiple copies of logs and using storage that cannot be rewritten.

Encrypting logs

Encrypt logs so that logs are not easily viewed.

4.9 Detecting Unauthorized Access

To address unauthorized access, it is necessary to establish a mechanism for detecting unauthorized access to databases and monitor access.

Communicating unauthorized access

Create a mechanism that notifies of detected unauthorized access, such as notifying the manager and the administrator, if an account lock occurs due to the limit for failed login attempts being exceeded.

Checking access times

Create a mechanism that can check for suspicious access to the information below outside of normal access hours, together with implementing measures to address such access.

Detecting access to database management information

- Monitor logs and detect access during timeframes that have not been applied for
- In the event a request for access permission outside of normal access hours is made, the log is checked for any discrepancies in the requested content and work result

Detecting access to general database information

- Decide on the timeframes during which access to the database is permitted for each general account
- Detect access outside of normal access hours from session information logs

Checking the connection source where access is not permitted

To detect access from connection sources that are not permitted, define the sources from where access is permitted, and detect access from connection sources that are not permitted.

Define the access patterns (connection source, operating system user and account) of database administrator accounts and general accounts, and check for access outside of these patterns.

4.10 Analyzing Logs

Create a mechanism that analyzes logs to detect unauthorized behavior in cases where information leakage, unauthorized access, or other such activity, is suspected. Analyses should include those shown below.

Periodic analysis of session information

Analyze session information of logs from the perspectives below to detect unauthorized logins:

- Trend of sessions with a large number of failed login attempts
- Trend of sessions with accounts that are logged in for long periods of time
- Trend of sessions in which a large amount of resources are used

Periodic analysis of database access information

Analyze SQL statements from the perspectives below to detect unauthorized access to the database:

- Trend of SQL being executed over a long period of time
- Trend of SQL using a large amount of resources

Chapter 5 Tasks of Users

The user performs the actions below as security measures when using the system.

5.1 Receiving Training

The user must receive security-related training as instructed by the manager or the administrator to learn about security. By having users with a common awareness relating to security, an even more stable security system can be established.

5.2 Managing Accounts/Passwords

Users can use the database system by using the account and password provided by the administrator. At such times, the user is to implement the measures below so that the account and password are not misused by others:

- Be responsible for managing the ID and password in a manner that ensures the account does not become locked during login
- Change the password regularly
- Comply with the expiry period set for the password by promptly changing the password when it is about to expire

Chapter 6 Audit Log Feature

In PostgreSQL, logs output as server logs can be used as audit logs by using the log output feature. There are, however, logs that cannot be analyzed properly, such as SQL runtime logs, which do not output the schema name. Additionally, because the output conditions cannot be specified in detail, log volumes can be large, which may lead to deterioration in performance.

The audit log feature of FUJITSU Enterprise Postgres enables retrieval of details relating to database access as an audit log by extending the feature to pgaudit. Additionally, audit logs can be output to a dedicated log file or server log. This enables efficient and accurate log monitoring.



Note

The audit log feature cannot be used if PostgreSQL is running in single-user mode.

6.1 Audit Log Output Modes

In pgaudit, the two types of audit log below can be output.

Session Audit Logging

Session Audit Logging outputs information related to SQL executed in backend processes (processes generated when connection requests are received from clients), information related to starting and connecting databases, and information related to errors, as a log. In Session Audit Logging, by specifying the log output conditions and filtering the logs to be output, performance degradation due to outputting large volumes of logs can be prevented.

Refer to "[6.4 Session Audit Logging](#)" for details.

Object Audit Logging

When SELECT, INSERT, UPDATE, and DELETE are executed for specific objects (tables, columns), Object Audit Logging outputs these as a log. TRUNCATE is not supported. Object Audit Logging outputs object operations for which privileges have been assigned to specified roles, as a log. Object Audit Logging can control log output at an even finer level of granularity than Session Audit Logging.

Refer to "[6.5 Object Audit Logging](#)" for details.



Information

Depending on the application or command, FUJITSU Enterprise Postgres may execute SQL internally and the audit logs may be retrieved.

Also, the audit logs of multiple SQLs with the same statement ID may be retrieved. This is because before the user executes the SQL, another SQL is executed internally by FUJITSU Enterprise Postgres.

6.2 Setup

This section describes the setup method of pgaudit.

1. Copy the pgaudit files

As superuser, run the following command. Note that "<x>" in paths indicates the product version.

```
$ su -  
Password: *****  
# cp -r /opt/fsepv<x>server64/OSS/pgaudit/* /opt/fsepv<x>server64
```

2. Create the pgaudit configuration file

Create the pgaudit configuration file, which describes the information required for pgaudit actions. Create the file using the same encoding as used for the database.

In addition, set write permissions for the database administrator only in the pgaudit configuration file so that policies related to the audit log are not viewed by unintended users.

Refer to "6.3 pgaudit Configuration File" for details.

Note

Do not define the rule section in the pgaudit configuration file at this point.

Example of a pgaudit configuration file

```
[output]
logger = 'auditlog'
```

3. Configure postgresql.conf

Configure the parameters below in postgresql.conf to use audit logs:

shared_preload_libraries

Specify "pgaudit".

pgaudit.config_file

Specify the deployment destination path of the pgaudit configuration file.

If a relative path is specified, the path will be relative to the data storage directory.

log_replication_commands

Specify "on".

log_min_messages

Check if "ERROR" or higher has been specified.

If outputting an audit log to a server log ("serverlog" is specified in the logger parameter of the pgaudit configuration file), check the parameters below relating to server logs.

logging_collector

Check if "on" has been specified.

log_destination

Check if "stderr" has been specified.

log_file_mode

Check if the server log permissions are appropriate, so that only the permitted persons can access it.

Information

The default for the log_file_mode parameter is 0600, which only allows the database administrator to have access.

For example, to permit other members of the group to which the database administrator belongs to view the audit logs, specify 0640 for log_file_mode.

Example

```
log_file_mode = 0640
```

The database administrator can also be prevented from viewing audit logs by specifying 0000. However, write privileges are assigned for outputting logs.

If outputting an audit log to a dedicated log file ("auditlog" is specified in the logger parameter of the pgaudit configuration file), check the parameter below.

max_worker_processes

If the max_worker_processes parameter has been set, add 1 to the specified value.



Refer to "Error Reporting and Logging" in the PostgreSQL Documentation for details on server logs.

If using database multiplexing, refer to "6.6 Database Multiplexing" for details.

Example of postgresql.conf

In the example below, only the parameters that need to be configured when using the audit log feature are described.

```
shared_preload_libraries = 'pgaudit'  
pgaudit.config_file = 'pgaudit.conf'  
log_replication_commands = on  
log_min_messages = WARNING
```

4. Start the instance

Start the instance and check if the message below is output.

```
LOG: pgaudit extension initialized
```

5. Create the pgaudit extension

Execute CREATE EXTENSION to create the pgaudit extension.

```
$ psql  
=# CREATE EXTENSION pgaudit;  
=# \dx  
                List of installed extensions  
Name          | Version | Schema  | Description  
-----+-----+-----+-----  
pgaudit       | 1.0     | public  | provides auditing functionality  
plpgsql       | 1.0     | pg_catalog | PL/pgSQL procedural language  
(2 rows)
```

6. Configure the parameters in the pgaudit configuration file

Add or change the parameters in the pgaudit configuration file as required.

Refer to "6.3 pgaudit Configuration File" for details.

7. Restart the instance

Restart the instance to apply the changes to the pgaudit configuration file. After restarting, check if the changes have been reflected correctly.

```
LOG: log_catalog = 1  
LOG: log_level_string =  
LOG: log_level = 15  
LOG: log_parameter = 0  
LOG: log_statement_once = 0  
LOG: role =  
LOG: logger = auditlog  
LOG: log_directory = pgaudit_log  
LOG: log_filename = pgaudit-%Y-%m-%d_%H%M%S.log  
LOG: log_file_mode = 0600  
LOG: log_rotation_age = 1440  
LOG: log_rotation_size = 10240  
LOG: log_truncate_on_rotation = 0  
LOG: fifo_directory = /tmp
```

```
LOG: Rule 0
LOG: pgaudit extension initialized
```

6.3 pgaudit Configuration File

In the pgaudit configuration file, specify the information required for pgaudit actions. The pgaudit configuration file comprises three sections: "output section", "option section", and "rule section".

output section

The output section is specified using the format below:

- *paramName* = 'value'

The valid parameters in the output section are shown in the table below.

Parameter name	Description	Remarks
logger	Dedicated log file (auditlog)/ <i>serverLog</i> (serverlog) that will be the output destination of the audit log The default is "auditlog" (dedicated log file).	The dedicated log file is output using the same encoding as used for the database.
log_directory	Directory where the audit log is to be created Specify the full path or the relative path from the data storage directory. The default is "pgaudit_log".	Enabled only if "auditlog" is specified for the logger parameter
log_filename	File name of the audit log Specify a file name that varies according to the time, in the same manner as for log_filename in the postgresql.conf file. The default is "pgaudit-%Y-%m-%d_%H%M%S.log".	Enabled only if "auditlog" is specified for the logger parameter
log_file_mode	Specify the permissions of the audit log so that only permitted persons can access it. The parameter value is the numeric mode specified in the format permitted in chmod and umask system calls. The default is "0600". Refer to "log_file_mode" in "6.2 Setup" for information on audit log file permissions.	Enabled only if "auditlog" is specified for the logger parameter
log_rotation_age	Maximum age of the audit log file A new audit log file is generated when the time (minute units) specified here elapses. To disable generation of new log files based on time, specify "0". The valid units are "min" (minutes), "h" (hours), and "d" (days). If the unit is omitted, "min" will be used. The default is "1d" (1 day).	Enabled only if "auditlog" is specified for the logger parameter
log_rotation_size	Maximum size of the audit log file A new log file will be generated after logs of the size specified here are output to a log file. To disable generation of new log files based on size, specify "0". The valid units are "kB" (kilobytes), "MB" (megabytes), and "GB" (gigabytes). If the unit is omitted, "kB" will be used.	Enabled only if "auditlog" is specified for the logger parameter

Parameter name	Description	Remarks
	The default is "10MB".	
log_truncate_on_rotation	If rotating audit log files based on time, this parameter is used to specify whether to overwrite (on)/not overwrite (off) existing audit log files of the same name. For example, if "on" is specified, and "pgaudit-%H.log" is specified for log_filename, 24 separate log files will be generated based on time, and those files will be cyclically overwritten. The default is "off". If "off" is specified, the logs will be written to the existing audit log files.	Enabled only if "auditlog" is specified for the logger parameter
fifo_directory	FIFO (named pipe) directory to be used between the daemon process that outputs audit log files and the backend process FIFO named p.PGAUDIT.nnnn (nnnn is the postmaster PID) are created in the fifo_directories directory. The files cannot be deleted manually. The default is "/tmp".	Enabled only if "auditlog" is specified for the logger parameter

Information

If the logger parameter is set to "serverlog", audit logs will be output to the server log as log messages, therefore the status information and message severity level according to the log_line_prefix parameter in postgresql.conf will be output to the beginning of the audit log.

If the logger parameter is omitted or set to "auditlog", audit logs will be output to a dedicated log file as dedicated logs, therefore the status information and message severity level according to the log_line_prefix parameter in the postgresql.conf file will not be output.

Refer to "Output format" in "6.4 Session Audit Logging" or "Output format" in "6.5 Object Audit Logging" for information on the output format of audit logs.

Point

The pgaudit log_file_mode configuration parameter setting is separate from, and unaffected by, the log_file_mode GUC parameter setting and the -g/-allow-group-access initdb option.

When using a dedicated pgaudit log file, since the pgaudit log_directory location defaults to inside the data storage directory, it is possible for the pgaudit log_file_mode permissions to conflict with the intended file permissions specified by the -g/-allow-group-access initdb option. In this case, the pgaudit log_directory should be specified to be a directory located outside of the data storage directory.

option section

The option section is specified using the format below:

```
- paramName = 'value'
```

The valid parameters in the option section are shown in the table below.

Parameter name	Description	Remarks
role	Name of roles used in Object Audit Logging If specifying a name containing uppercase characters, key words, multibyte characters and commas, enclose the name in double quotation marks.	Parameter used in Object Audit Logging only

Parameter name	Description	Remarks
log_catalog	Whether to enable (on)/disable (off) log output for pg_catalog Specify "off" if you do not want to retrieve audit logs that access pg_catalog. The default is "on" (enabled).	
log_parameter	Whether to enable (on)/disable (off) output of values passed by parameters in SQL execution The default is "off" (disabled).	
log_statement_once	Whether to control (on)/not control (off) output for the second and subsequent SQL statements if the same SQL statement is the log output target The default is "off" (do not control).	
log_level	Log level of audit logs The valid values are "DEBUG5", "DEBUG4", "DEBUG3", "DEBUG2", "DEBUG1", "INFO", "NOTICE", "WARNING", and "LOG". The default is "LOG".	Enabled only if "serverlog" is specified for the logger parameter

rule section

The rule section is used in Session Audit Logging. Refer to "6.4 Session Audit Logging" for details.



Note

Do not specify the rule section if the role parameter has been specified in the option section. If you specify the rule section, the audit logs of Object Audit Logging and Session Audit Logging will be output intermingled and you will be unable to view the logs in CSV format.

6.4 Session Audit Logging

In Session Audit Logging, specify the rules for filtering logs to be output in the rule section in the pgaudit configuration file.

Rules are specified using the formats below. Multiple values can be specified, using a comma as the delimiter.

- *paramName* = 'value'
- *paramName* != 'value'

If [rule] is described on its own in the rule section with no parameters specified, all audit logs will be output.

Example

```
[output]
logger = 'auditlog'
[rule]
```

If the rule section is not described ([rule] is not described), the audit logs will not be output.

Example

```
[output]
logger = 'auditlog'
```

The valid parameters in the rule section are shown in the table below.

Parameter name	Description	Example
timestamp	Timestamp range Refer to " timestamp " for details on how to specify timestamps.	timestamp = '09:00:00 - 10:00:00, 18:00:00 - 18:30:00'
database	Database name To specify a blank value, use a pair of double quotation marks (""). When specifying a name containing uppercase characters, key words, multibyte characters and commas, enclose the name in double quotation marks.	database = 'prodcut_db'
audit_role	Role name To specify a blank value, specify use a pair of double quotation marks (""). When specifying a name containing uppercase characters, key words, multibyte characters and commas, enclose the name in double quotation marks.	audit_role = 'appuser1'
class	Operation class Select from the values below. Multiple values can be specified. Refer to " class " for details on the meaning of each class. <ul style="list-style-type: none"> - BACKUP - CONNECT - DDL - ERROR - FUNCTION - MISC - READ - ROLE - WRITE - SYSTEM 	class = 'READ, WRITE'
object_type	Object type This parameter is enabled when the class parameter is "READ" and "WRITE". Select from the values below. Multiple values can be specified. <ul style="list-style-type: none"> - TABLE - INDEX - SEQUENCE - TOAST_VALUE - VIEW - MATERIALIZED_VIEW - COMPOSITE_TYPE - FOREIGN_TABLE 	object_type = 'TABLE, INDEX'

Parameter name	Description	Example
	- FUNCTION	
object_name	<p>Object name</p> <p>This parameter is enabled when the class parameter is "READ" and "WRITE".</p> <p>For objects that can be modified by a schema, such as a table, modify such objects by schema name.</p> <p>When specifying a name containing uppercase characters, key words, multibyte characters and commas, enclose the name in double quotation marks. When specifying the object name "<i>schemaName.tableName</i>", enclose the entire object name modified by schema name in double quotation marks.</p> <p>To specify a blank value, use a pair of double quotation marks ("").</p>	<p>object_name = 'myschema.tbl1'</p> <p>object_name = 'myschema.tbl1, "<i>mySchema.TABLE</i>"</p>
application_name	<p>Application name</p> <p>To specify a blank value, use a pair of double quotation marks ("").</p>	application_name = 'myapp'
remote_host	<p>Connection destination host name or IP address</p> <p>If "on" is specified for the log_hostname parameter in the postgresql.conf file, specify a host name. Otherwise, specify the IP address. If using a local host, specify "[local]".</p> <p>To specify a blank value, use a pair of double quotation marks ("").</p>	remote_host = 'ap_server'

timestamp

Specify a timestamp range from "*startTime*" to "*endTime*" for the log output target. The timestamp format is 'hh:mm:dd-hh:mm:dd' (hh is expressed in 24-hour notation, and hh, mm, and dd are expressed in two-digit notation).

The start time must be earlier than the end time. If specifying multiple ranges, specify each start and end timestamp using a comma as the delimiter.

End timestamps consider milliseconds. For example, if '11:00:00 - 11:59:59' is specified for the timestamp, "11:00:00:000" to "11:59:59:999" will be the target range.

The timestamps used by evaluation in the rule section of pgaudit are different to the timestamps issued in the log entries. That is because log entries are output after evaluation by pgaudit, with the timestamp being generated at that time.

class

The meaning of each class specified in the class parameter is below:

- READ: SELECT, COPY FROM
- WRITE: INSERT, UPDATE, DELETE, TRUNCATE, COPY TO
- FUNCTION: Function call, DO
- ROLE: GRANT, REVOKE, CREATE ROLE, ALTER ROLE, DROP ROLE
- DDL: All DDLs (such as CREATE and ALTER) other than the DDLs of the ROLE class
- CONNECT: Events relating to connecting (request, authenticate, and disconnect)

- SYSTEM: Instance start, promotion to primary server
- BACKUP: pg_basebackup
- ERROR: Event completed by an error (PostgreSQL error codes other than 00). This class can be used if ERROR or lower level is specified for the log_min_messages parameter in postgresql.conf.
- MISC: Other commands (such as DISCARD, FETCH, CHECKPOINT, and VACUUM)

Evaluation of the rule section

- When a log event occurs, all expressions in the rule section are evaluated at once. Log entries are only output if all parameters in the rule section are evaluated as being true.

For example, if the rule below has been set, of the operations performed by 'apserver' to 'myschema.tbl1', the operations applicable to classes other than 'WRITE' in the period from 10 a.m. to 11 a.m. will be output as audit logs.

```
[rule]
timestamp = '10:00:00-11:00:00'
remote_host = 'apserver'
object_name = 'myschema.tbl1'
class != 'WRITE'
```

- Multiple rule sections can be defined in the pgaudit configuration file. Log events are evaluated using each rule section, and an audit log is output for each matching rule section.

For example, if the rules below are set, duplicated audit logs will be output.

```
[rule]
object_name = 'myschema.tbl1'
[rule]
object_name = 'myschema.tbl1'
```

- If the same parameter is specified multiple times in one rule section, the last specified parameter is effective.

For example, if the rule below has been set, "object_name = 'myschema.tbl3'" will take effect.

```
[rule]
object_name = 'myschema.tbl1'
object_name = 'myschema.tbl2'
object_name = 'myschema.tbl3'
```

Output format

In Session Audit Logging, audit logs are output in the format below:

```
AUDIT: SESSION,READ,2020-03-12 19:00:58 PDT,
(1)      (2)      (3)
[local],19944,psql,appuser,postgres,2/8, 2, 1,SELECT,,TABLE,myschema.account, ,
(4)     (5)     (6)     (7)      (8)     (9)(10)(11)(12)(13)(14)   (15)      (16)
SELECT * FROM myschema.account;,<not logged>
(17)                                (18)
```

No	Content
(1)	Log header Fixed as "AUDIT: SESSION".
(2)	Class
(3)	SQL start time
(4)	Remote host name

No	Content
	If using a local host, [local] is output.
(5)	Backend process ID
(6)	Application name If an application name is not specified, [unknown] is output.
(7)	User name
(8)	Database name
(9)	Virtual transaction ID
(10)	Statement ID
(11)	Substatement ID
(12)	Command tag
(13)	SQLSTATE
(14)	Object type
(15)	Object name
(16)	Error message
(17)	SQL If the SQL contains a password, such as for CREATE ROLE, and so on, it will be replaced with "<REDACTED>". Additionally, if "on" is specified for the log_statement_once parameter of the option section in the pgaudit configuration file, "<previously logged>" is output for the second and subsequent statements.
(18)	Depending on the log_parameter parameter value of the option section in the pgaudit configuration file, the output content will be as below. - log_parameter=on is specified If parameters are specified in the SQL, the parameters are concatenated and output, using a space as the delimiter. If parameters are not specified in the SQL, "<none>" is output. - log_parameter=off (default) is specified "<not logged>" is output. Additionally, if "on" is specified for the log_statement_once parameter of the option section in the pgaudit configuration file, "<previously logged>" is output for the second and subsequent statements.

Information

If accessing resources that use the features below, the command tag (12) may be output as "UNKNOWN".

- INSTEAD OF trigger
- RULE
- VIEW
- Security policy per row
- Table inheritance

Example

Below is an example of retrieving audit logs in Session Audit Logging.

1. Settings

In the pgaudit configuration file, specify the rule section below.

```
[rule]
class = 'READ, WRITE'
object_name = 'myschema.account'
```

2. Retrieving logs

Execute the SQL below from the client.

```
CREATE TABLE myschema.account
(
  id int,
  name text,
  password text,
  description text
);
INSERT INTO myschema.account (id, name, password, description) VALUES (1, 'user1', 'HASH1', 'blah,
blah');
SELECT * FROM myschema.account;
```

The audit log below can be retrieved.

'DDL' is not defined in the class parameter, so CREATE TABLE is not output as an audit log.

```
AUDIT: SESSION,WRITE,2020-03-12 19:00:49 PDT,[local],19944,psql,appuser,postgres,
2/7,1,1,INSERT,,TABLE,myschema.account,, "INSERT INTO myschema.account (id, name, password,
description) VALUES (1, 'user1', 'HASH1', 'blah, blah');" ,<not logged>
AUDIT: SESSION,READ,2020-03-12 19:00:58 PDT,[local],19944,psql,appuser,postgres,
2/8,2,1,SELECT,,TABLE,myschema.account,,SELECT * FROM myschema.account;,<not logged>
```

6.5 Object Audit Logging

In Object Audit Logging, retrieval of audit logs is achieved by using roles.

Roles are specified in the role parameter of the option section to retrieve audit logs. If there are privileges for commands executed by a role, or if privileges have been inherited from another role, those command operations are output as audit logs.

For example, after "auditor" is set for the role parameter of the option section, the SELECT and DELETE privileges for the account table are assigned to "auditor". In this case, when SELECT or DELETE is executed for the account table, audit logs are output.

Output format

In Object Audit Logging, audit logs are output in the format below:

```
AUDIT: OBJECT,1,1,READ,SELECT,TABLE,public.account,SELECT password FROM account;,<not logged>
(1) (2)(3)(4) (5) (6) (7) (8) (9)
```

No	Content
(1)	Log header Fixed as "AUDIT: OBJECT".
(2)	Statement ID
(3)	Substatement ID

No	Content
(4)	Class name
(5)	Command tag
(6)	Object type
(7)	Object name
(8)	SQL If "on" is specified for the log_statement_once parameter of the option section in the pgaudit configuration file, "<previously logged>" is output for the second and subsequent statements.
(9)	Depending on the log_parameter parameter value of the option section in the pgaudit configuration file, the output content will be as below. - When log_parameter=on If parameters are specified in the SQL, the parameters are concatenated and output, using a comma as the delimiter. If parameters are not specified in the SQL, "<none>" is output. - When log_parameter=off (default) "<not logged>" is output. Additionally, if "on" is specified for the log_statement_once parameter of the option section in the pgaudit configuration file, "<previously logged>" is output for the second and subsequent statements.

Information

If accessing resources that use the features below, the command tag (5) may be output as "UNKNOWN".

- INSTEAD OF trigger
- RULE
- VIEW
- Security policy per row
- Table inheritance

Example

Below is an example of retrieving logs in Object Audit Logging.

By setting the target for assigning privileges to roles in detail, log output can be controlled.

In the example below, log retrieval of the account table is controlled by the privileges assigned to the columns, however, log retrieval of the account_role_map table is controlled by the privileges assigned to the table.

1. Settings

The role parameter below is specified for the option section in the pgaudit configuration file.

```
[option]
role = 'auditor'
```

2. Defining a role

A role is defined for Object Audit Logging.

```
CREATE USER auditor NOSUPERUSER LOGIN;
```

3. Retrieving logs

Execute the SQL below from the client.

```
CREATE TABLE account
(
  id int,
  name text,
  password text,
  description text
);
GRANT SELECT (password) ON public.account TO auditor;
SELECT id, name FROM account;
SELECT password FROM account;
GRANT UPDATE (name, password) ON public.account TO auditor;
UPDATE account SET description = 'yada, yada';
UPDATE account SET password = 'HASH2';
CREATE TABLE account_role_map
(
  account_id int,
  role_id int
);
GRANT SELECT ON public.account_role_map TO auditor;
SELECT account.password, account_role_map.role_id
FROM account
INNER JOIN account_role_map ON account.id = account_role_map.account_id;
```

The audit log below can be retrieved.

In the account table, only the operations for columns that privileges have been assigned to are output as logs.

In the account_role_map table, privileges are assigned to the table, so operations performed for the table are output as logs.

```
AUDIT: OBJECT,4,1,READ,SELECT,TABLE,public.account,SELECT password FROM account;,<not logged>
AUDIT: OBJECT,7,1,WRITE,UPDATE,TABLE,public.account,UPDATE account SET password = 'HASH2';,<not logged>
AUDIT: OBJECT,10,1,READ,SELECT,TABLE,public.account,"SELECT account.password,
account_role_map.role_id
FROM account
INNER JOIN account_role_map ON account.id = account_role_map.account_id;",<not logged>
AUDIT: OBJECT,10,1,READ,SELECT,TABLE,public.account_role_map,"SELECT account.password,
account_role_map.role_id
FROM account
INNER JOIN account_role_map ON account.id = account_role_map.account_id;",<not logged>
```

6.6 Database Multiplexing

This section describes audit log retrieval while in database multiplexing mode.

6.6.1 Setup

If setting up the audit log feature in a database multiplexing environment that has already been built, follow the procedure below.

1. Copy the pgaudit files

Copy the pgaudit files on the primary server and standby server.

Refer to step 1 in "6.2 Setup" for details on copying the pgaudit files.

2. Create the pgaudit configuration file

Create the pgaudit configuration file on the primary server. Copy the pgaudit configuration file you created to the standby server. Refer to step 2 in "6.2 Setup" for details on creating the pgaudit configuration file.

3. Configure postgresql.conf

In the postgresql.conf file on the primary server and standby server, configure the parameters for using audit logs. Set the same values for the parameters.

Refer to step 3 in "6.2 Setup" and "6.6.2 Configuring Audit Log Retrieval" for details on the parameters to configure.

4. Configure the *serverIdentifier.conf* file of Mirroring Controller

In the *serverIdentifier.conf* file on the primary server and standby server, configure the parameters for using audit logs.

Refer to "6.6.2 Configuring Audit Log Retrieval" for details on the parameters to be set.

5. Start the instance

Start the instance of the primary server and standby server.

6. Create the pgaudit extension

Execute CREATE EXTENSION on the primary server to create a pgaudit extension.

Refer to step 5 in "6.2 Setup" for details on creating pgaudit extensions.

7. Configure the parameters in the pgaudit configuration file

Add/change the parameters of the pgaudit configuration file on the primary server. Copy the pgaudit configuration file with the added/changed parameters to the standby server.

Refer to "6.3 pgaudit Configuration File" and "6.6.2 Configuring Audit Log Retrieval" for details on the parameters to set.

8. Restart the instance

Restart the instance of the primary server and standby server.

6.6.2 Configuring Audit Log Retrieval

In database multiplexing mode, Mirroring Controller periodically accesses the database to check the multiplexing status and detect failure. Due to this, audit logs are also periodically retrieved, so log files become used up. Therefore, set the parameters below so that audit logs are not retrieved by Mirroring Controller.

postgresql.conf

log_connections

Omit, or specify "off".

log_disconnections

Omit, or specify "off".

serverIdentifier.conf file of Mirroring Controller

target_db

Specify "template1".



.....
If creating a new database, create it after stopping Mirroring Controller, or specify a name other than "template1" for the template database.
.....

pgaudit configuration file

rule section database

Specify database != 'template1'.

6.7 Failover

This section explains audit log retrieval performed by the failover feature integrated with the cluster software.

6.7.1 Configuring Audit Log Retrieval

The failover feature accesses the database periodically to check the instance status. Due to this, audit logs are also periodically retrieved, so log files become depleted. Therefore, set the parameters below so that audit logs are not retrieved.

postgresql.conf

log_connections

Omit, or specify "off".

log_disconnections

Omit, or specify "off".

pgaudit configuration file

rule section database

Specify database != 'template1'.

6.8 View Audit Logs Using SQL

By using file_fdw of an additional module, audit logs can be accessed using SQL. This section describes how to view audit logs, using Session Audit Logging output to a dedicated log file as an example.

1. Install file_fdw

Execute CREATE EXTENSION to install file_fdw as an extension.

```
$ psql
=# CREATE EXTENSION file_fdw;
=# \dx
                                List of installed extensions
Name          | Version | Schema  | Description
-----+-----+-----+-----
file_fdw     | 1.0    | public  | foreign-data wrapper for flat file access
pgaudit      | 1.0    | public  | provides auditing functionality
plpgsql      | 1.0    | pg_catalog | PL/pgSQL procedural language
(3 rows)
```

2. Create an external server

Use CREATE SERVER to create an external server managed by file_fdw.

```
$ psql
=# CREATE SERVER auditlog FOREIGN DATA WRAPPER file_fdw;
```

3. Create an audit log table.

Use CREATE FOREIGN TABLE to define the table columns of audit logs, CSV file name and format.

```
$ psql
=# CREATE FOREIGN TABLE auditlog (
header text,
class text,
sql_start_time timestamp with time zone,
remote_host_name text,
backend_process_id text,
application_name text,
session_user_name text,
database_name text,
virtual_transaction_id text,
```

```
statement_id text,
substatement_id text,
command_tag text,
sqlstate text,
object_type text,
object_name text,
error_message text,
sql text,
parameter text
) SERVER auditlog
OPTIONS ( filename '/database/inst1/pgaudit_log/pgaudit-2020-03-12.log', format 'csv' );
```

Note

If an audit log file is rotated and multiple audit log files exist, it is necessary to create a table for each audit log file.

4. View audit logs

Use SELECT and view the audit logs.

```
$ psql
=# SELECT * FROM auditlog;
   header   | class | sql_start_time | remote_host_name | backend_process_id | ...
-----+-----+-----+-----+-----+-----+
AUDIT: SESSION | WRITE | 2020-03-12 19:00:49+09 | [local] | 19944 | ...
AUDIT: SESSION | READ  | 2020-03-12 19:00:58+09 | [local] | 19944 | ...
```

6.9 Removing Setup

This section describes how to remove the setup of pgaudit.

1. Start the instance
2. Remove the pgaudit extension

Execute DROP EXTENSION to remove the pgaudit extension from the database.

```
$ psql -d <database name>
=# DROP EXTENSION pgaudit;
=# \q
```

3. Change postgresql.conf

Remove the parameters below relating to pgaudit.

- shared_preload_libraries
- pgaudit.config_file

4. Restart the instance
5. Remove the pgaudit files

As superuser, run the following command. Note that "<x>" in paths indicates the product version.

```
$ su -
Password:*****
# rm -rf /opt/fsepv<x>server64/filesCopiedDuringSetup
```

Information

The files copied during setup can be checked below.

```
# find /opt/fsepv<x>server64/OSS/pgaudit
```

FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Cluster Operation Guide (Database Multiplexing)

Preface

Purpose of this document

This document describes the tasks required for using the database multiplexing feature of FUJITSU Enterprise Postgres.

Intended readers

This document is intended for those who set up and use the database multiplexing feature. Readers of this document are also assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of Database Multiplexing Mode](#)

Provides an overview of database multiplexing mode.

[Chapter 2 Setting Up Database Multiplexing Mode](#)

Describes how to set up database multiplexing mode.

[Chapter 3 Operations in Database Multiplexing Mode](#)

Explains periodic database multiplexing mode.

[Chapter 4 Action Required when an Error Occurs in Database Multiplexing Mode](#)

Explains the action required when an error occurs during a database multiplexing mode.

[Chapter 5 Managing Mirroring Controller Using WebAdmin](#)

Explains how to set up and manage Mirroring Controller in a streaming replication cluster using WebAdmin.

[Appendix A Parameters](#)

Explains the configuration files and parameters required for database multiplexing mode.

[Appendix B Supplementary Information on Building the Primary Server and Standby Server on the Same Server](#)

Explains supplementary information on building the primary server and standby server on the same server.

[Appendix C User Commands](#)

Explains the user commands.

[Appendix D Notes on Performing Automatic Degradation Immediately after a Heartbeat Abnormality](#)

Provides notes when performing automatic degradation unconditionally after a heartbeat abnormality is detected during heartbeat monitoring of an operating system or server.

[Appendix E WebAdmin Disallow User Inputs Containing Hazardous Characters](#)

Explains characters not allowed in WebAdmin.

[Appendix F Collecting Failure Investigation Data](#)

Explains how to collect data for initial investigation.

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Chapter 1 Overview of Database Multiplexing Mode

This chapter provides an overview of database multiplexing mode.

Point

In this and subsequent chapters, the word "Mirroring Controller" may be used in the process or management directory name or explanation.

1.1 What is Database Multiplexing Mode

Database multiplexing mode is an operation mode (log shipping mode) based on PostgreSQL streaming replication. Other software such as cluster software is not required.

This mode replicates the database on all servers that comprise the cluster system. It achieves this by transferring the updated transaction logs of the database from the server that receives the updates (primary server) to another server (standby server), and then reflecting them on the standby server. The client driver automatically distinguishes between the primary and standby servers, so applications can be connected transparently regardless of the physical server.

It consists of a feature that detects faults in the elements that are essential for the continuity of the database operation (such as the database process, disk, and network), as well as simplified switchover and standby server disconnection features. Furthermore, referencing can be performed on the standby server. The database will be copied in synchronous mode.

Note

If using WebAdmin or Mirroring Controller, FUJITSU Enterprise Postgres supports cluster systems comprising one primary server and one standby server.

- Although it is possible to connect an asynchronous standby server to the cluster system as an additional server, the standby server is not targeted for monitoring by Mirroring Controller.
- A synchronous standby server cannot be connected to the cluster system as an additional server.

See

The streaming replication feature is not described in this manual.

Refer to "High Availability, Load Balancing, and Replication" in the PostgreSQL Documentation for information on the streaming replication feature.

Figure 1.1 Failover from the primary server to the standby server

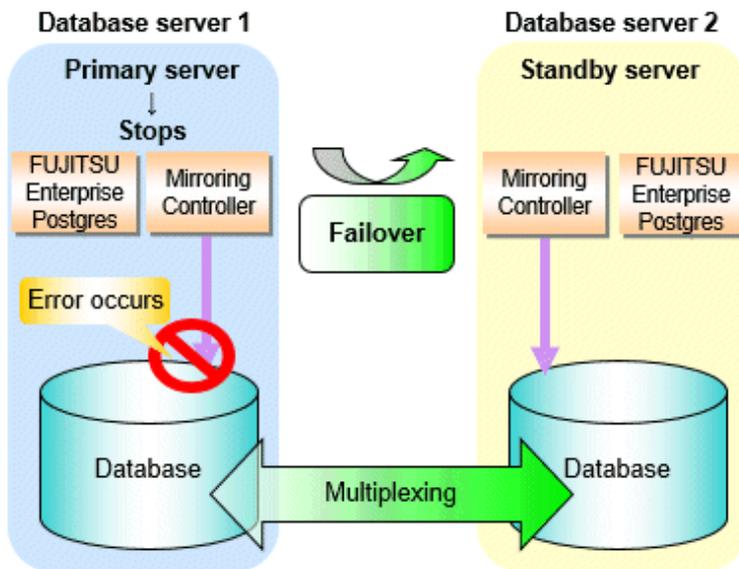
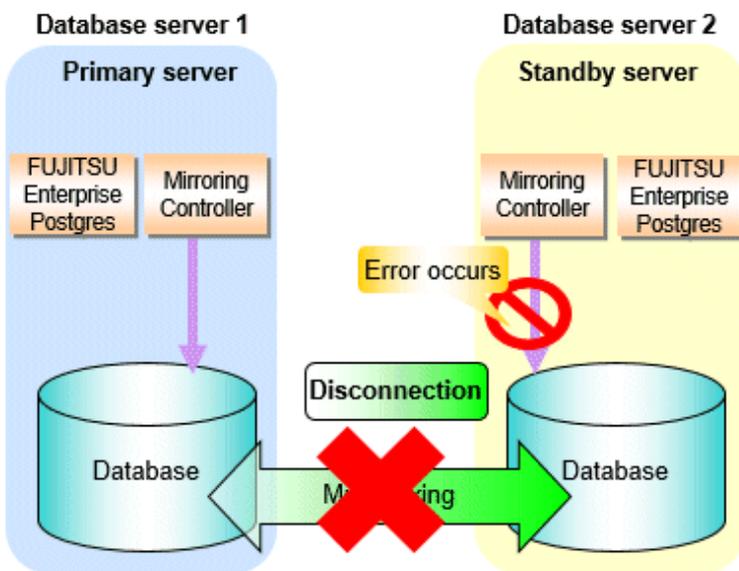


Figure 1.2 Standby server disconnection



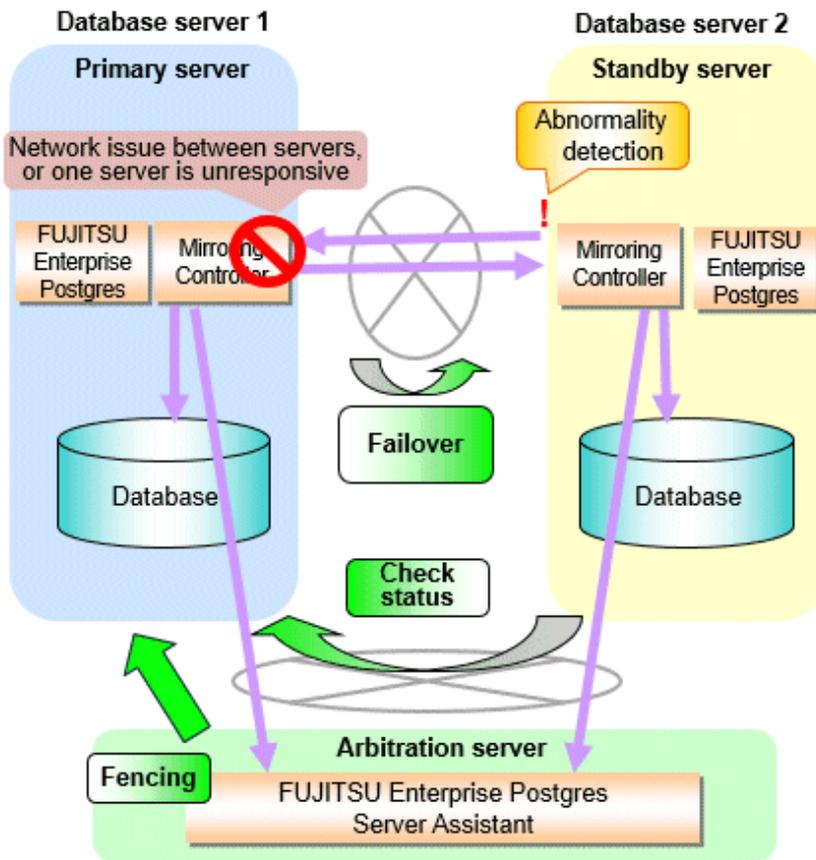
Database degradation using the arbitration server

FUJITSU Enterprise Postgres provides the Server Assistant that objectively determines the status of database servers as a third party, and if necessary, isolates affected databases if the database servers are unable to accurately ascertain their mutual statuses in database multiplexing mode, such as due to a network error between database servers, or server instability. Database degradation can be performed by using the server (arbitration server) on which the Server Assistant is installed.

For database degradation using the arbitration server, if the database servers are unable to check their mutual statuses (due to a network error between database servers or server instability), then the database server queries the arbitration server for the status of the other database server. If it is determined based on the heartbeat result that the status is unstable, the applicable database server will be isolated from the cluster system (fencing). The arbitration server periodically heartbeats the database server so that it can respond immediately to queries from the database server. The fencing process can be customized according to the environment where Mirroring Controller is used.

Additionally, the database servers are always performing their heartbeats for the arbitration server so that it can perform check requests any time.

Figure 1.3 Database degradation using the arbitration server



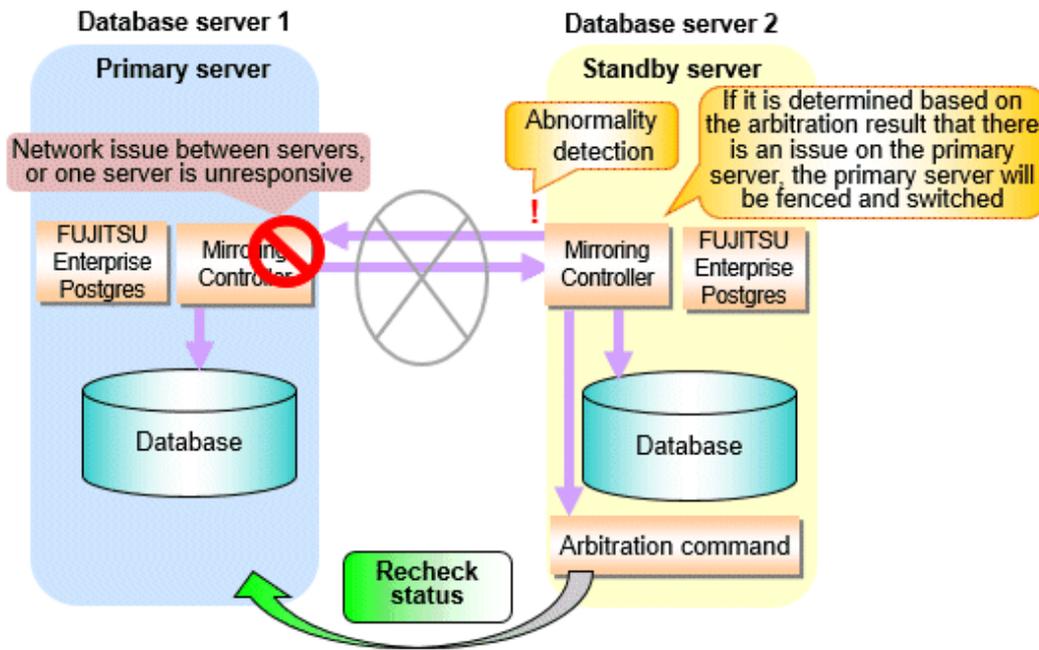
 Note

Install the arbitration server on a different physical server to that of the database server. Refer to "[1.2 System Configuration for Database Multiplexing Mode](#)" for information on the system configuration when using the arbitration server.

Database degradation using the arbitration command

The arbitration command is a user command that performs arbitration processing in lieu of the arbitration server. If an arbitration server cannot be deployed, arbitration of the database server can be performed using the arbitration command.

Figure 1.4 Database degradation using the arbitration command



 See

Refer to "2.6 Creating a User Command for a Database Server" or "Appendix C User Commands" for information on user commands.

1.1.1 Monitoring Using Database Multiplexing Mode

In database multiplexing mode, perform the monitoring below.

- Operating system or server failures, and no-response state

By generating a heartbeat between Mirroring Controller on each server, operating system or server errors are detected and acknowledged between the relevant servers.

The optimal operating method for environments where database multiplexing mode is performed can be selected from the following:

- Use the arbitration server to perform automatic degradation (switch/disconnect)

This is the default method.

The arbitration server objectively determines the status of database servers, then isolates and degrades from the cluster system the ones with an unstable status.

Refer to "Database degradation using the arbitration server" for details.

- Call the user command that will perform the degradation decision, and perform automatic degradation

If the arbitration server cannot be installed, select if arbitration processing can be performed by the user instead.

Mirroring Controller queries the user command on whether to degrade. The user command determines the status of the database server, and notifies Mirroring Controller whether to perform degradation.

Refer to "Database degradation using the arbitration command" for details.

- Notification messages

Use this method if using a two-database server configuration.

Mirroring Controller outputs messages to the system log when an abnormality is detected. This ensures that a split brain will not occur due to a heartbeat abnormality - however, automatic switching will not be performed if the primary server operating system or server fails or becomes unresponsive.

- Perform automatic degradation unconditionally after a heartbeat abnormality

This method is not recommended, because Mirroring Controller unconditionally will perform automatic degradation after heartbeat abnormalities.

- Database process failures, and no-response state

Mirroring Controller periodically accesses the database processes and checks the status. A process error is detected by monitoring whether an access timeout occurs.

- Disk failure

Mirroring Controller periodically creates files on the data storage destination disk below. A disk error is detected when an I/O error occurs.

- Data storage destination disk
- Transaction log storage destination disk
- Tablespace storage destination disk

Failures that can be detected are those that physically affect the entire system, such as disk header or device power failures.

- Streaming replication issue

Mirroring Controller detects streaming replication issues (log transfer network and WAL send/receive processes) by periodically accessing the PostgreSQL system views.

- Mirroring Controller process failure and no response

In order to continue the monitoring process on Mirroring Controller, Mirroring Controller process failures and no responses are also monitored.

The Mirroring Controller monitoring process detects Mirroring Controller process failures and no responses by periodically querying the Mirroring Controller process. If an issue is detected, Mirroring Controller is automatically restarted by the Mirroring Controller monitoring process.

Point

- If output of messages is selected as the operation to be performed when a heartbeat abnormality is detected during heartbeat monitoring of the operating system or server, automatic degradation will not be performed. However, if an issue in the WAL send process is detected on the primary server, then the standby server will be disconnected, and as a result an automatic disconnection may be performed even if the standby server operating system or server fails or becomes unresponsive.
- You can select in the parameters if the primary server will be switched if a database process is unresponsive or if tablespace storage destination disk failure is detected. Refer to "[Appendix A Parameters](#)" for details.
- If the standby server was disconnected, Mirroring Controller will automatically comment out the `synchronous_standby_names` parameter in the `postgresql.conf` file of the primary server. Accordingly, you can prevent the application processing for the primary server being stopped.

Note

If the role of primary server was switched to another server and then starts degrading, the original primary server will not become the standby server automatically. Remove the cause of the error, and then change the role of the original primary server to the server currently acting as standby server. Refer to "[4.1 Action Required when Server Degradation Occurs](#)" for details.

1.1.2 Referencing on the Standby Server

1.1.2.1 If Prioritizing the Main Job on the Primary Server

If a reference job is performed on the standby server and the primary server is switched, this may impact the main job from the point of view of load and conflict. This is because, on the new primary server (that is, the original standby server), both the main job that was being executed on the original primary server and the reference job that was being continued on the original standby server will be processed.

Therefore, to degrade the reference job (so that the impact on the main job is reduced), you can select the user command below to disconnect the reference job that was performed on the original standby server.

- Post-switch command



.....
If continuing with the referencing job after switching the primary server, give careful consideration to the server resource estimates, and the likely impact on performance.
.....

1.1.2.2 If Performing the Referencing Job on the Synchronous Standby Server

If an issue such as a log transfer network failure obstructs the continuation of a job on the primary server, the standby server may be automatically disconnected from the cluster system.

Therefore, if operating the reference job on the assumption that the connection destination is the synchronous standby server, you can select to temporarily stop the job by using the user command or the feature below, so that unexpected referencing of past data does not occur as a result of the disconnection.

- Pre-detach command
- Forced stoppage of the standby server instance on disconnection (specify in the parameter of the server configuration file)

Additionally, if the standby server is incorporated into the cluster system, reference jobs can be started or resumed by using the user command below.

- Post-attach command



-
- Refer to "[2.6 Creating a User Command for a Database Server](#)" or "[Appendix C User Commands](#)" for information on each user command.
 - Refer to "[A.4.1 Server Configuration File for the Database Servers](#)" for information on the server configuration file of the database server.
-



.....
Mirroring Controller will continue processing regardless of the processing result of the above user commands and features.
.....

1.2 System Configuration for Database Multiplexing Mode

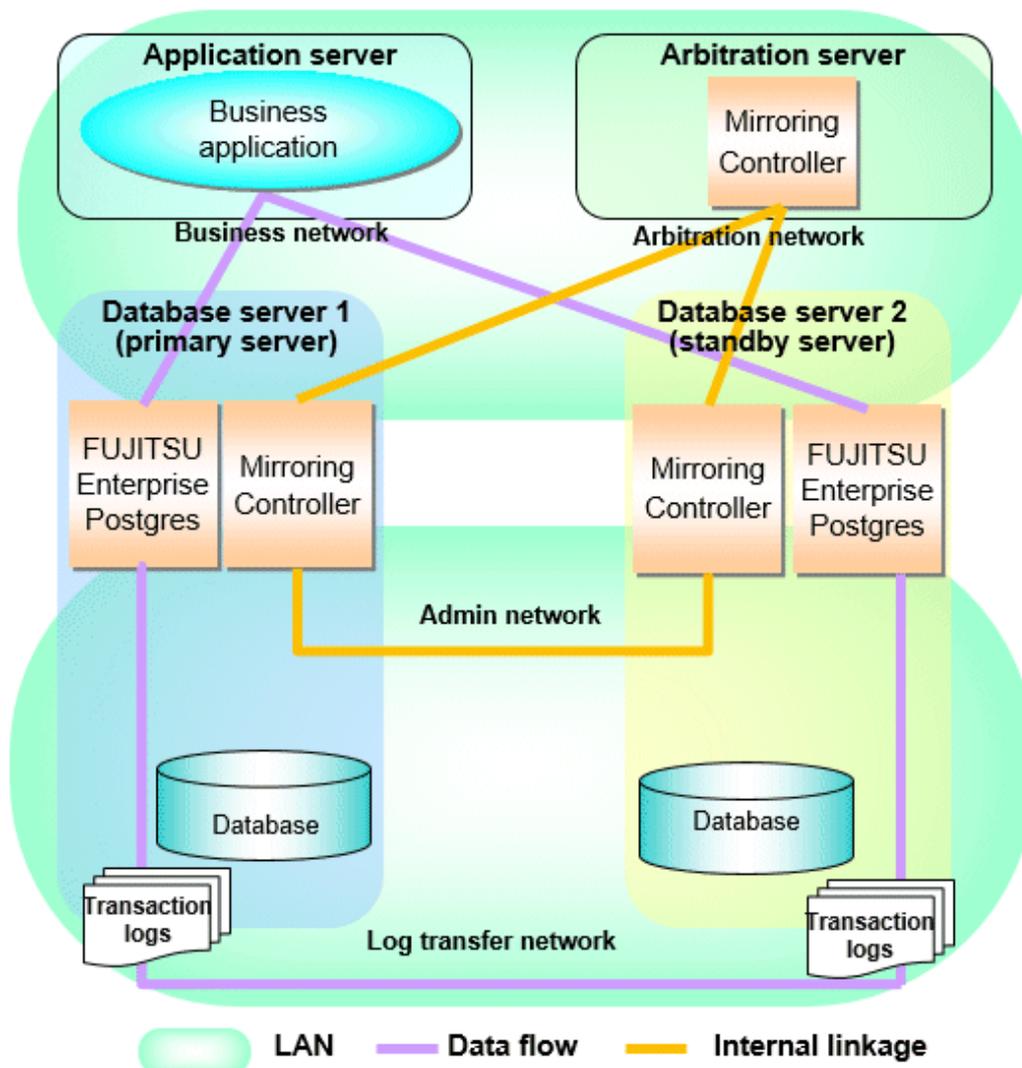
This section explains the products, features, and networks that are part of a database multiplexing system.

The following table shows the network types used by database multiplexing systems.

Network type	Description
Job network	Network between the application that accesses the database, and the database server.

Network type	Description
Arbitration network	Network used by the arbitration server to check the status of the primary server and standby server, and communicate with Mirroring Controller of the database servers. Additionally, if the job network is disconnected from outside, it can also be used as the arbitration network. Refer to " 1.4 Security in Database Multiplexing " for details on network security.
Admin network	Network used by the primary server and the standby server to monitor each other using Mirroring Controller, and to control Mirroring Controller of other servers.
Log transfer network	Network used to transfer the transaction logs of the database, which is part of database multiplexing.

Figure 1.5 System configuration for database multiplexing mode



The arbitration server is installed to check the database server status as a third party, and to perform fencing. Therefore, to obtain the intended benefits, consider the following.

- Install the arbitration server on a different server to that of the database server.
- For the arbitration network, use a network that will not be impacted by line faults or the load on the admin network or log transfer network. This is necessary to correctly determine issues on the admin network or log transfer network.

Point

- The arbitration server can also be used as an application server. However, consider the server load.
- It is recommended to link the arbitration server with other cluster systems, in order to provide redundancy.
- Use the arbitration server in combination with the same version of FUJITSU Enterprise Postgres as that of the primary server and standby server.
- The arbitration server can be built on a different platform to that of the database server.

Note

Because the ping command of the operating system is used for heartbeat monitoring of the database server, configure the network so that ICMP can be used on the admin network and the arbitration network.

1.2.1 Mirroring Controller Resources

This section describes the database server and arbitration server resources of Mirroring Controller.

1.2.1.1 Database Server Resources

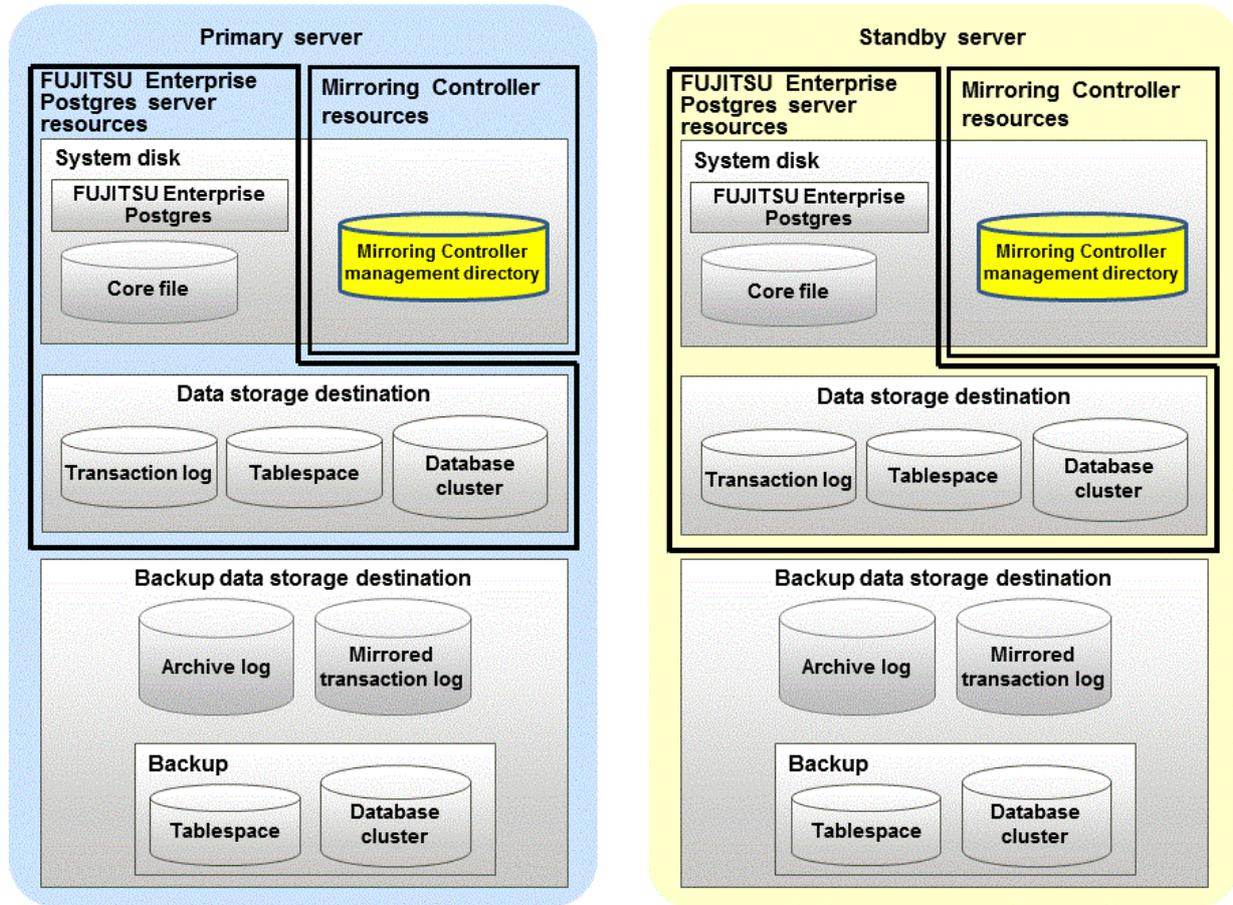
The only Mirroring Controller resource is the Mirroring Controller management directory, which stores the files that define the Mirroring Controller behavior, and the temporary files that are created when Mirroring Controller is active.

Note

- Do not create the Mirroring Controller management directory in a directory managed by FUJITSU Enterprise Postgres, otherwise it may be deleted by mistake or may cause unexpected problems when FUJITSU Enterprise Postgres recovery is performed (such as old version of files being restored).
Refer to "Preparing Directories for Resource Deployment" in the Installation and Setup Guide for Server for information on the directories managed by FUJITSU Enterprise Postgres.
- The backup methods described in "Backing Up the Database" in the Operation Guide cannot be used to back up the Mirroring Controller resources. Therefore, users must obtain their own backup of Mirroring Controller resources, in addition to FUJITSU Enterprise Postgres server resources. Retrieve backups after stopping Mirroring Controller.
- If the automatic switch/disconnection is enabled, do not edit `synchronous_standby_names` for the Mirroring Controller monitoring target instance. Otherwise, if Mirroring Controller is switched after editing, data may be lost or SQL access may stop.
- If you are building on a virtual machine or cloud, make sure the virtual machines are on different physical servers. Refer to your virtual machine software and cloud vendor documentation for instructions on how to deploy virtual machines.

The content on the primary server will be backed up. You cannot tell which server is the primary server to be backed up, because switching and failback may be performed between the servers. It is also impossible to tell which server is to be restored using the backed up data. Accordingly, ensure that you create a backup of each server when it is working as the primary server.

Figure 1.6 Configuration when backing up Mirroring Controller resources



1.2.1.2 Arbitration Server Resources

The only arbitration server resource is the Mirroring Controller arbitration process management directory. This directory stores the files that define the Mirroring Controller arbitration process behavior and the temporary files created when Mirroring Controller is active.

1.2.2 Mirroring Controller Processes

This section describes the database server and arbitration server processes of Mirroring Controller.

1.2.2.1 Database Server Processes

The database server processes comprise the Mirroring Controller process and Mirroring Controller monitoring process.

Process type	Description
Mirroring Controller process	Performs operating system/server and process heartbeat monitoring and disk abnormality monitoring between database servers. Additionally, it issues arbitration requests to the arbitration server.
Mirroring Controller monitoring process	Performs heartbeat monitoring of the Mirroring Controller process. If the Mirroring Controller process returns no response or is down, the monitoring process is restarted automatically.

1.2.2.2 Arbitration Server Process

The only arbitration process is the Mirroring Controller arbitration process.

Process type	Description
Mirroring Controller arbitration process	Performs rechecks for issues detected on the primary server or the standby server. Additionally, this process performs fencing if it determines that there is an issue on the primary server or the standby server.

1.2.3 Redundancy of the Admin and Log Transfer Networks

The admin network is an important one, because it is used by Mirroring Controller to check the status of each server.

Additionally, the log transfer network is an important one, because it is necessary to ensure data freshness.

Accordingly, configure a failure-resistant network by implementing network redundancy via channel bonding provided by the operating system or network driver vendor.

1.2.4 Notes on CPU Architecture and Products

A server using only PostgreSQL streaming replication cannot be specified as the database multiplexing system log transfer destination.

1.3 Deciding on Operation when a Heartbeat Abnormality is Detected

The operation to be performed when a heartbeat abnormality is detected using operating system/server heartbeat monitoring is decided on according to the environment where database multiplexing mode is performed or the operating method.

It is possible to select from the four operations below, and specify this in the parameters of Mirroring Controller:

- Use the arbitration server to perform automatic degradation (switch/disconnect)
- Call the user command that will perform the degradation decision, and perform automatic degradation
- Notification messages
- Perform automatic degradation unconditionally (switch/disconnect)

The table below shows if jobs can be continued on the primary server when an issue is detected during heartbeat monitoring of the operating system/server.

Continuation of jobs on the primary server when an issue is detected during heartbeat monitoring of the operating system/server

Operation	Abnormal event				
	Server/operating system failures or no responses		Admin network issue	Log transfer network issue	Issue on a network for both admin and log transfer
	Primary server	Standby server			
Automatic degradation using the arbitration server	Y (switch)	Y (disconnect)	Y	Y (disconnect)	Y (disconnect)
Call a user command and perform automatic degradation	Y (switch)	Y (disconnect)	Y	Y (disconnect)	Y (disconnect)
Notification messages	N (message notification only)	N (message notification only)	Y	Y (disconnect)	Y (disconnect)
Unconditional automatic degradation	Y (switch)	Y (disconnect)	N (split brain occurs)	Y (disconnect)	N (split brain occurs)

Y: Job can be continued

N: Job cannot be continued

1.4 Security in Database Multiplexing

The database server replicates the database on all servers that comprise the cluster system. It achieves this by transferring and reflecting the updated transaction logs of the database from the primary server to the standby server.

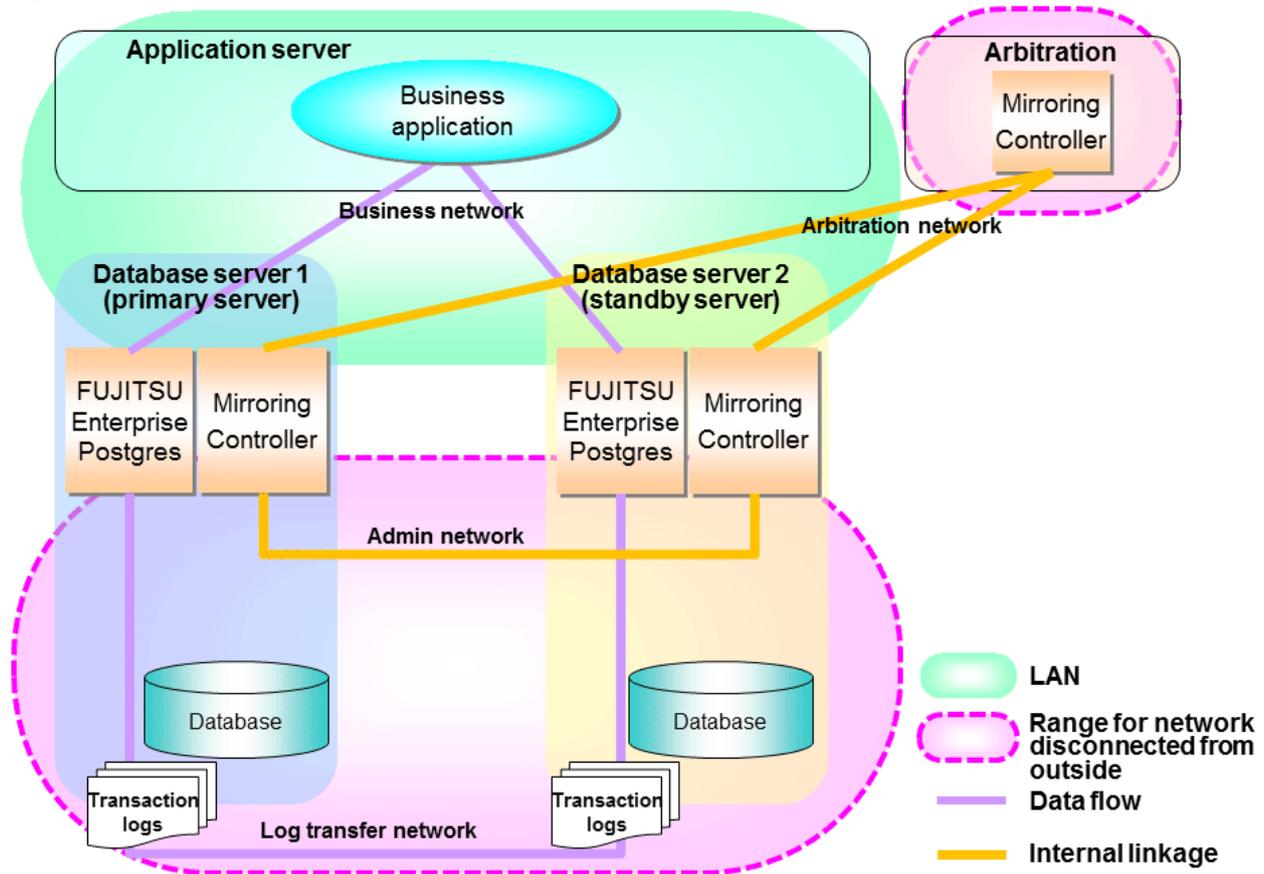
To safeguard the database against unauthorized access and preserve data confidentiality in transaction log transfers, carefully consider security and take note of the following when performing database multiplexing:

- Do not use trust authentication when using replication connection.
- Configure the admin network and the log transfer network so that they cannot be connected from the outside, as shown in [Figure 1.7 Security](#).

Additionally, for the line on which Mirroring Controller connects from the database server to the arbitration server, take note of the following points and consider security carefully.

- Build a network with the arbitration server disconnected from outside, as shown in [Figure 1.7 Security](#).

Figure 1.7 Security



However, it may not always be possible to adopt the configuration mentioned above. For example, you may want to place the servers in a nearby/neighboring office to minimize network delays.

In this case, combine the following features to enhance security:

- [Authentication of the Standby Server](#)
- [Encryption of Transaction Logs Transferred to the Standby Server](#)

When these features are combined, security will be achieved as shown below.

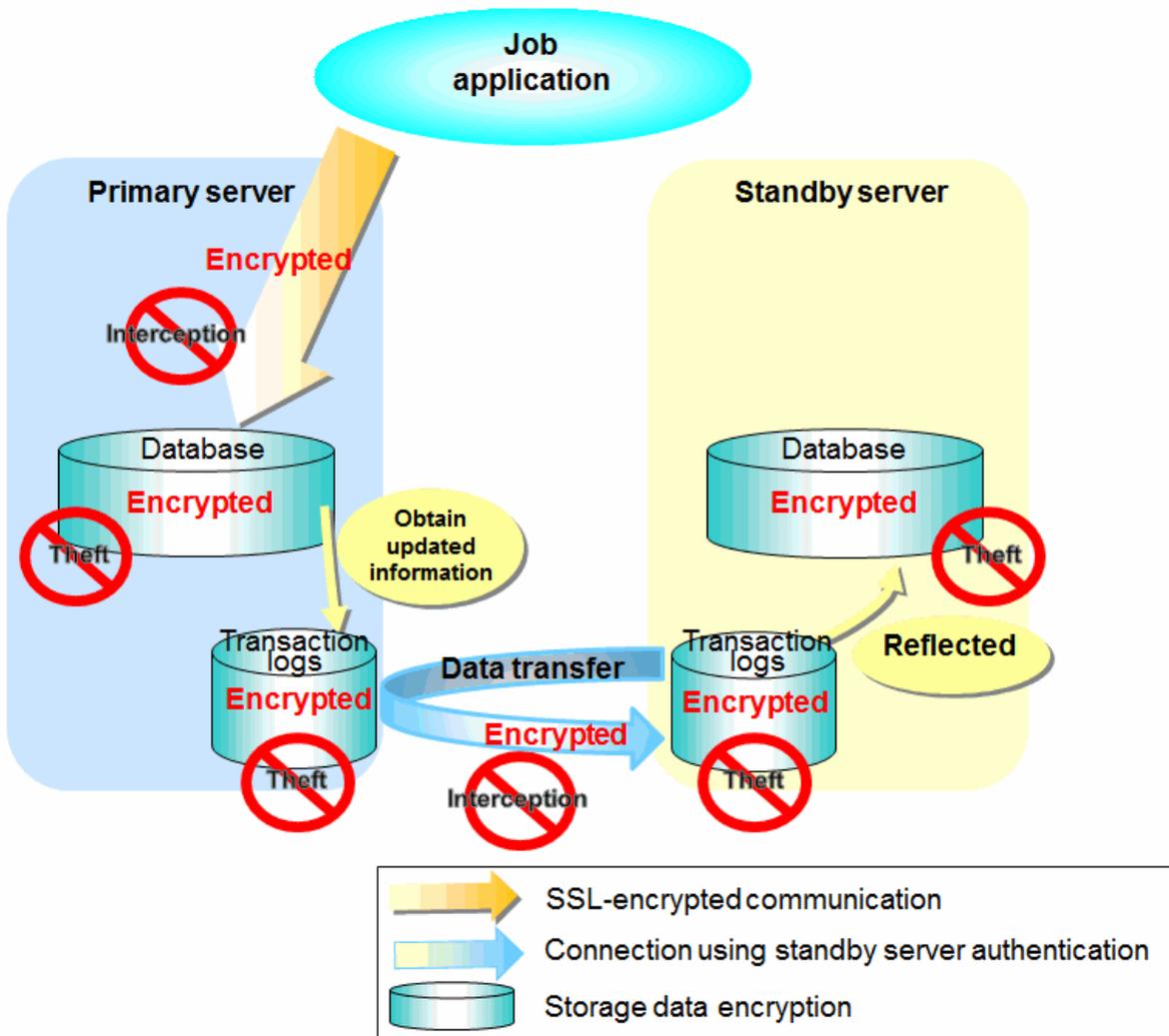
P Point

If the job network is disconnected from outside, it can be used as the arbitration network. However, if a network is to be used as both a job network and arbitration network, consider the load on the network.

N Note

If a port is blocked (access permission has not been granted) by a firewall, etc., enable use of the target port by granting access. Refer to the vendor document for information on how to open (grant access permission to) a port. Consider the security risks carefully when opening ports.

Figure 1.8 Security achieved when standby server authentication is combined with transaction log encryption



S See

Refer to "Performing Database Multiplexing" under "Configuring Secure Communication Using Secure Sockets Layer" in the Operation Guide for information on encrypting SSL communications.

1.4.1 Authentication of the Standby Server

You can prevent spoofing connections from an external server purporting to be the standby server by using authentication with a user name and password.

Configure the setting in the primary server `pg_hba.conf` file so that authentication is performed for connections from the standby server in the same way as for connections from the client.



See

.....
Refer to "Client Authentication" in the PostgreSQL Documentation for information on content that can be configured in `pg_hba.conf`.
.....

1.4.2 Encryption of Transaction Logs Transferred to the Standby Server

In case the authentication of the standby server is breached so that a malicious user purporting to be the standby server can spoof data, the transaction log data can be encrypted to prevent it from being deciphered. The transparent data encryption feature is used to encrypt the data.



See

.....
Refer to "Protecting Storage Data Using Transparent Data Encryption" in the Operation Guide for details.
.....

Chapter 2 Setting Up Database Multiplexing Mode

This chapter describes how to set up database multiplexing mode, and how to check it.

Users who perform setup and operations on the database server

Setup and operations of the database server must be performed by the instance administrator user.

Users who perform setup and operations on the arbitration server

The following users may perform setup and operations on the arbitration server when it is used for automatic degradation.

- Any operating system user.



Point

- Mirroring Controller selects a database superuser as the user who will connect to the database instance. This enables instance administrator users and database superusers who operate the Mirroring Controller commands to run database multiplexing mode in different environments.
- The application name for connecting to the database instance is "mc_agent".

Matching the system times

Before starting the setup, ensure that the times in the primary server, standby server and arbitration server match, by using the operating system time synchronization feature, for example.

The tolerated difference is approximately one second.

If the system times are not synchronized (because the tolerated difference is exceeded, for example), problem investigation may be affected.

Configuring ICMP

Because the ping command of the operating system is used for heartbeat monitoring of the database server, configure the network so that ICMP can be used on the admin network and the arbitration network. Refer to the relevant operating system procedure for details.

Setup

The setup procedure is shown in the table below. However, the procedure on the arbitration server should be performed only when the arbitration server is used for automatic degradation. A distinction is made between the procedures on the primary server and standby server according to whether the arbitration server is used.

Step	Task			Refer to
	Primary server	Standby server	Arbitration server	
1	Installation			2.1 Installation
2	Preparing the database server		Preparing the arbitration server	2.2 Preparing for Setup
3			Configuring the arbitration server	2.3.1 Configuring the Arbitration Server
4			Creating a user command	2.3.2 Creating a User Command for the Arbitration Server
5			Starting the arbitration process	2.3.3 Starting the Mirroring Controller Arbitration Process
6	Setting up database multiplexing mode			2.4.1 Setting Up Database Multiplexing Mode on the Primary Server

Step	Task			Refer to
	Primary server	Standby server	Arbitration server	
7	Creating, setting, and registering the instance			2.4.2 Creating, Setting, and Registering the Primary Server Instance
8	Creating a user command			2.6 Creating a User Command for a Database Server
9	Starting Mirroring Controller			2.4.3 Starting Mirroring Controller on the Primary Server
10		Setting up database multiplexing mode		2.5.1 Setting Up Database Multiplexing Mode on the Standby Server
11		Creating, setting, and registering the instance		2.5.2 Creating, Setting, and Registering the Standby Server Instance
12		Creating a user command		2.6 Creating a User Command for a Database Server
13		Starting Mirroring Controller		2.5.3 Starting Mirroring Controller on the Standby Server
14	Confirming the streaming replication status			2.7 Confirming the Streaming Replication Status
15	Checking the connection status			2.8.1 Checking the Connection Status on a Database Server
16		Checking the connection status		2.8.1 Checking the Connection Status on a Database Server
17			Checking the connection status	2.8.2 Checking the Connection Status on the Arbitration Server
18	Creating applications			2.9 Creating Applications
19	Checking the behavior			2.10 Checking the Behavior

Explanations for each step are provided below.

 **Information**

- The setup procedure is also the same when changing the mode on a single server to database multiplexing mode. In this case, omit the installation of FUJITSU Enterprise Postgres and the creation of the instance.
Refer to "[3.9.2 Changing from Single Server Mode to Database Multiplexing Mode](#)" for details.
- The primary and standby server can be pseudo-configured on the same server for system testing, for example. In this case, the setup can be performed using the same procedure, however there will be some supplementary steps.
Before performing the setup, refer to "[Appendix B Supplementary Information on Building the Primary Server and Standby Server on the Same Server](#)".

2.1 Installation

Refer to the manuals below, and then install the product.

 **See**

- Refer to the Installation and Setup Guide for Server for details on how to install FUJITSU Enterprise Postgres.

- Refer to the Installation and Setup Guide for Server Assistant for information on installing the Server Assistant on the arbitration server.



Do not use the arbitration server also as a database server. The arbitration server is installed to check the database server status as a third party, and to perform fencing. Using the arbitration server also as a database server nullifies the effectiveness of the arbitration server.

2.2 Preparing for Setup

This section describes the preparation required before setting up Mirroring Controller.

2.2.1 Preparing the Database Server

2.2.1.1 Preparing the Backup Disk

In Mirroring Controller, by performing a backup, recovery is possible even if all server disks are corrupted.

The content on the primary server should be backed up. However, through switching and failback, the standby server may also become the primary server. Accordingly, prepare each of the backup disk devices for the primary and standby servers. Perform backup on the primary server used at the time of the backup.

2.3 Setting Up the Arbitration Server

This section explains how to set up the arbitration server.

2.3.1 Configuring the Arbitration Server

This section explains how to set up database multiplexing mode on the arbitration server.

In database multiplexing mode, the files that are required for operations are managed in the Mirroring Controller arbitration process management directory.

There is one Mirroring Controller arbitration process management directory for each arbitration process.



The arbitration process for each database multiplexing system can be started on a single arbitration server.



- Refer to the Reference for information on the mc_arb command.
- Refer to "[Appendix A Parameters](#)" for information on the parameters to be edited for the setup.

Perform the following procedure:

1. On the arbitration server, log in as any operating system user who starts and stops the arbitration process.
2. Configure the environment variables.

Set the following environment variables:

- PATH

Add the installation directory "/bin".

- MANPATH

Add the installation directory "/share/man".

- LD_LIBRARY_PATH

Add the installation directory "/lib".

Example

The following example configures environment variables when the installation directory is "/opt/fsepv<x>assistant".

Note that "<x>" indicates the product version.

sh, bash

```
$ PATH=/opt/fsepv<x>assistant/bin:$PATH ; export PATH
$ MANPATH=/opt/fsepv<x>assistant/share/man:$MANPATH ; export MANPATH
$ LD_LIBRARY_PATH=/opt/fsepv<x>assistant/lib:$LD_LIBRARY_PATH ; export LD_LIBRARY_PATH
```

csh, tcsh

```
$ setenv PATH /opt/fsepv<x>assistant/bin:$PATH
$ setenv MANPATH /opt/fsepv<x>assistant/share/man:$MANPATH
$ setenv LD_LIBRARY_PATH /opt/fsepv<x>assistant/lib:$LD_LIBRARY_PATH
```

3. Create the Mirroring Controller arbitration process management directory that will store the files required by the arbitration server.
Use ASCII characters in the Mirroring Controller arbitration process management directory.
4. In the network configuration file (network.conf), define the Mirroring Controller network configuration that will be managed by the Mirroring Controller arbitration process.

Create network.conf in the Mirroring Controller arbitration process management directory, based on the sample file. For network.conf, set read and write permissions only for the operating system user who starts and stops the arbitration process in step 1.

If users other than this are granted access permissions, the mc_arb command will not work. Accordingly, users other than the operating system user who starts and stops the arbitration process in step 1 are prevented from operating the Mirroring Controller arbitration process.

Sample file

```
/installDir/share/mcarb_network.conf.sample
```

In network.conf, specify the IP address or host name and port number of the primary server and standby server, and define the Mirroring Controller network configuration that will be managed by the Mirroring Controller arbitration process.

Refer to "[A.3 Network Configuration File](#)" for details.

A definition example is shown below.

Example)

The IDs of the servers are set to "server1" and "server2", and their port numbers are set to "27541".

```
server1 192.0.3.100 27541
server2 192.0.3.110 27541
```

5. In the arbitration configuration file (arbitration.conf), define the information related to control of the Mirroring Controller arbitration process.

Create arbitration.conf in the Mirroring Controller arbitration process management directory, based on the sample file. For arbitration.conf, set read and write permissions only for the operating system user who starts and stops the arbitration process in step 1. If users other than this are granted access permissions, the mc_arb command will not work.

Sample file

```
/installDir/share/mcarb_arbitration.conf.sample
```

Set the parameters shown in the table below in arbitration.conf.

Table 2.1 Parameters

Parameter	Content specified	Remarks
port	Port number of the Mirroring Controller arbitration process	The port number must be 0 to 65535. Ensure that the port number does not conflict with other software. Do not specify an ephemeral port that may temporarily be assigned by another program.
my_address	<i>'ipAddrOrHostNameThatAcceptsConnectionFromMirroringControllerProcessOnDbServer'</i> [Setting example] my_address = '192.0.3.120'	IPv4 and IPv6 addresses can be specified. Specify the IP address, enclosed in single quotation marks (').
syslog_ident	<i>'programName'</i>	Specify using single quotation marks (') to enclose the program name used to identify the Mirroring Controller arbitration process message in the system log. Use ASCII characters excluding spaces to specify this parameter. The default is 'MirroringControllerArbiter'.
fencing_command	<i>'fencingCmdFilePath'</i> [Setting example] fencing_command = '/arbiter/fencing_dir/execute_fencing.sh'	Specify the full path of the fencing command that fences a database server where it is determined that an error has occurred. Enclose the path in single quotation marks ('). Specify the path using less than 1024 bytes.
fencing_command_timeout	Timeout for fencing command (seconds)	If the command does not respond within the specified number of seconds, it is determined that fencing has failed and a signal (SIGTERM) is sent to the fencing command execution process. Specify a value between 1 and 2147483647. The default is 20 seconds.

Information

Refer to "[A.4.2 Arbitration Configuration File](#)" for information on the parameters and for other parameters.

2.3.2 Creating a User Command for the Arbitration Server

The only user command for the arbitration server is the fencing command.

The fencing command is a user command that is called by the Mirroring Controller arbitration process if Mirroring Controller performs arbitration processing and determines that a database server is unstable.

In the fencing command, the user implements a process that isolates a database server from a cluster system by, for example, stopping the target operating system or server. The fencing command that was created is to be specified for the parameter in the arbitration configuration file. Refer to "[A.4.2 Arbitration Configuration File](#)" for information on the parameters.

- Fencing the primary server during the switch
 - Prevent the Mirroring Controller management process on the primary server from communicating with the Mirroring Controller management process on the other server.
 - Prevent applications from connecting to the primary server instance.
- Fencing the standby server during disconnection
 - Prevent the Mirroring Controller management process on the standby server from communicating with the Mirroring Controller management process on the other server.
 - Prevent applications from connecting to the standby server instance.
 - Prevent the standby server from continuing streaming replication.



See

Refer to "[Appendix C User Commands](#)" for information on user commands.

2.3.3 Starting the Mirroring Controller Arbitration Process

This section explains how to start the Mirroring Controller arbitration process.

An operating system user who has logged in to the arbitration server can start the Mirroring Controller arbitration process by executing the `mc_arb` command in start mode.

Example)

```
$ mc_arb start -M /mcarb_dir/arbiter1
```

2.4 Setting Up the Primary Server

This section explains how to set up the primary server.

2.4.1 Setting Up Database Multiplexing Mode on the Primary Server

This section explains how to set up database multiplexing mode on the primary server.

In database multiplexing, the files that are required for operations are managed in the Mirroring Controller management directory.

There is one Mirroring Controller management directory for each instance.



Note

- Do not place the Mirroring Controller management directory in a directory managed by FUJITSU Enterprise Postgres, otherwise it may be deleted by mistake with the directories managed by FUJITSU Enterprise Postgres, and an old version of files may be restored.



See

- Refer to "Preparing Directories for Resource Deployment" in the Installation and Setup Guide for Server for details on the directories that are managed by FUJITSU Enterprise Postgres.
- Refer to "`mc_ctl`" in Reference for information on the command.
- Refer to "[Appendix A Parameters](#)" for details on each parameter to be edited for the setup.

Perform the following procedure:

1. Log in to the primary server.
2. Create the Mirroring Controller management directory that will store the files required by database multiplexing.
Use ASCII characters in the Mirroring Controller management directory.
Additionally, grant "Write" permission to the instance administrator user for the Mirroring Controller management directory.
3. In the network configuration file (network.conf), define the network configuration that will link between the Mirroring Controller processes.

Create the network.conf file in the Mirroring Controller management directory, based on the sample file. For network.conf, set read and write permissions for the instance administrator user only.

If users other than the instance administrator user are granted access, the mc_ctl command will not work. In this way, users other than the instance administrator user are prevented from operating Mirroring Controller.

Sample file

```
/installDir/share/mc_network.conf.sample
```

In network.conf, specify the IP address or host name and port number of the primary server and standby server, and define the network configuration that will link between the Mirroring Controller processes, and between Mirroring Controller processes and the Mirroring Controller arbitration process.

Refer to "[A.3 Network Configuration File](#)" for details.

A definition example is shown below.

The content to be defined depends on the operation settings at the time a heartbeat abnormality is detected.

When automatic degradation by the arbitration server is selected

Example)

The IDs of the primary server and standby server are set to "server1" and "server2", and their port numbers are set to "27540" and "27541". The ID of the server of the Mirroring Controller arbitration process is set to "arbiter", and its port number is set to "27541".

```
server1 192.0.2.100,192.0.3.100 27540,27541 server
server2 192.0.2.110,192.0.3.110 27540,27541 server
arbiter 192.0.3.120 27541 arbiter
```

Ensure that the port numbers set for the primary server, standby server, and arbitration server do not conflict with other software. In addition, when the arbitration server is used for automatic degradation, use a network in which the arbitration network is not affected by a line failure in the admin network.

When the server type is "server", two IP addresses or host names, and two port numbers need to be specified in the following order:

- IP address or host name of the database server used as the admin network
- IP address or host name of the database server used as the arbitration network
- Port number of the database server used as the admin network
- Port number of the database server used as the arbitration network

If the server type is "arbiter", specify the IP address or host name set for the my_address parameter and the port number set for the port parameter in arbitration.conf of the arbitration server.

When operation other than automatic degradation by the arbitration server is selected

Example)

The IDs of the servers are set to "server1" and "server2", and their port numbers are set to "27540".

```
server1 192.0.2.100 27540
server2 192.0.2.110 27540
```

Ensure that the port numbers for the primary and standby server do not conflict with other software.

Register in `/etc/services` the port number of the primary server, because programs such as WebAdmin use it to search for available port numbers.

Register any name as the service name.

4. Define the information related to Mirroring Controller monitoring and control in the `serverIdentifier.conf` file.

Create the `serverIdentifier.conf` file in the Mirroring Controller management directory, based on the sample file.

For `serverIdentifier.conf`, set read and write permissions for the instance administrator user only. If users other than the instance administrator user are granted access, the `mc_ctl` command will not work.

As the file name for the `serverIdentifier.conf` file, use the server identifier name that was specified in the `network.conf` file in step 3.

Sample file

```
/InstallDir/share/mc_server.conf.sample
```

Set the parameters shown in the table below in the `serverIdentifier.conf` file.

Table 2.2 Parameters

Parameter	Content specified	Remarks
db_instance	<code>'dataStorageDestinationDir'</code>	Use ASCII characters, enclosed in single quotation marks (').
db_instance_password	<code>'passwordOfInstanceAdminUser'</code>	If password authentication is performed, you must specify this parameter in the settings used when Mirroring Controller connects to a database instance. Use ASCII characters, enclosed in single quotation marks ('). If the specified value of this parameter includes ' or \, write \' or \\, respectively.
enable_hash_in_password	on or off	Specify on to treat the # in the db_instance_password specification as a password character, or off to treat it as a comment. The default is "off".
syslog_ident	<code>'programName'</code>	Specify the program name to be used to identify the Mirroring Controller messages in the system log. Use ASCII characters excluding spaces, enclosed in single quotation marks ('). Use the same program name as the parameter in the postgresql.conf file ensures that the Mirroring Controller output content can be referenced transparently, so log reference is easy.
remote_call_timeout	Admin communication timeout	Specify the timeout value (milliseconds) of the Mirroring Controller agent process for communication between servers. Specify a value that is less than the operation system TCP connection timeout.
heartbeat_error_action	Operation when a heartbeat abnormality is detected using operating system or server heartbeat monitoring	arbitration: Perform automatic degradation using the arbitration server. command: Call a user command to determine degradation, and perform automatic degradation if required.

Parameter	Content specified	Remarks
		<p>message: Notify messages.</p> <p>fallback: Perform automatic degradation unconditionally.</p> <p>Set the same value on the primary server and standby server.</p>
heartbeat_interval	Interval time for abnormality monitoring during heartbeat monitoring of the operating system or server (milliseconds)	<p>Abnormality monitoring of the operating system or server is performed at the interval (milliseconds) specified in heartbeat_interval.</p> <p>This parameter setting is used as the default for database process heartbeat monitoring, streaming replication abnormality monitoring, and disk abnormality monitoring. When setting the monitoring time, there are some considerations to take into account to optimize degradation using abnormality monitoring. Refer to "2.11.4.1 Tuning for Abnormality Monitoring of the Operating System or Server" for details.</p>
heartbeat_timeout	Timeout for abnormality monitoring during heartbeat monitoring of the operating system or server (seconds)	
heartbeat_retry	Number of retries for abnormality monitoring during heartbeat monitoring of the operating system or server (number of times)	
fencing_command	<p><i>'fencingCmdFilePath'</i></p> <p>[Setting example]</p> <p>fencing_command = '/mc/fencing_dir/execute_fencing.sh'</p>	<p>Specify the full path of the fencing command that fences a database server where an error is determined to have occurred.</p> <p>Enclose the path in single quotation marks (').</p> <p>This parameter must be specified when "command" is set for heartbeat_error_action.</p> <p>Specify the path using less than 1024 bytes.</p>
fencing_command_timeout	Fencing command timeout (seconds)	<p>If the command does not respond within the specified number of seconds, fencing is determined to have failed and a signal (SIGTERM) is sent to the fencing command execution process.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 20 seconds.</p>
arbitration_timeout	Timeout for arbitration processing in the Mirroring Controller arbitration process (seconds)	<p>The specified value must be at least equal to the heartbeat monitoring time of the operating system or server + fencing_command_timeout in the arbitration configuration file.</p> <p>If there is no response for at least the number of seconds specified, the primary server will not be switched and the standby server will not be disconnected. Therefore, perform degradation manually.</p> <p>Specify a value between 1 and 2147483647.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
arbitration_command	<p><i>'arbitrationCmdFilePath'</i></p> <p>[Setting example]</p>	Specify the full path of the arbitration command to be executed when an

Parameter	Content specified	Remarks
	arbitration_command = '/mc/arbitration_dir/ execute_arbitration_command.sh'	<p>abnormality is detected during heartbeat monitoring of the operating system or server.</p> <p>Enclose the path in single quotation marks (').</p> <p>This parameter must be specified when "command" is set for heartbeat_error_action.</p> <p>Specify the path using less than 1024 bytes.</p>
arbitration_command_timeout	Timeout for arbitration command (seconds)	<p>If the arbitration command does not respond within the specified number of seconds, it is determined that execution of the arbitration command has failed and a signal (SIGTERM) is sent to the arbitration command execution process.</p> <p>Specify a value between 1 and 2147483647.</p> <p>This parameter can be specified only when "command" is set for heartbeat_error_action.</p>

Information

Refer to "A.4.1 Server Configuration File for the Database Servers" for information on the parameters and for other parameters.

2.4.2 Creating, Setting, and Registering the Primary Server Instance

This section explains how to create, set, and register the primary server instance.

See

- Refer to "Client Authentication" in the PostgreSQL Documentation for information on the pg_hba.conf file.
- Refer to "A.1 Parameters Set on the Primary Server" for information on the postgresql.conf file.
- Refer to "mc_ctl" in Reference for information on the command.

Perform the following procedure:

1. Refer to "Setup" in the Installation and Setup Guide for Server, and then perform the FUJITSU Enterprise Postgres setup and create the FUJITSU Enterprise Postgres instance.

Use ASCII characters in the data storage destination directory.

Note

- If degradation starts occurring due to an error during operations in database multiplexing mode, recovery is required for the standby server. There are some conditions to execute the pg_rewind command to recover the standby server. One of the conditions can be satisfied by enabling checksums when executing the initdb command. This is not mandatory. Refer to "4.1.1.1.3 Identify cause of error and perform recovery" for details.
2. When using transparent data encryption, configure the encryption settings for the storage data.
Create the keystore file.
Refer to "Database Multiplexing Mode" in the Operation Guide for details, and then configure the settings.
 3. Add the following entry to the pg_hba.conf file to authenticate connections from the standby server.
Copy the file to the standby server later.

#	TYPE	DATABASE	USER	ADDRESS	METHOD
	host	replication	fsep	<i>standbyServerAddress</i>	<i>authenticationMethod</i>
	host	replication	fsep	<i>primaryServerAddress</i>	<i>authenticationMethod</i>

For the primary and standby server addresses, specify the IP address that will connect to the log transfer network.

Additionally, all servers can be used as the primary server or the standby server, so add entries for the addresses of all servers that comprise the database multiplexing system.

Point

Setting an authentication method other than trust authentication

If the primary server becomes the standby server, to perform automatic authentication of connections to the primary server, create the .pgpass file in the home directory of the instance administrator user, and then specify a password for the replication database. Accordingly, the instance administrator operating system user and the user registered in the database will be the same, so you can verify that the connection was not made by an unspecified user. Additionally, the password that was set beforehand will be used in the authentication, so that the connection will be automatic.

Note

If trust authentication is set, all OS users who can log in to the primary server will be able to connect, and if one of these is a malicious user, then that user can corrupt the standby server data, or cause the job system to fail, by sending an erroneous transaction log. Therefore, decide on the authentication method according to the security requirements of the system using database multiplexing mode.

Refer to "Authentication Methods" in the PostgreSQL Documentation for details on the authentication methods that can be set.

4. Configure this setting to enable the instance administrator user of the primary server to connect as a database application.

This setting enables the connection to the instance using the user name of the instance administrator user, so that Mirroring Controller can monitor instance errors. Configure this setting to enable the connection to the postgres database.

- If password authentication is used

In the `db_instance_password` parameter of the `serverIdentifier.conf` file, specify the password for the instance administrator user. This password is used to connect to the database instance. If a password is not specified in the `db_instance_password` parameter, the connection to the database instance from Mirroring Controller will fail, and it will not be possible to perform the process monitoring of the instance.

- If password authentication is not used

There is no need to specify the password in the `db_instance_password` parameter.

Even if the password for the instance administrator user is specified in the `db_instance_password` parameter, it will be ignored.

- If certificate authentication using SSL is used

Specify connection parameters for SSL in the `db_instance_ext_pq_conninfo` parameter and `db_instance_ext_jdbc_conninfo` parameter in the `serverIdentifier.conf` file. If the parameters are not specified, the connection to the database instance from Mirroring Controller will fail, and it will not be possible to perform the process monitoring of the instance. If certificate authentication using SSL is not performed, the parameters specification is not required.

An example of setting the authentication method is shown below.

#	TYPE	DATABASE	USER	ADDRESS	METHOD
	host	postgres	fsep	127.0.0.1/32	<i>authenticationMethod</i>

Note

Mirroring Controller uses the PostgreSQL JDBC 4.2 driver to connect to the database instance. Therefore, for the authentication method, specify a method supported by the JDBC driver. If an authentication method not supported by the JDBC driver is specified,

Mirroring Controller will fail to start. Refer to the PostgreSQL JDBC Driver Documentation for information on authentication methods supported by the JDBC driver.

5. To use database multiplexing mode, specify the parameters shown in the table below in the postgresql.conf file.

The postgresql.conf file is copied when the standby server instance is created. Accordingly, set the required parameters in the standby server.

To use database multiplexing mode, specify the parameters shown in the table below in the postgresql.conf file. After editing the postgresql.conf file, restart the instance.

Table 2.3 Parameters

Parameter	Content specified	Remarks
wal_level	replica or logical	Specify "logical" when logical decoding is also to be used.
max_wal_senders	2 or more	Specify "2" when building a Mirroring Controller cluster system. When additionally connecting asynchronous standby servers to the cluster system, add the number of simultaneous connections from these standby servers.
synchronous_standby_names	'standbyServerName'	Specify the name that will identify the standby server. Enclose the name in single quotation marks (''). Do not change this parameter while Mirroring Controller is running. Do not specify multiple names to this parameter as the Mirroring Controller can manage only one standby server.
hot_standby	on	
wal_keep_segments	Number of file segments	If a delay exceeding the value set in this parameter occurs, the WAL segment required later by the primary server may be deleted. Additionally, if you stop a standby server (for maintenance, for example), consider the stop time and set a value that will not cause the WAL segment to be deleted. Refer to "Estimating Transaction Log Space Requirements" in the Installation and Setup Guide for Server for information on estimating the WAL segment.
wal_log_hints	on	When using the pg_rewind command to recover a standby server, specify this parameter or enable checksums when executing the initdb command.
wal_sender_timeout	Timeout (milliseconds)	Specify the time period after which it is determined that an error has occurred in the transaction log transfer on the primary server. By aligning this value with the value for the database process heartbeat monitoring time, you can unify the time after which it is determined that an error has occurred.
archive_mode	on	Specify the archive log mode.
archive_command	'installDir/bin/pgx_walcopy.cmd "%p" " <i>backupDataStorageDestinationDirectory</i> /archived_wal/%f''	Specify the command and storage destination to save the transaction log.

Parameter	Content specified	Remarks
backup_destination	Backup data storage destination directory	Specify the name of directory where to store the backup data. Set the permissions so that only the instance administrator user can access the specified directory. Specify the same full path on all servers, so that the backup data of other servers can be used to perform recovery.
max_connections	Number of simultaneous client connections to the instance + superuser_reserved_connections	The value specified is also used to restrict the number of connections from client applications and the number of connections for the management of instances. Refer to "When an Instance was Created with the initdb Command" in the Installation and Setup Guide for Server, and "Connections and Authentication" in the PostgreSQL Documentation, for details.
superuser_reserved_connections	Add the number of simultaneous executions of mc_ctl status (*1) + 2	Specify the number of connections reserved for connections from database superusers. Add the number of connections from Mirroring Controller processes. Also reflect the added value in the max_connections parameter.
wal_receiver_timeout	Timeout (milliseconds)	Specify the time period after which it is determined that an error has occurred when the transaction log was received on the standby server. By aligning this value with the value for the heartbeat monitoring time of the database process, you can unify the time after which it is determined that an error has occurred.
restart_after_crash	off	If "on" is specified, or the default value is used for this parameter, behavior equivalent to restarting FUJITSU Enterprise Postgres, including crash recovery, will be performed when some server processes end abnormally. However, when database multiplexing monitoring is used, a failover will occur after an error is detected when some server processes end abnormally, and the restart of those server processes is forcibly stopped. Specify "off" to prevent behavior such as this from occurring for no apparent reason.
synchronous_commit	on or remote_apply	Specify up to what position WAL send is to be performed before transaction commit processing returns a normal termination response to a client. The recommended value is "on" or "remote_apply" to prevent data loss caused by operating system or server down immediately after a switch or switch.
recovery_target_timeline	latest	Specify "latest" so that the new standby server (original primary server) will follow the new primary server when a switch occurs. This parameter is required when the original primary server is incorporated as a new standby server after the primary server is switched.

*1: Number of simultaneous executions of the mc_ctl command in the status mode.

2.4.3 Starting Mirroring Controller on the Primary Server

This section explains how to start Mirroring Controller on the primary server.

When the arbitration server is used for automatic degradation, start the Mirroring Controller arbitration process on the arbitration server in advance.

1. Start the Mirroring Controller process.

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mcdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mcdir/inst1 -F
```

Note

- When the arbitration server is used for automatic degradation, the database server must connect to the arbitration server, and as a result, Mirroring Controller startup may take longer than when the arbitration server is not used.
- If the parameter for heartbeat monitoring of operating systems or servers set by the arbitration server is greater than parameter for heartbeat monitoring of operating systems and servers of the Mirroring Controller, the Mirroring Controller may fail to start. In this case, check the contents of the message notification and review the parameters for heartbeat monitoring of operating systems or servers for the arbitration server or Mirroring Controller.
- If the `heartbeat_error_action` parameter in `serverIdentifier.conf` is set to "message", even if automatic switch/disconnection is enabled and Mirroring Controller is started, only message output is performed when a heartbeat abnormality is detected during heartbeat monitoring of operating systems and servers - switch/disconnection is not performed.
- Mirroring Controller startup usually fails if the standby server is mistakenly started as the primary server or if the old primary server is not recovered after the switch and is then mistakenly started as the primary server. However, if the admin network is disconnected, then startup does not fail, and both servers may become primary servers. Therefore ensure that the admin network is connected before starting Mirroring Controller.

Point

- The `mc_ctl` command fails if the Mirroring Controller arbitration process has not been started on the arbitration server when the arbitration server is used for automatic degradation. However, if the Mirroring Controller arbitration process cannot be started in advance, it can be started by specifying the `--async-connect-arbiter` option in the `mc_ctl` command.
- After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

2. Obtain the backup.

Use the `pgx_dmpall` command to collect the backup.

2.5 Setting Up the Standby Server

This section explains how to set up the standby server.

2.5.1 Setting Up Database Multiplexing Mode on the Standby Server

This section explains how to set up database multiplexing mode on the standby server.

In database multiplexing, the files that are required for operations are managed in the Mirroring Controller management directory.

There is one Mirroring Controller management directory for each instance.

Note

- Do not place the Mirroring Controller management directory in a directory managed by FUJITSU Enterprise Postgres, otherwise it may be deleted by mistake with the directories managed by FUJITSU Enterprise Postgres, and an old version of files may be restored.
 - When creating a standby server for a large database, stop job system operations, specify a large value for the `wal_keep_segments` parameter, or use replication slots.
This is because WALs generated after the standby server is built using the `pg_basebackup` command, but before it is started, need to be retained. However, the number of WAL segments that can be retained is constrained by the `wal_keep_segments` parameter. Additionally, setting the `wal_keep_segments` parameter requires consideration regarding stabilization of the database multiplexing mode (refer to "2.11.1 Tuning to Stabilize the Database Multiplexing Mode" for details).
-

See

- Refer to "Preparing Directories for Resource Deployment" in the Installation and Setup Guide for Server for details on the directories that are managed by FUJITSU Enterprise Postgres.
 - Refer to "pg_basebackup" in "Reference" in the PostgreSQL Documentation for information on the `pg_basebackup` command.
 - Refer to "mc_ctl" in Reference for information on the command.
 - Refer to "Appendix A Parameters" for details on each parameter to be edited for the setup.
 - Refer to "Replication Slots" in the PostgreSQL Documentation for information on replication slots.
-

Perform the following procedure:

1. Log in to the standby server.

2. Create the Mirroring Controller management directory that will store the files required by database multiplexing.

Use ASCII characters in the Mirroring Controller management directory.

Additionally, grant "Write" permission to the instance administrator user for the Mirroring Controller management directory.

3. Copy, and then deploy, the `network.conf` file of the primary server.

Copy the `network.conf` file that was defined in the primary server setup, and deploy it to the Mirroring Controller management directory of the standby server.

Set read and write permissions for the instance administrator user only. If users other than the instance administrator user are granted access, the `mc_ctl` command will not work. Accordingly, users other than the instance administrator user are prevented from operating Mirroring Controller.

Register in `/etc/services` the port number of the standby server that was specified in the `network.conf` file, because programs such as WebAdmin use it to search for available port numbers.

Register any name as the service name.

4. Copy, and then deploy, the `serverIdentifier.conf` file of the primary server.

Copy the `serverIdentifier.conf` file that was defined in the primary server setup, and deploy it to the Mirroring Controller management directory of the standby server.

Set read and write permissions for the instance administrator user only. If users other than the instance administrator user are granted access permissions, the `mc_ctl` command will not work.

2.5.2 Creating, Setting, and Registering the Standby Server Instance

This section explains how to create, set, and register the standby server instance.



See

- Refer to "[Appendix A Parameters](#)" for details on each parameter.
- Refer to "mc_ctl" in Reference for information on the command.

Perform the following procedure:

1. Set the kernel parameters.
Refer to "Configuring Kernel Parameters" in the Installation and Setup Guide for Server for details.
2. When using transparent data encryption, configure the encryption settings for the storage data.
Deploy a copy of the keystore file of the primary server on the standby server.
Refer to "Database Multiplexing Mode" in the Operation Guide for details.
3. Execute the `pg_basebackup` command to create a copy of the primary server instance on the standby server.

Example)

```
$ pg_basebackup -D /database/inst1 -X fetch --waldir=/transaction/inst1 --progress --verbose -R  
--dbname='application_name=standbyServerName' -h primaryServerIpAddress -p  
primaryServerPortNumber
```



Note

- Use the `pg_basebackup` command with the `-R` option to create a `standby.signal` file. If you do not create the `standby.signal` file, the Mirroring Controller cannot be started as a standby server.
- If using a method that requires password authentication for connections to the primary server, you will need to ensure that authentication is performed automatically. If the `-R` option is specified for the `pg_basebackup` command and the password parameter is specified for the `--dbname` option, the `pg_basebackup` command will set the password in the `primary_conninfo` parameter in `postgresql.auto.conf` file, enabling connections to be performed automatically.
If a password is not set in the `primary_conninfo` parameter in `postgresql.auto.conf` file, it will be necessary to create a `.pgpass` file in the home directory of the instance administrator user, and specify a password for the replication database.
- The `primary_conninfo` parameter should not be set in the `postgresql.conf` file, but only in the `postgresql.auto.conf` file using the `pg_basebackup` command.
- When executing the `pg_basebackup` command, consider the following for collection of transaction logs.
 - When "fetch" is specified for the `-X` option of the command
Transaction logs are collected at the end of the backup, so it is necessary to ensure that transaction logs that occur during backup are not deleted from the primary server. Therefore, allow for a sufficient value for the `wal_keep_segments` parameter in `postgresql.conf`.
 - When the `-X` option is omitted or "stream" is specified for the `-X` option of the command
Transaction logs are streamed, so when Mirroring Controller is running on the primary server, the connection is changed to a synchronous standby server on detection of a streaming replication connection using this command. Therefore, if a job has started on the primary server, the primary server will be impacted, therefore execute this command after stopping only the Mirroring Controller process on the primary server.



Refer to "Hot Standby" in the PostgreSQL Documentation for information on the standby.signal file.

4. Set the parameters shown in the table below in the postgresql.conf file.

Table 2.4 Parameters

Parameter	Content specified	Remarks
synchronous_standby_names	<i>'primaryServerName'</i>	<p>Required after switching the primary server and then changing the original primary server to the new standby server.</p> <p>Enclose the name in single quotation marks (').</p> <p>Do not change this parameter while Mirroring Controller is running.</p> <p>Do not specify multiple names to this parameter as the Mirroring Controller can manage only one standby server.</p>

2.5.3 Starting Mirroring Controller on the Standby Server

This section explains how to start Mirroring Controller on the standby server.

When the arbitration server is used for automatic degradation, start the Mirroring Controller arbitration process on the arbitration server in advance.

1. After ensuring that the Mirroring Controller process of the primary server has started, start Mirroring Controller on the standby server.

Enabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode with the -f option specified. This action enables automatic switch/disconnection.

If you start Mirroring Controller and the instance without specifying the -f option, automatic switch/disconnection will not be enabled. To enable both, start Mirroring Controller and then execute the mc_ctl command in enable-failover mode or restart Mirroring Controller with the -f option specified.

Example)

```
$ mc_ctl start -M /mcdire/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode with the -F option specified.

Example)

```
$ mc_ctl start -M /mcdire/inst1 -F
```

2. Check the status of the Mirroring Controller process.

As the instance administrator user, execute the mc_ctl command in status mode. Ensure that "mirroring status" is switchable.

Example)

```
$ mc_ctl status -M /mcdire/inst1
```



- When the arbitration server is used for automatic degradation, the time required for the database server to connect to the arbitration server is added on. Therefore, Mirroring Controller startup may take longer than when the arbitration server is not used.
- If the parameter for heartbeat monitoring of operating systems or servers set by the arbitration server is greater than parameter for heartbeat monitoring of operating systems and servers of the Mirroring Controller, the Mirroring Controller may fail to start. In this

case, check the contents of the message notification and review the parameters for heartbeat monitoring of operating systems or servers for the arbitration server or Mirroring Controller.

- If the `heartbeat_error_action` parameter in `serverIdentifier.conf` is set to "message", even if automatic switch/disconnection is enabled and Mirroring Controller is started, only message output is performed when a heartbeat abnormality is detected during heartbeat monitoring of operating systems and servers - switch/disconnection is not performed.
- Mirroring Controller startup usually fails if the standby server is mistakenly started as the primary server or if the old primary server is not recovered after the switch and is then mistakenly started as the primary server. However, if the admin network is disconnected, then startup does not fail, and both servers may become primary servers. Therefore, ensure that the admin network is connected before starting Mirroring Controller.

Point

- The `mc_ctl` command fails if the Mirroring Controller arbitration process has not been started on the arbitration server when the arbitration server is used for automatic degradation. However, if the Mirroring Controller arbitration process cannot be started in advance, it can be started by specifying the `--async-connect-arbiter` option in the `mc_ctl` command.
- After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

2.6 Creating a User Command for a Database Server

This section explains how to create a user command for a database server.

The following user commands are called by Mirroring Controller management processes.

The user can create user commands as required.

Specify the user commands that were created for the parameters in the server configuration file of the database server. Refer to "[A.4.1 Server Configuration File for the Database Servers](#)" for information on these parameters.

User command types

- Fencing command

This user command performs fencing if Mirroring Controller performs arbitration processing and determines that a database server is unstable.

- Arbitration command

This user command performs arbitration processing in lieu of the arbitration server when there is no arbitration server.

- State transition commands

These user commands are called when Mirroring Controller performs state transition of a database server.

It includes the following types:

- Post-switch command

This user command is called after a promotion from standby server to primary server.

- Pre-detach command

This user command is called before the standby server is disconnected from a cluster system.

If the pre-detach command is specified on both the primary server and standby server, it is called first on the standby server and then on the primary server.

If the settings are configured to forcibly stop the instance on the standby server when the standby server is disconnected, the pre-detach command is called on the standby server and then the instance on the standby server is stopped.

- Post-attach command

This user command is called after the standby server has been attached to a cluster system.

If the post-attach command is specified on both the primary server and standby server, it is called first on the primary server and then on the standby server.

Point

When the arbitration server is used for automatic degradation and the requirements can be satisfied using the fencing command on the arbitration server only, the fencing command on the database server is not required. In addition, if the requirements can be satisfied using the fencing command on the database server only, create a fencing command on the arbitration server for termination processing only (without implementation).

Table 2.5 Availability of user commands, and database server calling the command

User command	Operation when a heartbeat abnormality is detected using operating system or server heartbeat monitoring				Database server calling the command	
	Message output	Automatic degradation by arbitration server	Automatic degradation by arbitration command	Unconditional automatic degradation	Primary server	Standby server
Fencing command	Y (*1)	Y (*2)	R	N	Y	Y
Arbitration command	N	N	R	N	Y	Y
Post-switch command	Y	Y	Y	Y	Y	N
Pre-detach command	Y	Y	Y	Y	Y	Y (*3)
Post-attach command	Y	Y	Y	Y	Y	Y (*3)

R: Required

Y: Can be used

N: Cannot be used

*1: Called only when the mc_ctl command is used to execute forced switching or forced disconnection.

*2: Creation of a fencing command on a database server is optional, but it must be created on the arbitration server.

*3: If message output or unconditional automatic degradation is selected, this command is called only from the primary server.

See

Refer to "[Appendix C User Commands](#)" for information on the interface for each user command.

2.7 Confirming the Streaming Replication Status

Before performing the setup of the database multiplexing mode, ensure that the prerequisite streaming replication feature has been set up correctly.

Perform the following procedure:

1. On the primary server, ensure that single-row searches can be performed using the pg_stat_replication statistics view.

An example output of the psql command is shown below.

Example)

```

postgres=# select * from pg_stat_replication;
-[ RECORD 1 ]-----+-----
pid                | 10651
usesysid           | 10
username           | fsep
application_name   | standby
client_addr        | 192.0.2.210
client_hostname    |
client_port        | 55098
backend_start      | 2020-03-23 11:17:49.628793+09
backend_xmin       |
state              | streaming
sent_lsn           | 0/3000060
write_lsn          | 0/3000060
flush_lsn          | 0/3000060
replay_lsn         | 0/3000060
write_lag          |
flush_lag          |
replay_lag         |
sync_priority      | 1
sync_state         | sync
reply_time         | 2020-03-23 11:23:27.703366+09

```

2. Confirm the search results of step 1.
Ensure that the connection established with the intended standby server is in synchronous mode.

Table 2.6 Items to be checked

Item	Required value
application_name	Value specified for synchronous_standby_names parameter in the postgresql.conf file of the primary server.
client_addr	IP address of the standby server.
state	"streaming".
sync_state	"sync".



-
- Refer to "The Statistics Collector" in "Server Administration" in the PostgreSQL Documentation for information on the pg_stat_replication statistics view.
 - Note that the pg_stat_replication statistics view may change in the future.
-

2.8 Checking the Connection Status

This section explains how to check the connection status from a database server or the arbitration server.

2.8.1 Checking the Connection Status on a Database Server

This section explains how to use a database server to check the connection status of the Mirroring Controller arbitration process and the Mirroring Controller process on the primary server and standby server.

Perform the following procedure:

1. On the primary server and standby server, execute the mc_ctl command in status mode with the --arbiter option specified.

Example)
The mc_ctl command is executed with the --arbiter option specified, and the status is output.

```

$ mc_ctl status --arbiter -M /mcdir/inst1

arbiter_id  host          status
-----
arbiter     192.0.3.120  online

```

2. On the primary server and standby server, check the result displayed by executing the mc_ctl command in status mode in step 1.

Items to be checked

Check that the output status" is "online".



See

Refer to the Reference for information on the mc_ctl command.

2.8.2 Checking the Connection Status on the Arbitration Server

This section explains how to use the arbitration server to check the connection status of the Mirroring Controller arbitration process and the Mirroring Controller process on the primary server and standby server.

Perform the following procedure:

1. Execute the mc_arb command in status mode on the arbitration server.

The example below executes the mc_arb command, and shows the status.

Example)

```

$ mc_arb status -M /mcarb_dir/arbiter1

server_id  host          status
-----
server1    192.0.3.100  online
server2    192.0.3.110  online

```

2. Check the result displayed by executing the mc_arb command in step 1.

Items to be checked

Check that the output status is "online" on both lines.



See

Refer to the Reference for information on the mc_arb command.

2.9 Creating Applications

This section explains how to create applications using database multiplexing, and points that should be noted when you create the applications.

2.9.1 Application Connection Server Settings

If database multiplexing is used and a failover occurs, it will be necessary to switch the application connection server. Accordingly, use the application connection switch feature to create applications.



See

Refer to "Application Connection Switch Feature" in the Application Development Guide for details.

2.10 Checking the Behavior

To check if the environment setup was performed correctly, start the application and then check the behavior of the switch and rebuild.

2.11 Tuning

This section explains how to tune database multiplexing mode.

2.11.1 Tuning to Stabilize the Database Multiplexing Mode

When large amounts of data are updated, the write-to load for the database will become great, and the multiplexing state may become unstable.

Accordingly, by editing the parameters below in the postgresql.conf file, a stable multiplexing state can be maintained. Refer to "Estimating Transaction Log Space Requirements" in the Installation and Setup Guide for Server for information on transaction log space requirements.

Table 2.7 Parameters

Parameter	Content
wal_keep_segments	Refer to "2.4.2 Creating, Setting, and Registering the Primary Server Instance" for details.
max_wal_size	The transaction log is written out according to the checkpoint trigger. If a transaction log with the capacity of the value specified in this parameter is generated, the checkpoint will be executed. If a large value is specified in this parameter, the time required for crash recovery will increase. If a small value is specified in this parameter, many checkpoints will be generated, which will affect the performance of the applications that connect to the primary server.

2.11.2 Tuning to Stabilize Queries on the Standby Server

Queries made using reference jobs on the standby server may be canceled by jobs executed on the primary server.

To reduce the possibility of a job being canceled, specify as large a value as possible for the max_standby_archive_delay parameter in the postgresql.conf file.



See

- Refer to "Handling Query Conflicts" in the PostgreSQL Documentation for details.
- Refer to "Standby Servers" in the PostgreSQL Documentation for details on the max_standby_archive_delay parameter.

2.11.3 Tuning to Stabilize Queries on the Standby Server (when Performing Frequent Updates on the Primary Server)

If jobs are updated on the primary server regularly and frequently, it will be easy for the query made by the reference job on the standby server to be canceled. In this case, edit one of the postgresql.conf file parameters shown in the table below.

Table 2.8 Parameters

Parameter	Description
hot_standby_feedback	When "on" is set, the deletion (vacuum) of the data area that was deleted or updated on the primary server is suppressed.

Parameter	Description
	Accordingly, the query on the standby server will not be canceled. (*1)
vacuum_defer_cleanup_age	The deletion (vacuum) of the data area that was deleted or updated on the primary server is delayed until the specified number of transactions is processed. Accordingly, the probability that the query on the standby server will be canceled decreases.

*1: Because the vacuum is delayed, the data storage destination disk space of the primary server comes under pressure. Additionally, if there is conflict between accesses and queries executed on the standby server, transaction logs indicating this conflict will be transferred. Accordingly, specify as large a value as possible for the max_standby_archive_delay parameter so that access conflicts do not occur.



See

- Refer to "Standby Servers" in the PostgreSQL Documentation for details on the hot_standby_feedback parameter.
- Refer to "Master Server" in the PostgreSQL Documentation for details on the vacuum_defer_cleanup_age parameter.

2.11.4 Tuning for Optimization of Degradation Using Abnormality Monitoring

Mirroring Controller uses a monitoring method that outputs an error if the timeout or number of retries is exceeded when accessing resources targeted for monitoring. Setting inappropriate values in these settings may lead to misdetection or a delay in automatic degradation, so you must design these values appropriately.

For example, the following type of issue occurs if the tuning related to abnormality monitoring is not performed appropriately.

- If the timeout is too short
Results in redundant degradation and availability falls.
- If the timeout is too long
It takes longer for automatic degradation to be performed even when an error affecting operational continuity occurs, potentially causing downtime.

You can optimize degrading operation by editing the values for the parameters in the server configuration file described below in accordance with the system. Refer to "[A.4 Server Configuration File](#)" for information on how to edit these parameters.

2.11.4.1 Tuning for Abnormality Monitoring of the Operating System or Server

Tuning for abnormal monitoring of the operating system or server depends on the operation when heartbeat abnormality is detected by the heartbeat monitoring of operating systems or servers.



See

Refer to "[1.1.1 Monitoring Using Database Multiplexing Mode](#)" for the operation when heartbeat abnormality is detected in the the heartbeat monitoring of operating systems or servers.

2.11.4.1.1 Tuning Abnormality Monitoring for Operations that Use an Arbitration Server for Automatic Degeneration

In an operation that use an arbitration server for automatic degeneration, the database server is periodically monitored for abnormalities so that the Mirroring Controller arbitration process can immediately respond to an arbitration request from the Mirroring Controller. The automatic degradation using the arbitration server can optimize the time from error detection to automatic degradation of the operating systems or servers by editing the following parameters.

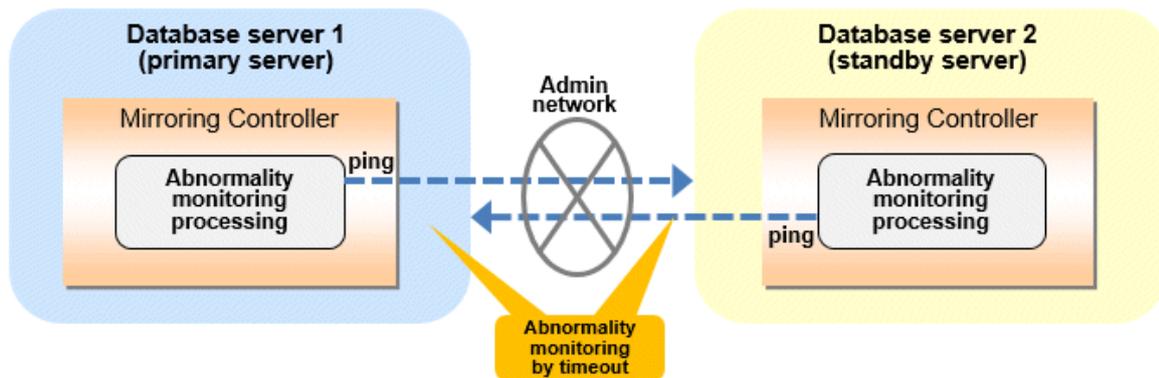
- [Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server](#)
- [Parameters for the abnormality monitoring of the operating system or server in the arbitration configuration file](#)

- Parameters for the arbitration processing and fencing

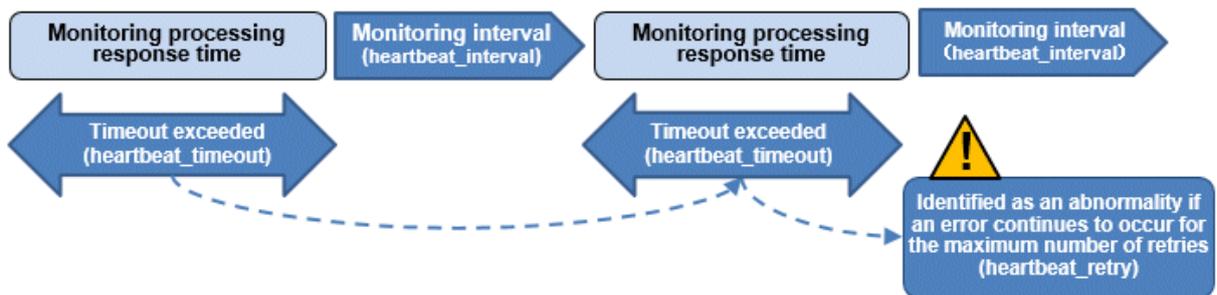
Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server

Table 2.9 Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server

Parameter	Description
Abnormality monitoring interval (heartbeat_interval)	Mirroring Controller is configured so that abnormality monitoring does not place a load on the system. This parameter does not normally need to be set. (The default is 800 milliseconds.)
Abnormality monitoring timeout (heartbeat_timeout)	Take into account the time during which a load is placed continuously on the server or admin network performance. For example, it is envisaged that this parameter will be used in situations such as when performing high-load batch jobs or when a large number of online jobs occur continuously and concurrently. (The default is 1 second.)
Abnormality monitoring retries (heartbeat_retry)	This parameter can be set when needing a safety value for situations in which the value specified for heartbeat_timeout is exceeded, for example, when using systems with fluctuating loads, however, this parameter does not normally need to be set. (The default is 2 times.)



Flow of abnormality monitoring by timeout



The expression for calculating the time required to detect an abnormality by Mirroring Controller is shown below.

$$\text{Abnormality detection time of Mirroring Controller} = (\text{heartbeat_timeout(seconds)} + \text{heartbeat_interval(milliseconds)} / 1000) \times (\text{heartbeat_retry(number of times)} + 1)$$

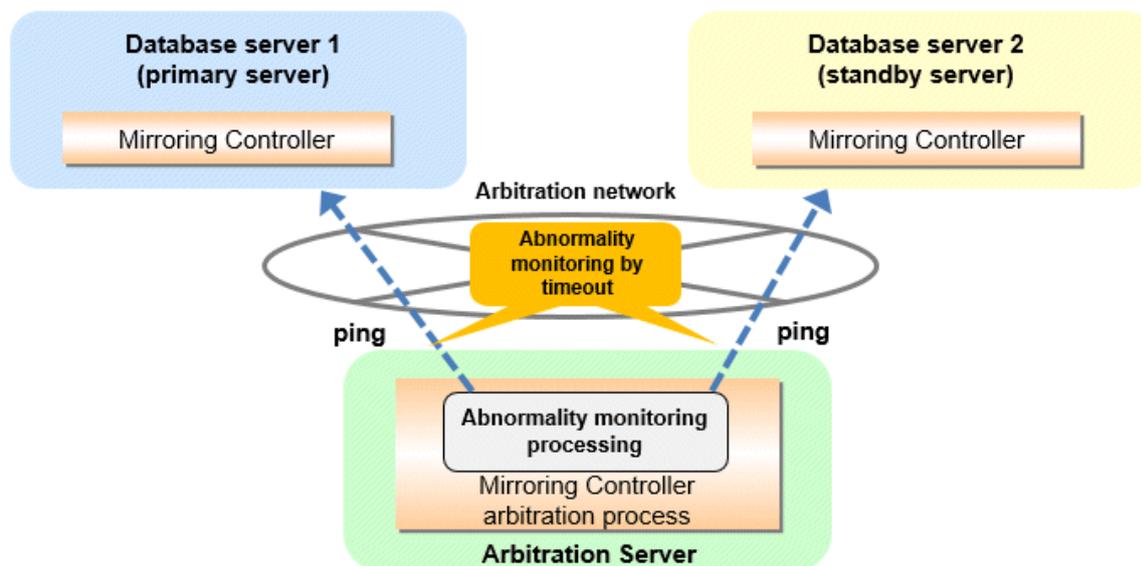
The abnormality detection time when the default value is used is shown below.

$$\begin{aligned} \text{Abnormality detection time of Mirroring Controller} &= (1 + 800 / 1000) \times (2 + 1) \\ &= 5.4(\text{seconds}) \end{aligned}$$

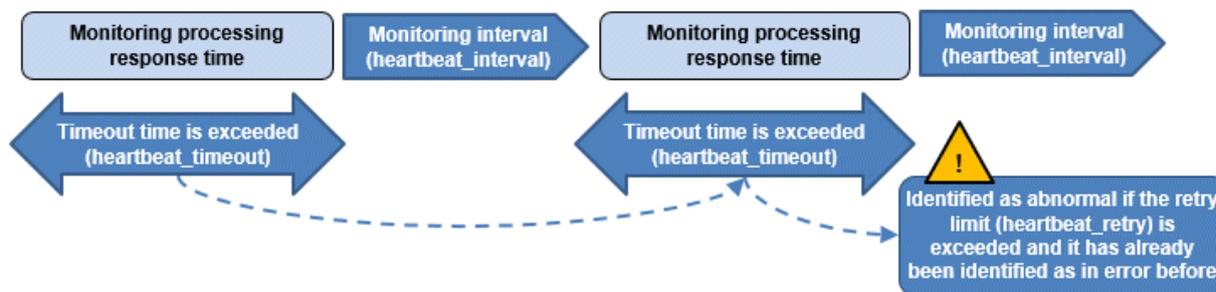
Parameters for the abnormality monitoring of the operating system or server in the arbitration configuration file

Table 2.10 Parameters for the abnormality monitoring of the operating system or server in the arbitration configuration file

Parameter	Description
Abnormality monitoring interval (heartbeat_interval)	Mirroring Controller arbitration process is configured so that abnormality monitoring does not place a load on the system. This parameter does not normally need to be set. (The default is the value set in heartbeat_interval in the server configuration file of the database server.) (milliseconds).
Abnormality monitoring timeout (heartbeat_timeout)	Take into account the time during which a load is placed continuously on the server and arbitration network capabilities. (The default is the value set in heartbeat_timeout in the server configuration file of the database server.) (seconds).
Abnormality monitoring retries (heartbeat_retry)	This parameter can be set when needing a safety value for situations in which the value specified for heartbeat_timeout is exceeded, for example, when using systems with fluctuating loads, however, this parameter does not normally need to be set. (The default is the value set in heartbeat_retry in the server configuration file of the database server.) (number of times)



Flow of abnormality monitoring by timeout



The expression for calculating the time required to detect an abnormality by Mirroring Controller arbitration process is shown below.

$$\text{Abnormality detection time of Mirroring Controller arbitration process} = (\text{heartbeat_timeout}(\text{seconds}) + \text{heartbeat_interval}(\text{milliseconds}) / 1000) \times (\text{heartbeat_retry}(\text{number of times}) + 1)$$

The abnormality detection time when the default value is used is shown below.

$$\begin{aligned} \text{Abnormality detection time of Mirroring Controller arbitration process} &= (1 + 800 / 1000) \times (2 + 1) \\ &= 5.4(\text{seconds}) \end{aligned}$$

Point

The abnormality detection time of the operation for automatic degradation using the arbitration server can be calculated as follows.

$$\text{Abnormality detection time} = \text{Max}(\text{Abnormality detection time by Mirroring Controller, Abnormality detection time by Mirroring Controller arbitration process})$$

Note

If the heartbeat_interval is set in the arbitration configuration file, the relationship between the parameter for operating system or server abnormality monitoring specified in the server configuration file of the database server file and the heartbeat_interval of the arbitration configuration file must satisfy the following relational expression.

$$\begin{aligned} &\text{Heartbeat_interval in the arbitration configuration file (milliseconds) / 1000} < \\ &(\text{heartbeat_timeout(seconds)} + \text{heartbeat_interval(milliseconds) / 1000}) * \text{heartbeat_retry(number of} \\ &\text{times)} + \text{heartbeat_timeout(seconds)} \end{aligned}$$

Parameters for the arbitration processing and fencing

Table 2.11 Parameters for the arbitration processing and fencing

Parameter	Description
Arbitration processing timeout (arbitration_timeout in the server configuration file of the database server)	Take into account the time to perform arbitration processing on the Mirroring Controller arbitration process. The value must be greater than or equal to abnormality detection time of Mirroring Controller arbitration process + fencing_command_timeout in the arbitration configuration file (seconds).
Fencing timeout (fencing_command_timeout in the arbitration configuration file)	Take into account the time to execute the fencing command (seconds).

Flow from the abnormality detection to the automatic degeneracy

When performing automatic degradation using the arbitration server, the flow from the abnormality detection in the operating system or server to the occurrence of automatic degeneracy and the parameters is shown below.

Flow from the abnormality detection to the automatic degeneracy	Description	Parameter
(1) Abnormality detection	Mirroring Controller detect the database server operating system or server errors.	Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server
(2) Arbitration request	Mirroring Controller that detect the operating system or server error asks the Arbitration Server to check the status of the other server's operating system or server.	-
(3) Arbitration processing	The Mirroring Controller arbitration process checks the status of the other server's operating system or server. However, if the result of the operating system or server abnormality	Parameters for the abnormality monitoring of the operating system or

Flow from the abnormality detection to the automatic degeneracy	Description	Parameter	
	monitoring by the arbitration server has been determined before the arbitration request from the Mirroring Controller of the database server, this process is not performed.	server in the arbitration configuration file	
(4) Fencing	If the Mirroring Controller arbitration process determines that the other server is an abnormality of the operating system or server, it fences the other server and isolates it from the cluster system. If the Mirroring Controller arbitration process determines that the operating system or server status is normal, this process and the (6) are not performed.	fencing_command_timeout in the arbitration configuration file	
(5) Return of the arbitration results	Returns the results of the arbitration to the Mirroring Controller of the database server that requested the arbitration.	-	
(6) Automatic degradation	The automatic degradation is performed. If fencing fails in (4), this procedure is not performed.	-	

-: No associated parameters

Note

If the fencing_command parameter is specified in the server configuration file of the database server, the fencing command is invoked on the database server if fencing is successful on the arbitration server. In that case, add the value of the fencing_command_timeout parameter in the server configuration file of the database server to the estimate.

Figure 2.1 When the Mirroring Controller on the primary server detects an operating system or server error

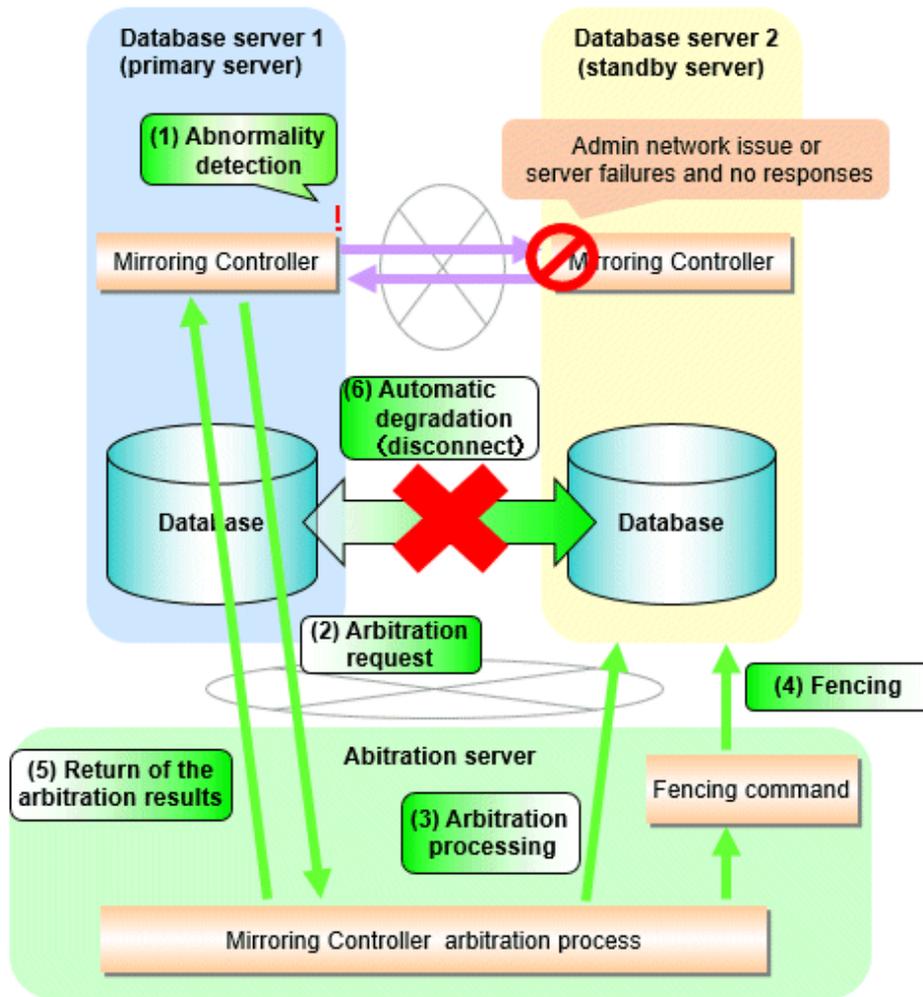
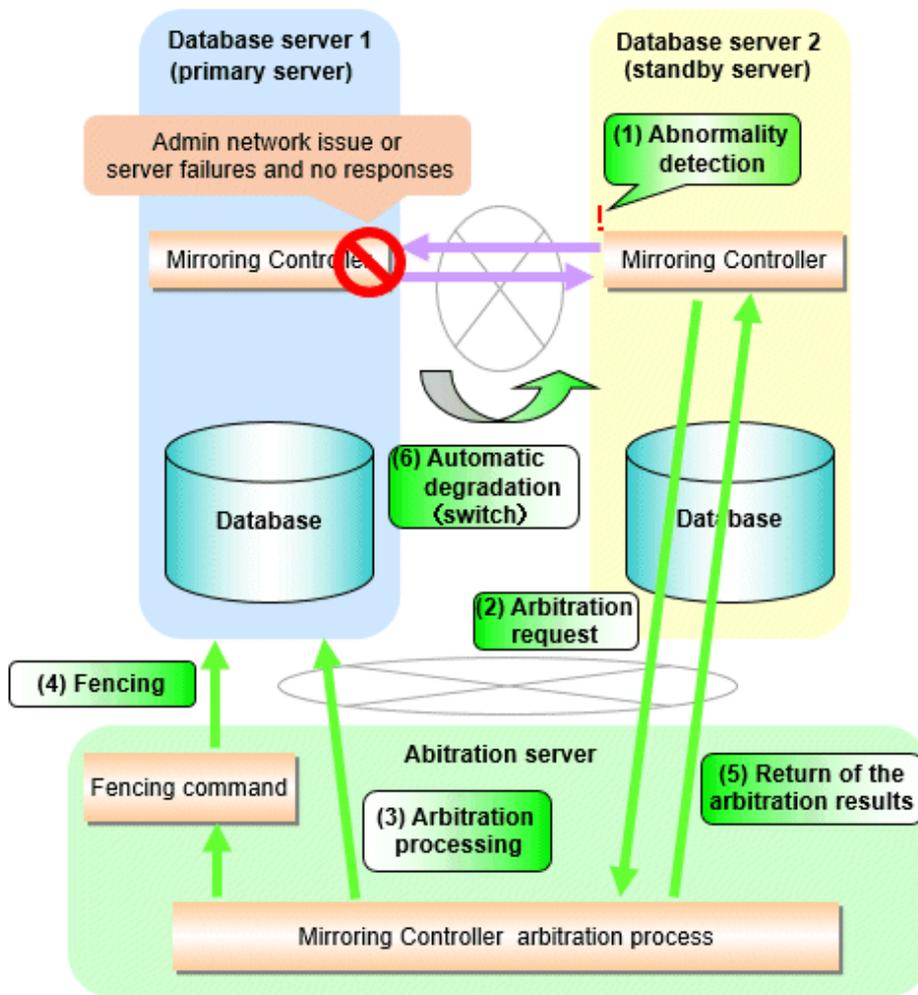


Figure 2.2 When the Mirroring Controller on the standby server detects an operating system or server error



2.11.4.1.2 Tuning Abnormality Monitoring for Operations that Perform Automatic Degeneration by Calling a User Command that Determines Degeneration

In an operation that perform automatic degeneration by calling a user command that determines degeneration, you can optimize the time from operating system or server abnormality detection to automatic degradation by editing the operating system or server abnormality monitoring parameters and parameters related to arbitration processing and fencing in the server configuration file of the database server. Refer to "[Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server](#)" for information on the operating system or server abnormality monitoring parameters in the server configuration file of the database server.

Table 2.12 Parameters for the arbitration processing and fencing

Parameter	Description
Arbitration processing timeout (arbitration_command_timeout)	Take into account the time to execute the arbitration command(seconds).
Fencing timeout (fencing_command_timeout)	Take into account the time to execute the fencing command (seconds).

Flow from the abnormality detection to the automatic degeneracy

When performing automatic degradation by calling a user command that determines degeneration, the flow from the abnormality detection in the operating system or server to the occurrence of automatic degeneracy and the parameters is shown below.

Flow from the abnormality detection to the automatic degeneracy	Description	Parameter
(1) Abnormality detection	Mirroring Controller detect the database server operating system or server errors.	Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server
(2) Arbitration processing	An arbitration command is executed to check the status of the other server's operating system or server.	arbitration_command_timeout in the server configuration file of the database server
(3) Fencing	If the operating system or server status of the other server is abnormal in (2), it fences the other server and isolates it from the cluster system. If the operating system or server status of the other server is normal in (2), this process and (4) are not executed.	fencing_command_timeout in the server configuration file of the database server
(4) Automatic degradation	The automatic degradation is performed. If fencing fails in (3), this procedure is not performed.	-

-: No associated parameters

Figure 2.3 When the Mirroring Controller on the primary server detects an operating system or server error

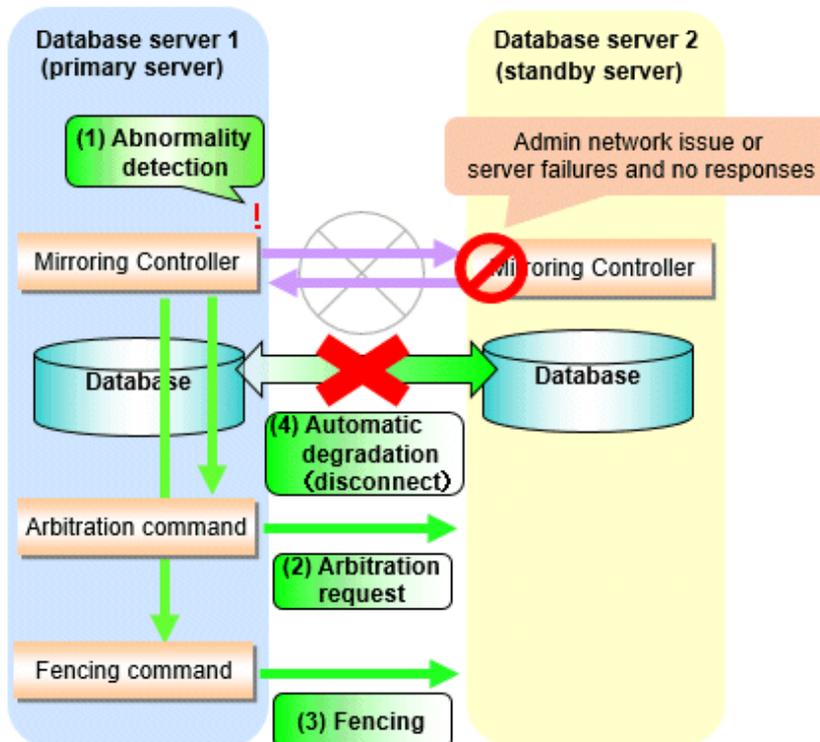
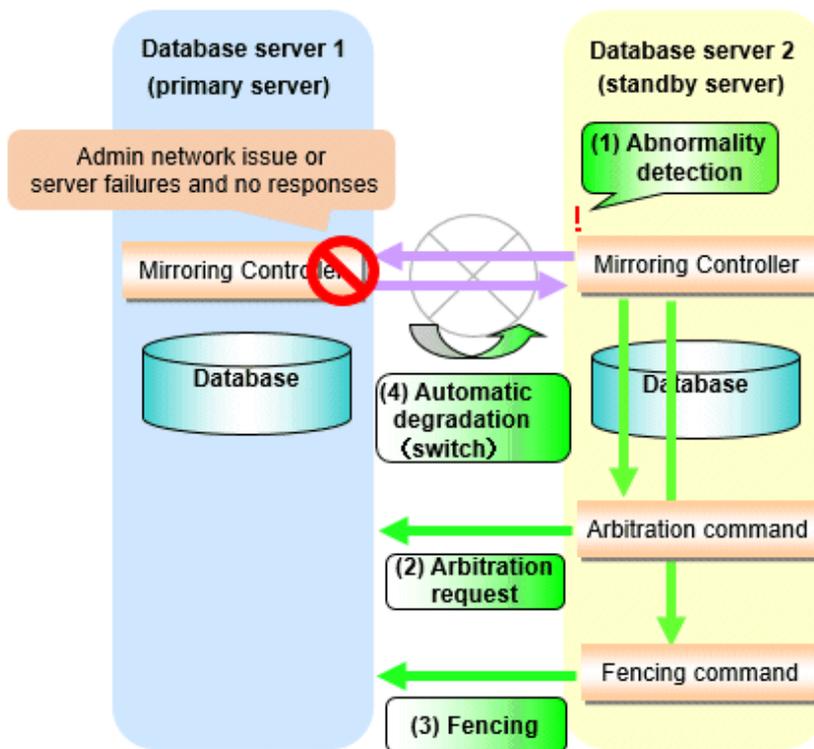


Figure 2.4 When the Mirroring Controller on the standby server detects an operating system or server error



2.11.4.1.3 Tuning Abnormality Monitoring for Operations that Notify Messages

In an operation that notify messages, you can optimize the abnormality detection time by editing the operating system or server abnormality monitoring parameters in the server configuration file of the database server. Refer to "[Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server](#)" for information on the operating system or server abnormality monitoring parameters in the server configuration file of the database server. In addition, when the Mirroring Controller detects an error, it does not perform the arbitration processing, fencing, or automatic degradation, but only notification messages is performed.

2.11.4.1.4 Tuning Abnormality Monitoring for Operations that Perform Automatic Degenerate Unconditionally due to Heartbeat Abnormality

In an operation that perform automatic degenerate unconditionally due to heartbeat abnormality, you can optimize the time from operating system or server abnormality detection to automatic degradation by editing the operating system or server abnormality monitoring parameters in the server configuration file of the database server. Refer to "[Parameters for the abnormality monitoring of the operating system or server in the server configuration file of the database server](#)" for information on the operating system or server abnormality monitoring parameters in the server configuration file of the database server. In addition, when the Mirroring Controller detects an error, it does not perform the arbitration processing, fencing, or automatic degradation, but only automatic degenerate unconditionally is performed.

Note

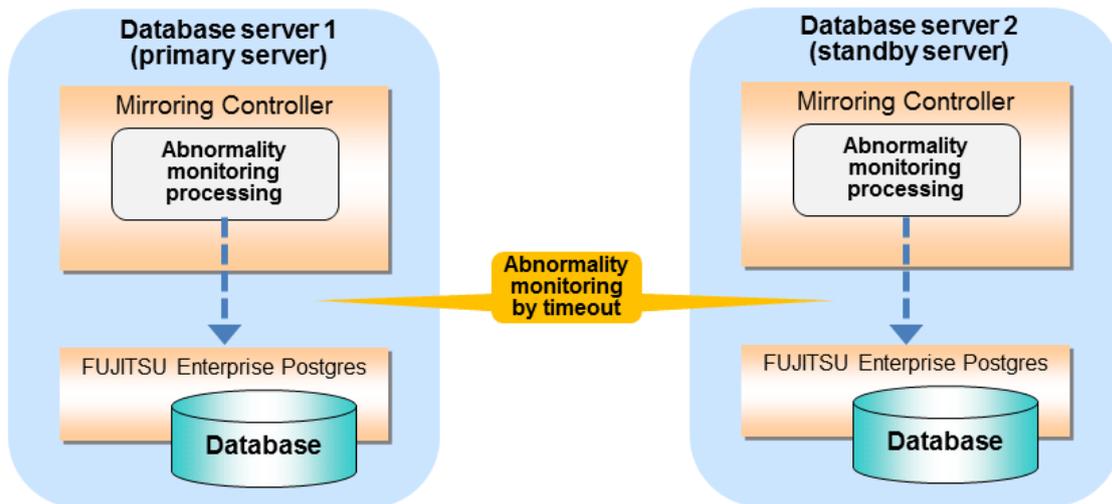
Refer to "[Appendix D Notes on Performing Automatic Degradation Immediately after a Heartbeat Abnormality](#)" for notes on the operation that perform automatic degenerate unconditionally due to heartbeat abnormality.

2.11.4.2 Tuning for Abnormality Monitoring of Database Processes

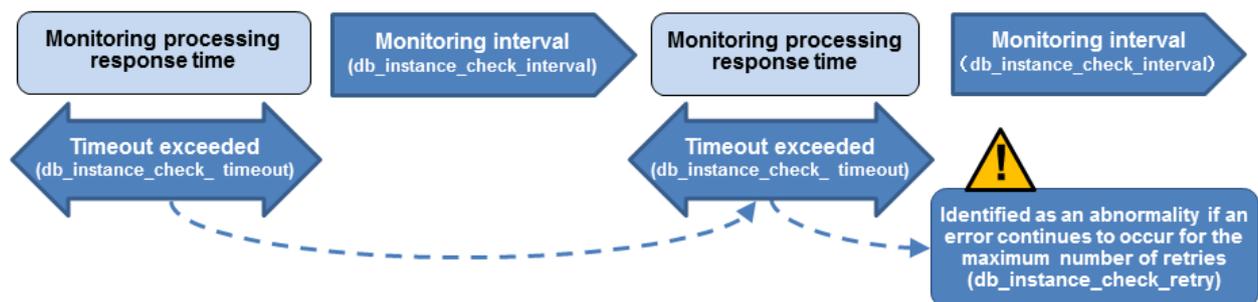
In an abnormality monitoring of database processes, you can optimize by editing the following parameters in the server configuration file of the database server.

Table 2.13 Parameters for abnormality monitoring of database processes

Parameter	Description
Abnormality monitoring interval (db_instance_check_interval)	Abnormality monitoring by Mirroring Controller is set so as not to place load on the system, but normally it does not need to be set. (The default is the value set in heartbeat_interval.) (milliseconds)
Timeout for abnormality monitoring of database processes (db_instance_check_timeout)	Take into account the time during which a load is placed continuously on the database. For example, it is envisaged that this parameter will be used in situations such as when performing high-load batch jobs or when a large number of online jobs occur continuously and concurrently. (The default is the value set in heartbeat_timeout.) (seconds)
Abnormality monitoring retries (db_instance_check_retry)	This parameter can be set when needing a safety value for situations in which the value specified for db_instance_check_timeout is exceeded, for example, when using systems with fluctuating loads, however, this parameter does not normally need to be set. (The default is the value set in heartbeat_retry.) (number of times)



Flow of abnormality monitoring by timeout



The expression for calculating the time required to detect an abnormality is shown below.

$$\text{Abnormality detection time} = (\text{db_instance_check_timeout}(\text{seconds}) + \text{db_instance_check_interval}(\text{milliseconds}) / 1000) \times (\text{db_instance_check_retry}(\text{number of times}) + 1)$$

The abnormality detection time when the default value is used is shown below.

$$\begin{aligned} \text{Abnormality detection time} &= (1 + 800 / 1000) \times (2 + 1) \\ &= 5.4(\text{seconds}) \end{aligned}$$

Note

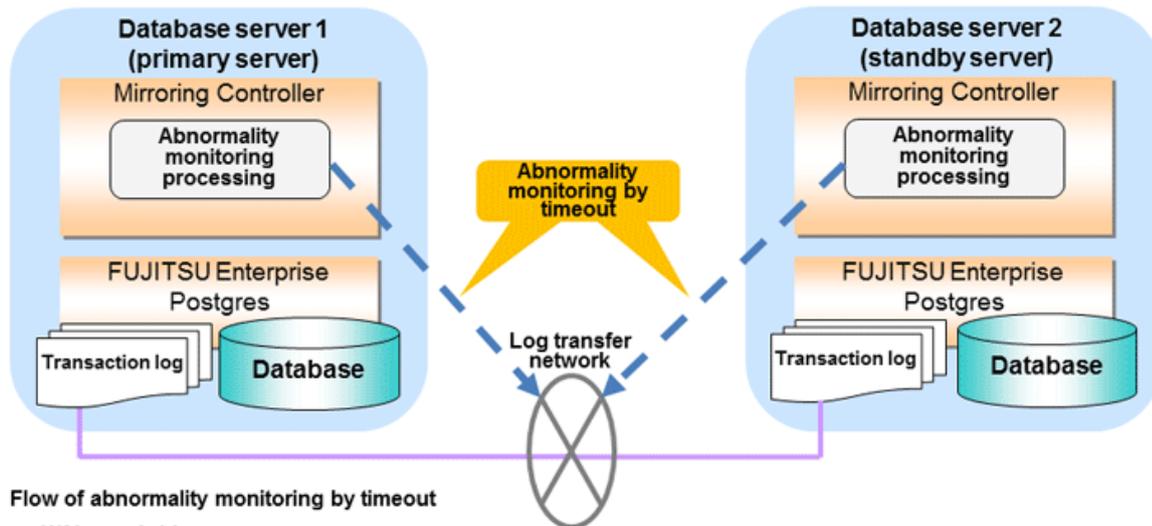
- If the `db_instance_timeout_action` parameter in `serverIdentifier.conf` is set to "message", and the `db_instance_check_timeout` parameter is set to a short value, a crash of the database process will be detected as "no response", and it may take time for automatic degradation to occur. Therefore, specify an appropriate timeout for `db_instance_check_timeout`.
- If a high load on the database and an event that prevents connection to an instance occur at the same time, it is judged as abnormal without retrying monitoring.

2.11.4.3 Tuning for Abnormality Monitoring of Streaming Replication

In an abnormality monitoring of streaming replication, you can optimize by editing the following parameters in the server configuration file of the database server.

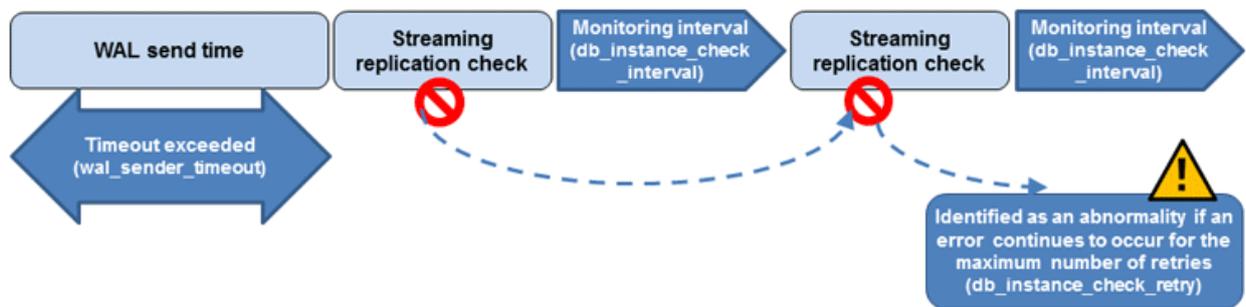
Table 2.14 Parameters for abnormality monitoring of streaming replication

Parameter	Description
Abnormality monitoring interval (<code>db_instance_check_interval</code>)	Abnormality monitoring by Mirroring Controller is set so as not to place load on the system, but normally it does not need to be set. (The default is the value set in <code>heartbeat_interval</code> .) (milliseconds)
Abnormality monitoring retries (<code>db_instance_check_retry</code>)	This parameter can be set when needing a safety value, such as when it is anticipated that a temporary log transfer LAN error may occur, but it does not normally need to be set. (The default is the value set in <code>heartbeat_retry</code> .) (number of times)
Timeout for abnormality monitoring of streaming replication (<code>wal_sender_timeout</code> and <code>wal_receiver_timeout</code> in <code>postgresql.conf</code>)	Take into account the capacity and load of the log transfer network and the time during which a load is placed continuously on the database. For example, if there is a succession of data update jobs that generate a high WAL volume, you must configure the settings to avoid misdetection. (The default is 60 seconds.)

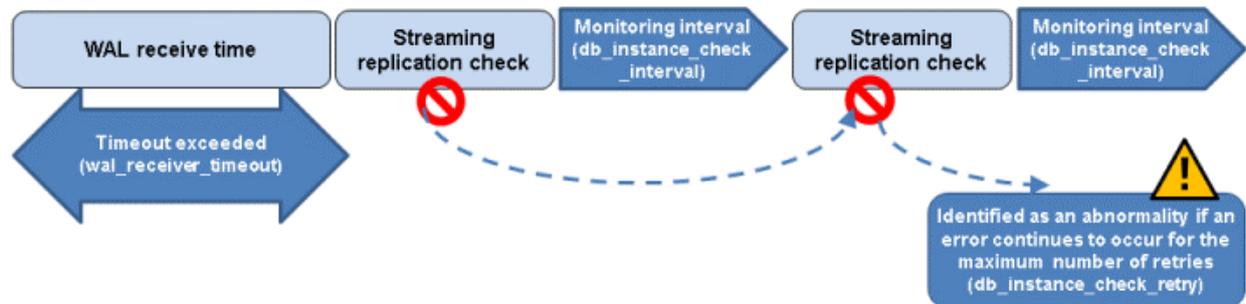


Flow of abnormality monitoring by timeout

- WAL send side



- WAL receive side



The expression for calculating the time required to detect an abnormality is shown below.

$$\text{Abnormality detection time} = (\text{wal_sender_timeout(seconds)} + \text{db_instance_check_interval(milliseconds)} / 1000 \times (\text{disk_check_retry(number of times)} + 1)) \text{ Or,} \\ = (\text{wal_receiver_timeout(seconds)} + \text{db_instance_check_interval(milliseconds)} / 1000 \times (\text{disk_check_retry(number of times)} + 1))$$

The abnormality detection time when the default value is used is shown below.

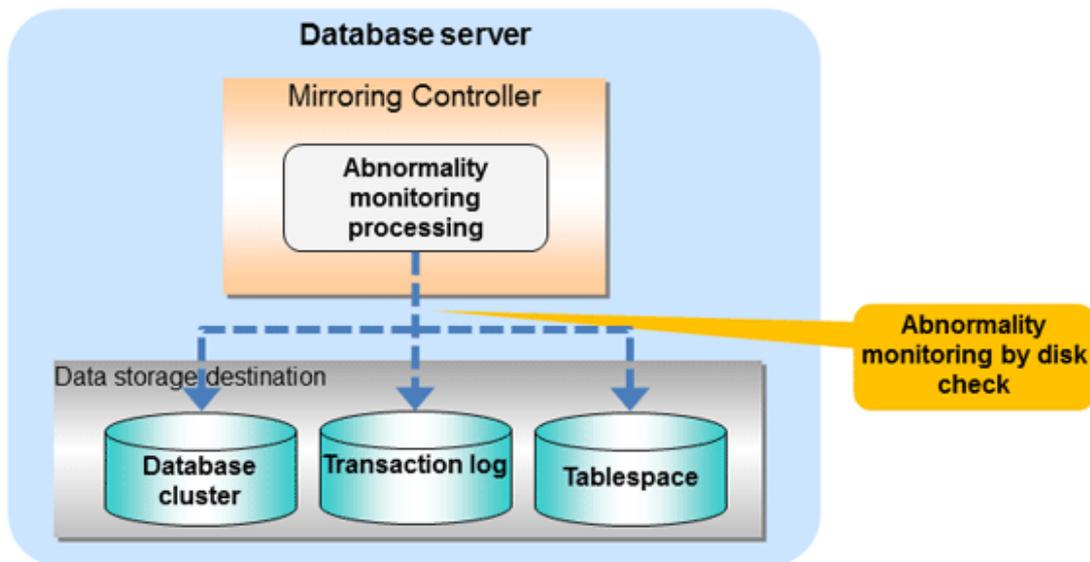
$$\text{Abnormality detection time} = 60 + (800 / 1000 \times (2 + 1)) \\ = 62.4(\text{seconds})$$

2.11.4.4 Tuning for Disk Abnormality Monitoring

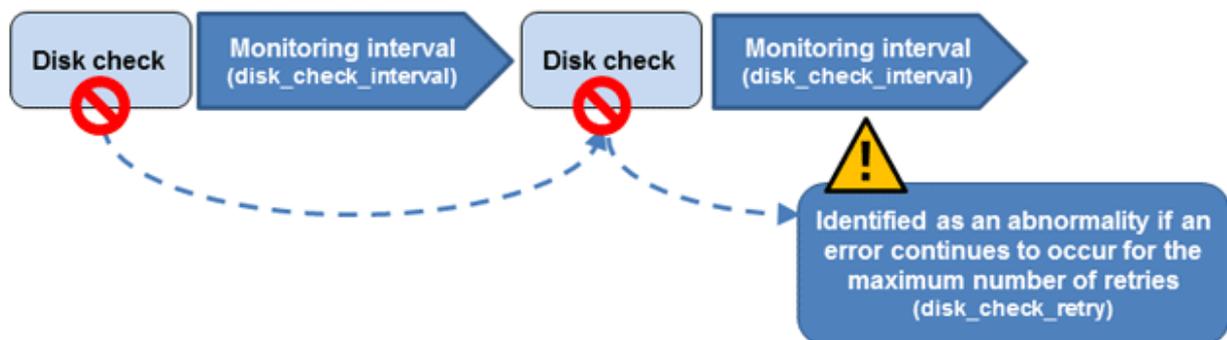
In an abnormality monitoring of the disk, you can optimize by editing the following parameters in the server configuration file of the database server.

Table 2.15 Parameters for disk abnormality monitoring

Parameter	Description
Abnormality monitoring interval (disk_check_interval)	Abnormality monitoring by Mirroring Controller is set so as not to place load on the system, but normally it does not need to be set. (The default is the value set in heartbeat_interval.) (milliseconds)
Abnormality monitoring retries (disk_check_retry)	This parameter can be set when needing a safety value, such as when it is anticipated that a temporary disk input/output error may occur, but normally it does not need to be set. (The default is the value set in heartbeat_retry.) (number of times)



Flow of abnormality monitoring by disk check



The expression for calculating the time required to detect an abnormality is shown below.

$$\text{Abnormality detection time} = \text{disk_check_interval (milliseconds)} / 1000 \times (\text{disk_check_retry (number of times)} + 1)$$

The abnormality detection time when the default value is used is shown below.

$$\begin{aligned} \text{Abnormality detection time} &= 800 / 1000 \times (2 + 1) \\ &= 2.4(\text{seconds}) \end{aligned}$$

Note

- The tuning described above impacts on the time taken from detection of a timeout until switching the primary server. Therefore, modify the values while taking into account the switch/disconnection time, using a design for which misdetection does not occur.
- Immediately selecting automatic degradation when a heartbeat abnormality occurs in operating system or server heartbeat monitoring risks causing split brain. Refer to "[Appendix D Notes on Performing Automatic Degradation Immediately after a Heartbeat Abnormality](#)" for details.

Information

Mirroring Controller uses connections to database instances and SQL access to monitor abnormality in some resources targeted for monitoring. The connection destination database names and connection user names used for abnormality monitoring conform to the parameters in the server configuration file. The application name is "mc_agent".

2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances

Multiplexed instances and Mirroring Controller can be started and stopped automatically in line with the starting and stopping of the operating system of the database server.

Note

To guarantee the startup sequence of Mirroring Controller on the primary and standby servers, first confirm that the primary server has started, and then start the standby servers in sequence.

The startup sequence of the Mirroring Controller process on the database server and the Mirroring Controller arbitration process on the arbitration server is not guaranteed. If the arbitration server cannot be started first, execute the mc_ctl command in start mode with the --async-connect-arbiter option specified to start the Mirroring Controller process.

If using an rc script

Perform the following procedure:

1. Set the OS user account of the instance administrator user

If you logged in using the OS user account of the instance administrator user, set the environment variables required for starting the instance.

This setting is required for executing the "su -" command.

2. Edit the shell script

Copy the sample shell script, and edit the environment variables in the shell script to suit the environment.

Sample shell script

```
/installDir/share/rc_mcoi.sample
```

3. Copy the revised shell script and set access permissions

As the OS superuser, copy the revised shell script to /etc/rc.d/init.d, and then set and register the access rights.

In the following example, the shell script was created as "rc_mc_inst1".

Example)

```
# cp rc_mc_inst1 /etc/rc.d/init.d/  
# chmod 755 /etc/rc.d/init.d/rc_mc_inst1
```

4. Register and enable automatic start and stop

As the OS superuser, execute the chkconfig command to register and enable the script. To register and enable the script, specify the options shown in the table below.

Option	Description
--add	Registers the shell script as the startup script.
--level	Sets and enables the startup script for each run level.

In the following example, the shell script is registered, and then enabled for run levels 3 and 5.

Example)

```
# chkconfig --add rc_mc_inst1
# chkconfig --level 35 rc_mc_inst1 on
```

If using systemd



Note

If you use systemd to start the Mirroring Controller and multiplexed instances, wait for time correction, network setup, and so on.

Perform the following procedure:

1. Create a unit file

Copy the unit file sample stored in the directory below, and revise it to match the target instance.

Sample file

```
/installDir/share/mcoi.service.sample
```

Example)

In the following example, the installation directory is "/opt/fsepv<x>server64", and the instance name is "inst1". Note that "<x>" indicates the product version.

```
# cp /opt/fsepv<x>server64/share/mcoi.service.sample /usr/lib/systemd/system/
mcoi_inst1.service
```

Revise the underlined portions of the options below in the unit file.

Section	Option	Specified value	Description
Unit	Description	FUJITSU Enterprise Postgres MirroringController <u>instanceName</u>	Specifies the feature overview. Specifies the name of the target instance. (*1)
		/bin/bash -c ' <u>installDir</u> /bin/mc_std start <u>installDir</u> <u>MirroringControllerManagementDi</u> <u>t mc_ctlOption</u> '	Command to be executed when the service is started. Specify the option you want to add when the mc_ctl command is executed without the -M option in the mc_ctl option. Note that the content specified in this mc_ctl option is carried over from the mc_std command to the mc_ctl command. (*2)
	ExecStop	/bin/bash -c ' <u>installDir</u> /bin/mc_std stop <u>installDir</u>	Command to be executed when the service is stopped.

Section	Option	Specified value	Description
		<i>MirroringControllerManagementDir</i> <i>'mc_ctlOption'</i>	Specify the option you want to add when the mc_ctl command is executed without the -M option in the mc_ctl option. However, to use the --mc-only option to stop only Mirroring Controller, you must use the --mc-only option at startup. Note that the content specified in this mc_ctl option is carried over from the mc_std command to the mc_ctl command.
	User	<u>User</u>	OS user account of the instance administrator user.
	Group	<u>Group</u>	Group to which the instance administrator user belongs.

*1: The instance name should be as nameThatIdentifiesTheInstance.
The naming conventions for identifying the instance are as follows:

- Up to 16 bytes
- The first character must be an ASCII alphabetic character
- The other characters must be ASCII alphanumeric characters

*2: When the arbitration server is used for automatic degradation, start the Mirroring Controller arbitration process on the arbitration server and then start the Mirroring Controller process on the database server. If the arbitration server cannot be started first, specify the --async-connect-arbiter option to start the Mirroring Controller process.

2. Enable automatic start and stop

As the OS superuser, use the systemctl command to enable automatic start and stop.

Example)

```
# systemctl enable mcoi_inst1.service
```

Note

If automatic start and stop of Mirroring Controller has been configured using systemd, to stop Mirroring Controller, do not use the mc_ctl command, but instead use the systemctl command as the OS superuser.

Example)

```
# systemctl stop mcoi_inst1.service
```

If the instance does not stop, refer to "Actions in Response to Failure to Stop an Instance" in the Operation Guide to stop the instance. Then, specify the -e option in the mc_ctl command to forcibly stop Mirroring Controller.

Example)

```
$ mc_ctl stop -M /mcdirest1 -e
```

If Mirroring Controller is stopped using the mc_ctl command, the message below is output to the system log, however there is no issue because automatic stop is executed by systemd.

Message

```
FATAL: failed to stop Mirroring Controller target server:"{0}" (MCA00043)
```

2.13 Setting Automatic Start and Stop of the Mirroring Controller Arbitration Process

You can automatically start or stop the Mirroring Controller arbitration process when the operating system on the arbitration server is started or stopped.

If using an rc script

Perform the following procedure:

1. Set the operating system user.

Configure the environment variables required for starting the Mirroring Controller arbitration process.

2. Edit the shell script.

Copy the sample shell script, and edit the environment variables in the shell script to suit the environment.

Sample shell script

```
/installDir/share/rc_mcarb.sample
```

3. Copy the revised shell script and set access permissions.

Copy the revised shell script to /etc/rc.d/init.d, and then set and register the access rights.

Example)

In the following example, the shell script was created as "rc_mcarb_arbiter1".

```
# cp rc_mcarb_arbiter1 /etc/rc.d/init.d/  
# chmod 755 /etc/rc.d/init.d/rc_mcarb_arbiter1
```

4. Register and enable automatic start and stop.

As the operating system superuser, execute the chkconfig command to register and enable the script. To register and enable the script, specify the options shown in the table below.

Option	Description
--add	Registers the shell script as the startup script.
--level	Sets and enables the startup script for each run level.

Example)

In the following example, the shell script is registered, and then enabled for run levels 3 and 5.

```
# chkconfig --add rc_mcarb_arbiter1  
# chkconfig --level 35 rc_mcarb_arbiter1 on
```

If using systemd



If you use systemd to start the Mirroring Controller arbitration process, wait for time correction, network setup, and so on.

Perform the following procedure:

1. Create a unit file.

Copy the unit file sample stored in the directory below, and revise it to match the target instance.

Sample file

```
/installDir/share/mcarboi.service.sample
```

Example)

In the following example, the installation directory is "/opt/fsepv<x>assistant", and the identifier of the arbitration process is "arbiter1". Note that "<x>" indicates the product version.

```
# cp /opt/fsepv<x>assistant/share/mcarboi.service.sample /usr/lib/systemd/system/  
mcarboi_arbiter1.service
```

Revise the underlined portions of the options below in the unit file.

Section	Option	Specified value	Description
Unit	Description	FUJITSU Enterprise Postgres Mirroring Controller Arbiter <arbitrationProcessId>	Specifies the feature overview. Specifies the identifier of the targeted arbitration process. (*1)
Service	ExecStart	/bin/bash -c ' <u>installDir</u> /bin/mc_arb_std start <u>installDir</u> <u>mirroringControllerArbitrationProcessMgmtDir</u> <u>mc_arbOption</u> '	Command to be executed when the service is started. Specify the option you want to add when the mc_arb command is executed without the -M option in the mc_arb option. Note that the content specified in this mc_arb option is carried over from the mc_arb_std command in "Specified value" to the mc_arb command.
	ExecStop	/bin/bash -c ' <u>installDir</u> /bin/ mc_arb_std stop <u>installDir</u> <u>mirroringControllerArbitrationProcessMgmtDir</u> <u>mc_arbOption</u> '	Command to be executed when the service is stopped. Specify the option you want to add when the mc_arb command is executed without the -M option in the mc_arb option. Note that the content specified in this mc_arb option is carried over from the mc_arb_std command in "Specified value" to the mc_arb command.
	User	<u>User</u>	Specify the account of the operating system user.
	Group	<u>Group</u>	Specify the group to which the user belongs.

*1: The arbitration process identifier used here is a name for identifying the Mirroring Controller arbitration process.

The naming conventions for identifying the Mirroring Controller arbitration process are as follows:

- Up to 16 bytes
- The first character must be an ASCII alphabetic character
- The other characters must be ASCII alphanumeric characters

2. Enable automatic start and stop.

As the operating system superuser, use the `systemctl` command to enable automatic start and stop.

Example)

```
# systemctl enable mcarboi_arbiter1.service
```

2.14 Backup Operation

This section explains the backup operation for database multiplexing mode.

2.14.1 Backing up Database Multiplexing Mode Information

When changing the Mirroring Controller settings, in addition to backing up the database, back up the configuration file in the Mirroring Controller management directory so that the Mirroring Controller settings are not lost.

When the arbitration server is used for automatic degradation, also back up the configuration file in the Mirroring Controller arbitration process management directory.

2.14.2 Database Backup Operation

Using database multiplexing mode is the same as obtaining the backup data on the standby server as a safeguard against a disk failure. Note that all server disks may be corrupted due to some cause.

As a safeguard against this type of case, execute the `pgx_dmpall` command on the primary server to create the backup data.

However, it is not definite as to which server runs as the primary server, so ensure that the `pgx_dmpall` command is executed periodically on all servers, so that the backup data will be obtained. For example, create a script to obtain the backup data, and set it in the operation management software.



When the `pgx_dmpall` command is executed on the standby server, it will not match the statuses, however the error message shown below will be output and return the value "1".

If a script that ignores only this type of error is executed on all servers, the backup data of the primary server can be obtained.

Error message

```
ERROR:recovery is in progress (10095)
```



- Consider the possibility that the server that runs as the primary server may be destroyed alongside the backup data, so it is recommended to promote another server to become the primary server, and then back up the data on the new primary server without waiting for the next scheduled backup.
- Specify the same backup directory name for the primary and standby servers. If different backup directory names are specified, and recovery is performed using the backup data of the other server, the recovery cannot be performed correctly.



See

- Period backups allow shorter recovery time and reduction in disk usage. Refer to "Backing Up the Database" in the Operation Guide for details on the backup operation.
- Refer to "[Chapter 4 Action Required when an Error Occurs in Database Multiplexing Mode](#)" for details on recovery based on the backup data that was obtained using the `pgx_dmpall` command.

Chapter 3 Operations in Database Multiplexing Mode

This chapter describes the periodic operations that are performed when running database multiplexing mode.

The periodic operations are the same as the operations on a single server.



Refer to "Periodic Operations" in the Operation Guide for information on the periodic operations.

3.1 Starting and Stopping the Mirroring Controller Arbitration Process

This section describes how to start and stop the Mirroring Controller arbitration process.

3.1.1 Starting the Mirroring Controller Arbitration Process

While the Mirroring Controller arbitration process is in a stopped state, execute the `mc_arb` command in start mode to start the Mirroring Controller arbitration process.

Example)

```
$ mc_arb start -M /mcarb_dir/arbiter1
```



Refer to the Reference for information on how to specify the `mc_arb` command.

3.1.2 Stopping the Mirroring Controller Arbitration Process

While the Mirroring Controller arbitration process is running, execute the `mc_arb` command in stop mode to stop the Mirroring Controller arbitration process.

Example)

```
$ mc_arb stop -M /mcarb_dir/arbiter1
```



Refer to the Reference for information on how to specify the `mc_arb` command.



- The arbitration server will be forcibly stopped when the service is stopped.
- Before shutting down the operating system on the arbitration server, either stop the Mirroring Controller on the primary server or standby server or shut down the operating system on the primary server or standby server.

3.2 Starting and Stopping Mirroring Controller

When database multiplexing mode is used, use the `mc_ctl` command to start and stop the instance and Mirroring Controller at the same time.

Do not start or stop the instance by itself.

Starting Mirroring Controller

While Mirroring Controller is in a stopped state, execute the `mc_ctl` command in start mode to start Mirroring Controller.

Enabling automatic switch/disconnection

Execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mcdir/inst1
```

When only the instance is started and stopped, the following will happen:

- When only the instance is started
Features such as automatic switch and automatic disconnection will not work until Mirroring Controller is started.
- When only the instance is stopped
Mirroring Controller determines that an error has occurred in the instance, and performs an unnecessary automatic switch.
Automatic switch may also stop working correctly in some cases.

Disabling automatic switch/disconnection

Execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mcdir/inst1 -F
```

When only the instance is started and stopped, the following will happen:

- When only the instance is started
Errors indicated in "[1.1 What is Database Multiplexing Mode](#)" will not be detected until Mirroring Controller is started.
- When only the instance is stopped
Mirroring Controller determines that an error has occurred in the instance, and outputs an error to the system log.

Point

- To start the Mirroring Controller process only, execute the `mc_ctl` command in start mode with the `--mc-only` option specified.
- After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.
- When the arbitration server is used for automatic degradation, the Mirroring Controller process startup fails on the database server if the Mirroring Controller arbitration process has not been started on the arbitration server in advance. However, even if the Mirroring Controller arbitration process cannot be started in advance, the Mirroring Controller process can be started by specifying the `--async-connect-arbiter` option in the `mc_ctl` command.

Note

- When the arbitration server is used for automatic degradation, the database server must connect to the arbitration server, and as a result, Mirroring Controller startup may take longer.
- Mirroring Controller startup usually fails if the standby server is mistakenly started as the primary server or if the old primary server is not recovered after the switch and is then mistakenly started as the primary server. However, if the admin network is disconnected,

then startup does not fail, and both servers may become primary servers. Therefore, ensure that the admin network is connected before starting Mirroring Controller.

Stopping Mirroring Controller

While Mirroring Controller is running, execute the `mc_ctl` command in stop mode to stop Mirroring Controller process.

Example)

```
$ mc_ctl stop -M /mcdire/inst1
```

Point

To stop the Mirroring Controller process only, execute the `mc_ctl` command in stop mode with the `--mc-only` option specified.

Note

To prevent an unintended automatic switch, before shutting down the operating system on the primary server, you must stop the Mirroring Controller, or shut down the operating system on the standby server.

See

Refer to the Reference for information on how to specify the `mc_ctl` command.

3.3 Checking the Database Multiplexing Mode Status

3.3.1 Checking the Status of the Database Server

This section describes how to check the status of the database server.

Check the multiplexed database status by executing the `mc_ctl` command in status mode.

Additionally, errors can be detected by monitoring the Mirroring Controller messages. If the status or messages are monitored periodically, you can react quickly following an automatic switch failure.

Checking the status of the multiplexing database

When the `mc_ctl` command is executed, the details of the multiplexing configuration, information about whether switch is possible following the error, and location and details of the error that caused the switch or disconnection are displayed.

After starting database multiplexing mode, execute the `mc_ctl` command in status mode to check the multiplexing status.

An example of the status displayed when the `mc_ctl` command is executed is shown below.

Example)

```
$ mc_ctl status -M /mcdire/inst1

mirroring status
-----
switchable
server_id  host_role      host           host_status    db_proc_status  disk_status
-----
server1    primary        192.0.2.100    normal         normal          normal
server2    standby        192.0.2.110    normal         normal          normal
```

Checking the status of connection to the Mirroring Controller arbitration process

When the arbitration server is used for automatic degradation, the status of the connection to the Mirroring Controller arbitration process can be checked by specifying the `--arbiter` option. If the output status is "online", it indicates that an arbitration request can be made from the database server to the arbitration server. When the arbitration server is used for automatic degradation, regularly execute the command in status mode with the `--arbiter` option specified and check that the output status is "online".

Example)

The `mc_ctl` command is executed with the `--arbiter` option specified, and the status is output.

```
$ mc_ctl status --arbiter -M /mcdire/inst1

arbiter_id  host          status
-----
arbiter     192.0.3.120  online
```

Checking the status of data synchronization

Additionally, by referencing the `pg_stat_replication` statistics view on the primary server, the data synchronization status can be confirmed. However, when creating the monitoring program, note that the content of `pg_stat_replication` may be changed in the future.

The following example shows that the locations of the transaction log after it is sent and received (`sent_lsn`, `replay_lsn`) match, and that they are fully synchronized.

Example)

```
postgres=# select * from pg_stat_replication;
-[ RECORD 1 ]-----+-----
pid           | 10651
usesysid     | 10
username     | fsep
application_name | standby
client_addr  | 192.0.2.210
client_hostname |
client_port  | 55098
backend_start | 2020-03-23 11:17:49.628793+09
backend_xmin |
state        | streaming
sent_lsn     | 0/3000060
write_lsn    | 0/3000060
flush_lsn    | 0/3000060
replay_lsn   | 0/3000060
write_lag    |
flush_lag    |
replay_lag   |
sync_priority | 1
sync_state   | sync
reply_time   | 2020-03-23 11:23:27.703366+09
```



See

- Refer to "mc_ctl" in Reference for information on the command.
- Refer to "Notes on Application Compatibility" in the Application Development Guide for information on retaining application compatibility.
- Refer to "The Statistics Collector" in "Server Administration" in the PostgreSQL Documentation for details on `pg_stat_replication`.

3.3.2 Checking the Status of the Arbitration Server

This section describes how to check the status of the arbitration server.

The status of the connection between the Mirroring Controller arbitration process and primary server/standby server can be checked by executing the `mc_arb` command in status mode.

The example below executes the `mc_arb` command, and shows the status.

Example)

```
$ mc_arb status -M /mcarb_dir/arbiter1

server_id      host           status
-----
server1        192.0.3.100    online
server2        192.0.3.110    online
```

3.4 Manually Switching the Primary Server

The primary server cannot be switched automatically in the following case:

- If automatic switch/disconnection is disabled
- If output of messages is selected for heartbeat abnormalities during heartbeat monitoring of the operating system or server and the operating system/server crashes or becomes unresponsive

In this case, to manually switch the primary server, execute the `mc_ctl` command in switch mode on either the primary server or the standby server.

Example)

```
$ mc_ctl switch -M /mcdire_dir/inst1
```



Point

.....
If automatic switch/disconnection is enabled, it is possible to perform switch of primary server at any time.
.....

3.5 Manually Disconnecting the Standby Server

The procedure to perform disconnection of the standby server differs depending on whether the automatic switch/disconnection is enabled or disabled.

If automatic switch/disconnection is enabled

Execute the `mc_ctl` command in stop mode on the standby server.

Example)

```
$ mc_ctl stop -M /mcdire_dir/inst1
```

If automatic switch/disconnection is disabled

1. Execute the `mc_ctl` command in stop mode on the standby server.

Example)

```
$ mc_ctl stop -M /mcdire_dir/inst1
```

2. Comment out the `synchronous_standby_names` parameter in the `postgresql.conf` file on the primary server.

3. Execute the `pg_ctl` command in reload mode on the primary server.

Example)

```
$ pg_ctl reload -D /database/inst1
```

Point

If automatic start and stop of Mirroring Controller has been configured using systemd, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

3.6 Action Required when a Heartbeat Abnormality is Detected

The message below is output when a heartbeat abnormality is detected during heartbeat monitoring of operating systems or servers:

```
detected an error on the monitored object "server(server identifier name)": no response:ping timeout
(MCA00019)
```

If the `heartbeat_error_action` parameter in `serverIdentifier.conf` is set to "message", even if automatic switch/disconnection is enabled and Mirroring Controller is started, automatic switch/disconnection is not performed when a heartbeat abnormality is detected. Therefore, user action will be necessary.

This section explains the action required when the `heartbeat_error_action` parameter is set to "message" and a heartbeat abnormality is detected.

1. Identify the cause of the heartbeat abnormality. The possible causes are below:

- The remote operating system or server crashed or is unresponsive
- An admin network issue occurred

2. Address the cause identified in step 1.

- The remote operating system or server crashed or is unresponsive

Manually perform switch or disconnection using the `mc_ctl` command.

- An admin network issue occurred

Refer to "[Chapter 4 Action Required when an Error Occurs in Database Multiplexing Mode](#)", and recover the database multiplexing system.

3.7 Monitoring Mirroring Controller Messages

The messages that are output by Mirroring Controller are output to both the database server and the arbitration server. If the automatic switch fails, for example, an important message related to the continuation of the operation may be output, so ensure that the system log messages are monitored.

If the arbitration server is used for automatic degradation, monitor messages on both the database server and the arbitration server.

Message output destination on the database server

Messages are output to the system log.

Message output destination on the arbitration server

Messages are output to the system log.

Point

- To monitor message types considered to be important, an operating system setting must be configured beforehand. Refer to the operating system manuals, check if the message is of a message type that is monitored to be output to the system log, and configure the setting if required.
- If the `heartbeat_error_action` parameter in `serverIdentifier.conf` is set to "message", only message output is performed when a heartbeat abnormality is detected during heartbeat monitoring of operating systems and servers - automatic switch/disconnection is not performed. Therefore users need to monitor the messages. Refer to "[3.6 Action Required when a Heartbeat Abnormality is Detected](#)" for details.

Display format on the database server

```
programName[processId]: messageType:messageText (messageNumber)
```

Specify the program name in the syslog_ident parameter of the serverIdentifier.conf file of the database server.

The message types output by Mirroring Controller, their severity, and their corresponding value in the system log are shown in the table below.

Table 3.1 Message type, severity, and corresponding value in the system log

Message type	Severity	Meaning	System log
INFO	Information	Provides information that does not fall under LOG or NOTICE.	INFO
LOG		Provides information recognized as a particularly important event in tracing the operation history. (Example: Automatic switch is complete)	
NOTICE	Notice	Outputs information that takes into account the user instructions within the program in response to an executed or automatically executed process.	NOTICE
WARNING	Warning	Provides a warning, for example it will soon be impossible to maintain the multiplexing state.	WARNING
ERROR	Error	Reports that an error other than FATAL or PANIC has occurred.	ERROR
FATAL		Reports that an abnormality was detected in multiplexed database systems requiring recovery of the system, and also the content and cause of the abnormality.	CRIT
PANIC		Reports that an abnormality was detected in all multiplexed database systems requiring immediate recovery of the system, and also the content and cause of the abnormality.	ALERT

The message severity has the following meanings:

- Information

Informational status. A message that was reported by the system is displayed. No action is required.

- Notice

Informational status, but a message that should be noted is displayed. If necessary, take the actions described in the "Action" section of the message.

- Warning

No error has occurred, but the user is requested to check, and take action. Take the actions described in the "Action" section of the message.

- Error

An error has occurred. Take the actions described in the "Action" section of the message.

Display format on the arbitration server

```
programName[processId]: messageType: messageText (messageNumber)
```

Specify the program name in the syslog_ident parameter of the arbitration.conf file of the arbitration server.

The message types output by Mirroring Controller, their severity, and their corresponding value in the output destination log are shown in the table below.

Table 3.2 Message type, severity, and corresponding value in the output destination log

Message type	Severity	Meaning	System log
INFO	Information	Provides information not categorized as LOG or NOTICE.	INFO
LOG		Provides information recognized as a particularly important event in tracing the operation history. (Example: Automatic switch is complete)	
NOTICE	Notice	Outputs information that takes into account the user instructions within the program in response to an executed or automatically executed process.	NOTICE
WARNING	Warning	Provides a warning, for example it will soon be impossible to perform the arbitration process.	WARNING
ERROR	Error	Reports that an error other than FATAL or PANIC has occurred.	ERROR
FATAL		Reports that an abnormality was detected in the arbitration server requiring recovery of the system, and also the content and cause of the abnormality.	CRIT
PANIC		Reports that an abnormality was detected in the arbitration server requiring immediate recovery of the system, and also the content and cause of the abnormality.	ALERT

The message severity has the following meanings:

- Information

Informational status. A message that was reported by the system is displayed. No action is required.

- Notice

Informational status, but a message that should be noted is displayed. If necessary, take the actions described in the "Action" section of the message.

- Warning

No error has occurred, but the user is requested to check, and take action. Take the actions described in the "Action" section of the message.

- Error

An error has occurred. Take the actions described in the "Action" section of the message.

3.8 Server Maintenance

To perform maintenance tasks such as periodic server inspections and the application of updates for software products including the operating system, you must perform a planned stop of the server, and then perform the maintenance.

3.8.1 Rolling Updates

In database multiplexing mode, rolling updates, that perform the maintenance for the servers that comprise the cluster system, can be performed while jobs continue.

First, perform the maintenance for the standby server, and then switch the standby server to the primary server. Then, perform the maintenance for the original primary server that was switched to the standby server. This enables maintenance to be performed while jobs continue.

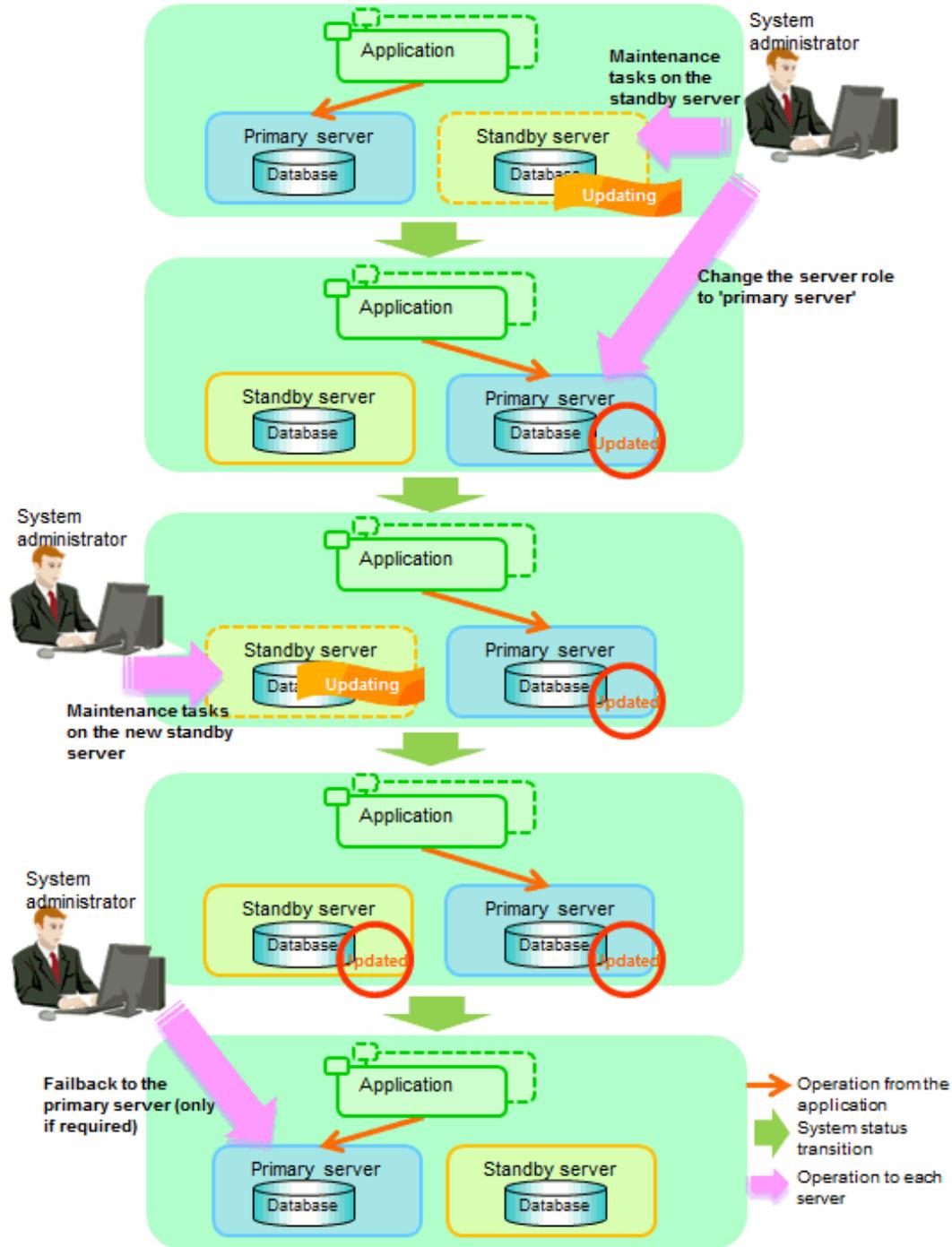
Note that arbitration server maintenance can be performed without affecting database server operation, so it is not necessary to consider rolling update.

 See

If the downtime due to the maintenance of the standby server is expected to be long, refer to "Standby server downtime" in "3.9.1 Changes Required when the Standby Server is Stopped".

The flow of a rolling update is shown below.

Figure 3.1 Performing a Rolling Update



Perform the following procedure as shown in the above figure:

Standby server maintenance tasks

1. To perform the maintenance on the standby server, stop Mirroring Controller.

Example)

```
$ mc_ctl stop -M /mcdir/inst1
```

2. Ensure that Mirroring Controller has completely stopped.

If the multiplexed instances and Mirroring Controller have been configured on the standby server to start and stop automatically when the operating system of the database server is started or stopped, cancel the setting to start and stop automatically.



Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for information on how to configure the multiplexed instances and Mirroring Controller to start and stop automatically when the operating system of the database server starts and stops.

If using an rc script

As the OS superuser, execute the `chkconfig` command to disable automatic start and stop.

In the example below, the shell script for automatic start and stop was created as "rc_mc_inst1" and is disabled for run levels 3 and 5.

Example)

```
# chkconfig --level 35 rc_mc_inst1 off
```

If using systemd

As the OS superuser, execute the `systemctl` command to disable automatic start and stop.

The example below disables automatic start and stop of "mcoi_inst1.service".

Example)

```
# systemctl disable mcoi_inst1.service
```

3. Perform maintenance tasks.
4. Create a copy of the primary server instance on the standby server.

Execute the `pg_basebackup` command to create data in the standby server by synchronizing with the primary server.

Example)

```
$ pg_basebackup -D /database/inst1 -X fetch --waldir=/transaction/inst1 --progress --verbose -R --dbname='application_name=standbyServerName' -h primaryServerHostName -p primaryServerPortNumber
```



The procedure for copying the primary server instance to the standby server is the same as the procedure for setting up the standby server.

Refer to "[2.5.2 Creating, Setting, and Registering the Standby Server Instance](#)", and then perform the recovery.

5. Check the settings for automatic start and stop of the multiplexed instances and Mirroring Controller.

If the multiplexed instances and Mirroring Controller were configured in step 2 to not start and stop automatically when the operating system of the database server starts and stops, then change the settings back. This step can be skipped if automatic start and stop are not required.

If using an rc script

As the OS superuser, execute the `chkconfig` command to enable the shell script.

In the example below, the shell script for automatic start and stop was created as "rc_mc_inst1" and is enabled for run levels 3 and 5.

Example)

```
# chkconfig --level 35 rc_mc_inst1 on
```

If using systemd

As the OS superuser, execute the `systemctl` command to enable automatic start and stop.

The example below disables automatic start and stop of "mcoi_inst1.service".

Example)

```
# systemctl enable mcoi_inst1.service
```

6. Start (rebuild) Mirroring Controller on the standby server.

This operation is required when determining the maintenance tasks on the standby server.

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mdir/inst1 -F
```

Point

After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

Switching to the primary server

To perform the maintenance on the primary server, execute the `mc_ctl` command in the switch mode on the primary server or the standby server.

Example)

```
$ mc_ctl switch -M /mdir/inst1
```

When the switch is complete, the `synchronous_standby_names` parameter in the `postgresql.conf` file of the new primary server will be commented as follows:

Example)

```
#synchronous_standby_names = 'primary'
```

New standby server maintenance tasks

1. Stop the Mirroring Controller.

On the new standby server (the primary server before the switch), execute the `mc_ctl` command in stop mode.

If automatic start and stop of Mirroring Controller has been configured using systemd, do not use the mc_ctl command, but instead use the systemctl command. Refer to "2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances" for details.

Example)

```
$ mc_ctl stop -M /mcdir/inst1
```

2. Ensure that Mirroring Controller has completely stopped.

If the multiplexed instances and Mirroring Controller have been configured on the new standby server to start and stop automatically when the operating system of the database server is started or stopped, cancel the setting to start and stop automatically now.



Refer to "2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances" for information on how to configure the multiplexed instances and Mirroring Controller to start and stop automatically when the operating system of the database server starts and stops.

If using an rc script

As the OS superuser, execute the chkconfig command to disable automatic start and stop.

In the example below, the shell script for automatic start and stop was created as "rc_mc_inst1" and is disabled for run levels 3 and 5.

Example)

```
# chkconfig --level 35 rc_mc_inst1 off
```

If using systemd

As the OS superuser, execute the systemctl command to disable automatic start and stop.

The example below disables automatic start and stop of "mcoi_inst1.service".

Example)

```
# systemctl disable mcoi_inst1.service
```

3. Perform the maintenance on the new standby server that was stopped.
4. Create a copy of the new primary server instance on the new standby server.

Execute the pg_basebackup command to create data in the new standby server by synchronizing with the new primary server.

Example)

```
$ pg_basebackup -D /database/inst1 -X fetch --waldir=/transaction/inst1 --progress --verbose -R  
--dbname='application_name=standbyServerName' -h primaryServerHostName -p  
primaryServerPortNumber
```



The procedure for copying the primary server instance to the standby server is the same as the procedure for setting up the standby server.

Refer to "2.5.2 Creating, Setting, and Registering the Standby Server Instance", and then perform the recovery.

5. Check the settings for automatic start and stop of the multiplexed instances and Mirroring Controller.

If the multiplexed instances and Mirroring Controller were configured in step 2 to not start and stop automatically when the operating system of the database server starts and stops, then change the settings back. This step can be skipped if automatic start and stop are not required.

If using an rc script

As the OS superuser, execute the `chkconfig` command to enable the shell script.

In the example below, the shell script for automatic start and stop was created as "rc_mc_inst1" and is enabled for run levels 3 and 5.

Example)

```
# chkconfig --level 35 rc_mc_inst1 on
```

If using systemd

As the OS superuser, execute the `systemctl` command to enable automatic start and stop.

The example below disables automatic start and stop of "mcoi_inst1.service".

Example)

```
# systemctl enable mcoi_inst1.service
```

6. After the maintenance is complete, edit the following parameters in the `postgresql.conf` file of the standby server as required.

Copying an instance results in the value of the `synchronous_standby_names` parameter becoming the specified value on the primary server. Therefore, correct it to the specified value on the standby server. If the parameter was commented out, then you must uncomment it.

7. On the standby server, start (rebuild) Mirroring Controller.

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mdir/inst1 -F
```



After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

Failback of the Primary Server

Revert the primary server and standby server to the original server configuration. Do this to execute the main job on the previous primary server. Refer to "4.1.1.3 Failback of the Primary Server" for details.



Obtain a backup as soon as this task is complete.

3.8.2 Stopping for Maintenance

Perform this procedure to stop all servers for periodic inspections, for example. On the server on which Mirroring Controller is running, execute the `mc_ctl` command in stop mode to stop the instance and Mirroring Controller.

If automatic start and stop of Mirroring Controller has been configured using systemd, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

After that, on the server where the Mirroring Controller arbitration process is running, execute the `mc_arb` command in stop mode to stop the Mirroring Controller arbitration process.

Stopping Mirroring Controller

Example)

```
$ mc_ctl stop -M /mcdir/inst1 -a
```

Stopping the Mirroring Controller arbitration process

Example)

```
$ mc_arb stop -M /mcarb_dir/arbiter1
```

3.8.3 Arbitration Server Maintenance

Arbitration server maintenance can be performed without affecting database server operation.

Follow the procedure below to perform arbitration server maintenance.

1. Execute the `mc_arb` command in stop mode to forcibly stop the Mirroring Controller arbitration process.

Example)

```
$ mc_arb stop -M /mcarb_dir/arbiter1 -e
```

2. Perform maintenance tasks.
3. Execute the `mc_arb` command in start mode to restart the Mirroring Controller arbitration process.

Example)

```
$ mc_arb start -M /mcarb_dir/arbiter1
```

4. Execute the `mc_arb` command in status mode to check that the arbitration server is connected to the database server.

The example below executes the `mc_arb` command, and shows the status.

Example)

```
$ mc_arb status -M /mcarb_dir/arbiter1

server_id  host          status
-----
server1    192.0.3.100  online
server2    192.0.3.110  online
```

5. Check the command output.

Items to be checked

Check that the output status is "online" on both lines.

3.9 Changes in Operation

The following changes in operation may be required:

- Changes required when the standby server is stopped
- Changing from single server mode to database multiplexing mode
- Changing from database multiplexing mode to single server mode
- Changing to database multiplexing mode when the arbitration server is used for automatic degradation
- Changing parameters
- Uninstalling in the database multiplexing mode

3.9.1 Changes Required when the Standby Server is Stopped

Operation when the standby server is stopped

Before performing maintenance for the primary server instance when the standby server has been stopped, stop Mirroring Controller on the primary server, comment out the `synchronous_standby_names` parameter in the `postgresql.conf` file of the primary server, and then execute the `pg_ctl` command in reload mode.

If this operation is not performed, operations performed on the primary server for the instance will remain in a wait state.



See

Refer to "pg_ctl" in Reference for information on the command.

Standby server downtime

If you specified the `synchronous_standby_names` parameter of the `postgresql.conf` file and then the standby server instance is stopped, consider the points below.

- The `wal_sender_timeout` parameter in the `postgresql.conf` file

If the standby server is stopped after the timeout set in this parameter was exceeded, an error stating that the transaction log could not be received may be output to the primary server system log, and all transaction logs that should be transferred to the standby server are accumulated.

- The `wal_keep_segments` parameter in the `postgresql.conf` file

If a transaction log that exceeds the value set in this parameter was generated while the standby server was stopped, the transaction log may be deleted.

Additionally, setting this parameter requires consideration regarding stabilization of the database multiplexing mode. Refer to "[2.11.1 Tuning to Stabilize the Database Multiplexing Mode](#)" for details.



Note

The standby server must be rebuilt if the pending transaction log to be transferred to the standby server is lost when the standby server is started after the maintenance task is complete.

Take the action advised in the recovery operation that starts from "[4.1.1.1.3 Identify cause of error and perform recovery](#)" through to "[4.1.1.2 Rebuild the Standby Server](#)".

3.9.2 Changing from Single Server Mode to Database Multiplexing Mode

The procedure for switching single server mode to database multiplexing mode for the purposes of high reliability and load distribution of the system is explained below.

This procedure is equivalent to the setup procedure explained in "[Chapter 2 Setting Up Database Multiplexing Mode](#)".



Note

If the data storage destination directory name is not comprised of ASCII characters

Stop the application job and then migrate to a directory with a name that uses only ASCII characters:

1. Stop the database instance on the primary server.
2. Change the name of the data storage destination directory to one that uses only ASCII characters.



See

When encrypting the storage data, refer to "Database Multiplexing Mode" in the Operation Guide, and then perform the setup for encryption on the primary and standby servers.

1. Install on the arbitration server

Perform this step only if the arbitration server is used for automatic degradation.

Install the Server Assistant on the server where the Mirroring Controller arbitration process is started.

Refer to "Installation" in the Installation and Setup Guide for Server Assistant for information on how to install the Server Assistant.

2. Install on the standby server

Install FUJITSU Enterprise Postgres on the server to be started as the standby server.

Refer to "Installation" in the Installation and Setup Guide for Server for information on how to install FUJITSU Enterprise Postgres.

Use ASCII characters in the data storage destination directory.

3. Stop the application jobs

Stop the application jobs to be connected to the primary server.

4. Change the primary server settings

To allow connections from the server to be started as the standby server, configure the settings in step 2 and thereafter of "[2.4.2 Creating, Setting, and Registering the Primary Server Instance](#)" on the primary server.

5. Set up the arbitration server

Refer to "[2.3 Setting Up the Arbitration Server](#)" for details.

Perform this step only if the arbitration server is used for automatic degradation.

6. Set up database multiplexing mode on the primary server

Refer to "[2.4.1 Setting Up Database Multiplexing Mode on the Primary Server](#)" for details.

7. Set up database multiplexing mode on the standby server

Refer to "[2.5.1 Setting Up Database Multiplexing Mode on the Standby Server](#)" for details.

8. Create the standby server instance and start it

Refer to "[2.5.2 Creating, Setting, and Registering the Standby Server Instance](#)" for details.

After the above steps are completed, refer to the remaining explanations in "[Chapter 2 Setting Up Database Multiplexing Mode](#)" and ensure that the required settings and operations are completed.

3.9.3 Changing from Database Multiplexing Mode to Single Server Mode

The procedure for stopping database multiplexing mode and changing to single server mode is explained below.

Some tasks must be performed on the database server, and others must be performed on the arbitration server.

The tasks on the arbitration server are required only if the arbitration server is used for automatic degradation.

Tasks on the database server

1. Determine the server for which the instance is to be stopped, and switch this server

Determine the server that is to be excluded as the database multiplexing mode target, and for which the instance is to be stopped.

If the server for which the instance is to be stopped is the primary server, execute the `mc_ctl` command in the switch mode to switch the standby server to the primary server.

The standby server after the switch is complete will be the server for which the instance is to be stopped.

If the server for which the instance is to be stopped is the standby server, there is no need to perform the switch operation.

Example)

```
$ mc_ctl switch -M /mcdir/inst1
```

2. Stop Mirroring Controller and the instance, and delete the file resources

On the server that was determined in step 1, execute the `mc_ctl` command in stop mode to stop Mirroring Controller and the instance.

If automatic start and stop of Mirroring Controller has been configured using `systemd`, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

Example)

```
$ mc_ctl stop -M /mcdir/inst1
```

Then, delete the following file resources:

- Data storage destination directory
- Mirroring Controller management directory

Example)

```
$ rm -rf /database/inst1
$ rm -rf /mcdir/inst1
```



See

Refer to "Security-Related Notes" in the Operation Guide for details on deleting the data securely.

3. Stop the application jobs

Stop the application jobs to be connected to the primary server.

4. Stop Mirroring Controller and the instance on the primary server

Execute the `mc_ctl` command in stop mode on the primary server.

If automatic start and stop of Mirroring Controller has been configured using `systemd`, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

Example)

```
$ mc_ctl stop -M /mcdir/inst1
```

5. Delete the database multiplexing mode settings that were configured for the primary server instance.

Reset the `postgresql.conf` file parameters to their values before the database multiplexing operation was set.

Delete the file resources from the Mirroring Controller management directory.

If the backup operation was performed, delete the following resources:

- Mirroring Controller management directory backup data obtained in database multiplexing mode

- Instance backup data obtained in database multiplexing mode

Additionally, if the `primary_conninfo` parameter is set in the `postgresql.auto.conf` file, execute the `ALTER SYSTEM RESET` statement to delete the setting.

Example)

An example execution of the `psql` command is shown below.

```
postgres=# ALTER SYSTEM RESET primary_conninfo;
```

After these actions are performed, ensure that the backup data is collected when starting the single operation.



- Refer to "Security-Related Notes" in the Operation Guide for details on deleting the data securely.
- Refer to "2.14 Backup Operation" for details on the backup operation.
- Refer to "Appendix A Parameters" for details on the `postgresql.conf` file parameters.



In the above procedure, if the `postgresql.conf` file of the single primary server can be changed by reloading the file, the operation mode can be changed without stopping the application job.

In that case, execute the `mc_ctl` command in stop mode with the `--mc-only` option specified to stop only Mirroring Controller in relation to stopping the primary server.

Tasks on the arbitration server

1. Execute the `mc_arb` command in stop mode to stop the Mirroring Controller arbitration process.

Example)

```
$ mc_arb stop -M /mcarb_dir/arbiter1
```

2. Delete the Mirroring Controller arbitration process management directory.

Example)

```
$ rm -rf /mcarb_dir/arbiter1
```

3.9.4 Changing to Database Multiplexing Mode when the Arbitration Server is Used for Automatic Degradation

This section provides the procedure to change to database multiplexing mode using the Mirroring Controller only on the database server when the arbitration server is used for automatic degradation.

Some tasks must be performed on the database server, and others must be performed on the arbitration server.

Tasks on the arbitration server

1. Set up the arbitration server.

Refer to "2.3 Setting Up the Arbitration Server" for information on how to set up the arbitration server.

Tasks on the database server

1. On the server where Mirroring Controller is running, execute the `mc_ctl` command in stop mode to stop Mirroring Controller on the primary server and standby server.

Example)

```
$ mc_ctl stop -M /mcdir/inst1 -a --mc-only
```

2. Edit the `network.conf` file of the primary server and standby server to add the information of the arbitration server.

Refer to "[A.3 Network Configuration File](#)" for details.

The definition example of the `network.conf` file of the primary server is shown below:

Example)

The IDs of the primary server and standby server are set to "server1" and "server2", and their port numbers are set to "27540" and "27541". The ID of the server of the Mirroring Controller arbitration process is set to "arbiter", and its port number is set to "27541".

```
server1 192.0.2.100,192.0.3.100 27540,27541 server
server2 192.0.2.110,192.0.3.110 27540,27541 server
arbiter 192.0.3.120 27541 arbiter
```

Note

- Ensure that the port numbers set for the primary server, standby server, and arbitration server do not conflict with other software. Also do not configure the same segment for the admin network and arbitration network.
- If the server type is "server", two IP addresses or host names, and two port numbers need to be specified in the following order:
 - IP address or host name of the database server used as the admin network
 - IP address or host name of the database server used as the arbitration network
 - Port number of the database server used as the admin network
 - Port number of the database server used as the arbitration network
- If the server type is "arbiter", specify the IP address or host name set for the `my_address` parameter and the port number set for the `port` parameter in `arbitration.conf`.

3. Edit the `serverIdentifier.conf` file of the primary server and standby server to add parameters required for the operation where the arbitration server is used for automatic degradation.

Refer to "[A.4.1 Server Configuration File for the Database Servers](#)" for information on the parameters required when the arbitration server is used for automatic degradation.

4. On the primary server and standby server, execute the `mc_ctl` command in start mode to start the Mirroring Controller process.

Example)

```
$ mc_ctl start -M /mcdir/inst1 --mc-only
```

Common tasks

1. Check the connection status from the database server or arbitration server.

Refer to "[2.8 Checking the Connection Status](#)" for details.

3.9.5 Changing Parameters

Stop Mirroring Controller before editing the Mirroring Controller server configuration file and network configuration file.

If the Mirroring Controller process crashes or becomes unresponsive, restart is performed automatically by the Mirroring Controller monitoring process, and the configuration file is reloaded. Therefore, if the configuration file was being edited, unintended behavior will occur.

3.9.6 Uninstalling in Database Multiplexing Mode

This section explains how to uninstall FUJITSU Enterprise Postgres on a server using database multiplexing mode.

Some tasks must be performed on the database server, and others must be performed on the arbitration server.

The tasks on the arbitration server are required only if the arbitration server is used for automatic degradation.

Tasks on the database server

1. Stop the multiplexed instances and Mirroring Controller

Refer to "[3.2 Starting and Stopping Mirroring Controller](#)" for information on how to stop the instance.

2. Uninstall FUJITSU Enterprise Postgres

Refer to "Uninstallation" in the Installation and Setup Guide for Server for information on how to uninstall FUJITSU Enterprise Postgres.

Tasks on the arbitration server

Refer to "Uninstallation" in the Installation and Setup Guide for Server Assistant, and uninstall the Server Assistant.

Chapter 4 Action Required when an Error Occurs in Database Multiplexing Mode

This chapter describes the action required if an error occurs in database multiplexing mode.

In database multiplexing mode, when an error is detected, the switch or disconnection of the standby server is performed automatically, so that only the primary server starts degrading. In this case, the recovery tasks will be required for the standby server on which the switch or disconnection was performed.

Other possible cases are as follows:

- When automatic switch fails
- When automatic disconnection fails
- When all servers or instances were stopped

4.1 Action Required when Server Degradation Occurs

If the server has started degrading, the recovery tasks will vary depending on whether the cause was the switch (failover or switchover), or the disconnection.

Execute the `mc_ctl status` command in status mode, or refer to the system log, and check if the cause of the server degradation was the switch or the disconnection.

In the example below, the `mc_ctl` command is executed in status mode.

If a switch has occurred, "switched" (the switch is complete and the server is in a degrading state) is displayed for "mirroring status".

Example)

```
$ mc_ctl status -M /mdir/inst1
mirroring status
-----
switched
:
```

If a disconnection has occurred, "not-switchable" (disconnection was performed so the server cannot be switched) is displayed for "mirroring status".

Example)

```
$ mc_ctl status -M /mdir/inst1
mirroring status
-----
not-switchable
:
```



If Mirroring Controller detects any errors on the server on which operations are continuing during recovery to database multiplexing mode from a degrading operation state, perform the procedure in "4.1.3 Addressing Errors During Degrading Operation", and then recover to database multiplexing mode.

4.1.1 Operations when the Server has Started Degrading after a Switch has Occurred

This section explains the operations when the server has started degrading after a switch has occurred.

Note

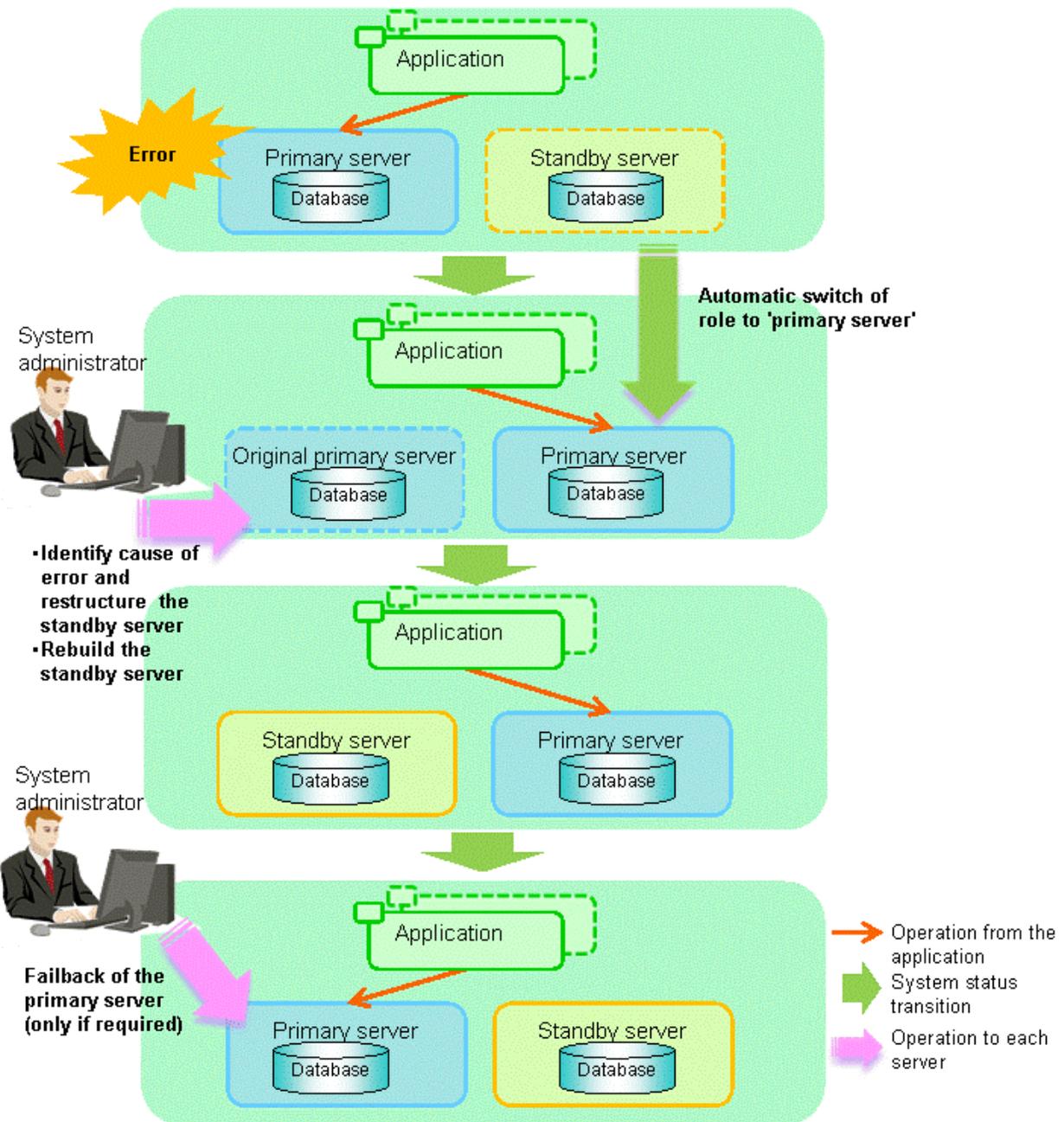
- After a switch has occurred as a result of an abnormality on the primary server, the database will not have a multiplexed configuration until the standby server is rebuilt. Remove the cause of the error as quickly as possible, and then rebuild the standby server.
 - If the reference job was executed on the standby server, and the servers are switched because an error occurred on the primary server, the load is concentrated on the new primary server. Accordingly, pause the reference job on the original standby server, rebuild the original primary server as the new standby server, and then resume the reference job for the new standby server.
 - If the instance on the new primary server is stopped before the original primary server where the error occurred is rebuilt as the new standby server, a split brain occurs at startup from the instance on the original primary server. Therefore, start the instance on the new primary server before rebuilding the standby server.
-

If the switch occurred and the server has started degrading, perform the following operations to recover the standby server and revert it to its original state:

- [Identify Cause of Error and Restore the Standby Server](#)
- [Rebuild the Standby Server](#)
- [Failback of the Primary Server](#) (only if required)

The flow of these operations is shown in the figure below.

Figure 4.1 Flow of operations



4.1.1.1 Identify Cause of Error and Restore the Standby Server

Perform the recovery according to the following procedure:

1. [Stop Mirroring Controller](#)
2. [Recovery of the Mirroring Controller management directory](#)
3. [Identify cause of error and perform recovery](#)

4.1.1.1.1 Stop Mirroring Controller

Execute the `mc_ctl` command in stop mode for the original primary server on which the error occurred.

If automatic start and stop of Mirroring Controller has been configured using `systemd`, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances" for details.

Example)

```
$ mc_ctl stop -M /mcdir/inst1
```

This also stops the instance that is required to perform the recovery.



If the instance does not stop, refer to "Actions in Response to Failure to Stop an Instance" in the Operation Guide, and then stop the instance. Then, specify the `-e` option in the above command to forcibly stop Mirroring Controller.

4.1.1.1.2 Recovery of the Mirroring Controller management directory

Copy the files in the Mirroring Controller management directory from the backup data, and then perform the recovery.

4.1.1.1.3 Identify cause of error and perform recovery

Refer to the system log of the primary server and the standby server to identify the cause of the error, and then perform recovery.

The following commands can be used to recover a standby server. Select depending on the recovery and the situation.

- `pg_basebackup`

Creates a copy of all resources of the primary server instance.

- `pg_rewind`

Creates a copy of only the updated files on the new primary server. For this reason, if this command is used to incorporate a new standby server, recovery time can be shortened. To use this command to build the original primary server as a new standby server, at least one of the following must be met:

- a. Checksums were enabled when an instance was created and the original primary server was stopped normally, or
- b. The original primary server was stopped normally and the `wal_log_hints` parameter of `postgresql.conf` was enabled when an instance was started.

Additionally, `full_page_writes` must be enabled, which is its default value.

If it is required to start the original primary server again to then stop it normally, both servers will temporarily operate as primary servers. If data is updated on the original primary server, data corruption will occur, so take measures such as changing settings in `pg_hba.conf` to disallow client connections.

When executing the `pg_rewind` command, the timeline ID of the source server and the target server must be different. However, immediately after promotion of the new primary server, it may not be possible to execute the `pg_rewind` command due to the application processing of unapplied update transaction logs and subsequent update processing of timeline IDs using checkpoint processing not being completed. Therefore, execute the `pg_rewind` command after unapplied update transaction logs are no longer on the new primary server and updating of timeline IDs is complete.



- Refer to "pg_basebackup" in "Reference" in the PostgreSQL Documentation for information on the `pg_basebackup` command.
- Refer to "pg_rewind" in "Reference" in the PostgreSQL Documentation for information on the `pg_rewind` command.

The example below executes the `pg_rewind` command to perform recovery by synchronizing data on the original primary server with the new primary server.

1. Use the `pg_ctl` command to start the original primary server instance.

Example)

```
$ pg_ctl start -D /database/inst1
```

- Use the `pg_ctl` command to stop the original primary server instance.

Example)

```
$ pg_ctl stop -D /database/inst1
```

- Wait for the application of unapplied update transaction logs on the new primary server.

Execute the SQL below on the new primary server, and wait until the result is false.

```
# select pg_is_in_recovery();
```

Example)

```
$ psql -h hostNameOfNewPrimaryServer -p portNumOfNewPrimaryServer -d dbName -c "select pg_is_in_recovery();" 
```

Any database can be connected to.

Note

If the `pg_rewind` command is executed immediately after promotion of the new primary server, the processing in steps 3 and 4 is required. If update-type SQL can be executed on the new primary server and checkpoint processing is executed after promotion, the processing in steps 3 and 4 will not be necessary.

- Update the timeline ID.

Execute checkpoint processing, and update the timeline ID.

```
$ psql -h hostNameOfNewPrimaryServer -p portNumOfNewPrimaryServer -d dbName -c "checkpoint;"
```

Any database can be connected to.

- Create a copy of the new primary server instance in the original primary server (new standby server).

Execute the `pg_rewind` command to synchronize the new standby server data with the new primary server.

Example)

```
$ pg_rewind -D /database/inst1 --source-server='user=userName host=newPrimaryServerHostName port=newPrimaryServerPortNumber dbname=dbName'
```

- Specify parameters in the `postgresql.conf` file of the original primary server (new standby server).

Set the parameters required for the standby server in `postgresql.conf`.

Refer to "[Table 2.4 Parameters](#)" for information on the parameters to set in `postgresql.conf`.

- Create the `standby.signal` file on the original primary server (new standby server).

The file will be used to connect to the new primary server for streaming replication.

- Change the connection string specified for the `primary_conninfo` parameter in `postgresql.auto.conf` file using as shown below.

Table 4.1 Changes to the connection string

Keyword	Content specified	Remarks
host	<i>hostNameOfNewPrimaryServer</i>	Specify informations for connecting to the primary server in the form of a PostgreSQL connection string.
port	<i>portNumOfNewPrimaryServer</i>	
application_name	<i>newstandbyServerName</i>	

Note

- If you need to set a connection string other than host, port and application_name, include it in the setting of the primary_conninfo parameter.
- The primary_conninfo parameter should not be set in the postgresql.conf file, but only in the postgresql.auto.conf file.

See

- Refer to "Hot Standby" in the PostgreSQL Documentation for details on the standby.signal file.
- Refer to "Setting Up a Standby Server" in the PostgreSQL Documentation for details on the primary_conninfo.

Note

A new timeline is branched for the new primary server due to promotion, so 'latest' needs to be specified for the recovery_target_timeline parameter so that the old primary server (new standby server) follows the new primary server.

4.1.1.2 Rebuild the Standby Server

The starting of the recovered original primary server as the standby server is referred to as the "standby server rebuild".

On the original primary server, start Mirroring Controller and the instance.

Enabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode.

Example)

```
$ mc_ctl start -M /mcdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode with the -F option specified.

Example)

```
$ mc_ctl start -M /mcdir/inst1 -F
```

Point

After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the enable-failover or disable-failover mode of the mc_ctl command.

4.1.1.3 Failback of the Primary Server

To revert the primary server and standby server to the original server configuration after rebuilding the standby server, perform failback for the primary server.

Do this to execute the main job on the previous primary server.

Perform the following procedure:

1. Failback of the primary server

Execute the mc_ctl command in switch mode on the primary server or the standby server.

Example)

```
$ mc_ctl switch -M /mcdir/inst1
```

After executing the mc_ctl command in switch mode, the status will be as follows:

Example)

```
$ mc_ctl status -M /mcdir/inst1
mirroring status
-----
switched
server_id  host_role                host          host_status  db_proc_status  disk_status
-----
server1    primary                    192.0.2.100  normal       abnormal(postmaster) normal
server2    none(inactivated primary) 192.0.2.110  normal       abnormal(postmaster) normal
```

2. Stop the original primary server

On the original primary server, execute the mc_ctl command in stop mode to stop Mirroring Controller and the instance.

If automatic start and stop of Mirroring Controller has been configured using systemd, do not use the mc_ctl command, but instead use the systemctl command. Refer to "2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances" for details.

Example)

```
$ mc_ctl stop -M /mcdir/inst1
```

3. Create a copy of the new primary server instance in the original primary server (new standby server)

Execute the pg_basebackup command to create data in the new standby server by synchronizing with the new primary server.

Example)

```
$ pg_basebackup -D /database/inst1 -X fetch --waldir=/transaction/inst1 --progress --verbose -R
--dbname='application_name=standbyServerName' -h primaryServerHostName -p
primaryServerPortNumber
```



See

The procedure for copying the new primary server instance to the new standby server is the same as the procedure for setting up the new standby server.

Refer to "2.5.2 Creating, Setting, and Registering the Standby Server Instance", and then perform the recovery.

4. Rebuild the standby server

On the standby server, start Mirroring Controller and the instance.

Enabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode.

Example)

```
$ mc_ctl start -M /mcdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode with the -F option specified.

Example)

```
$ mc_ctl start -M /mcdir/inst1 -F
```

Point

After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the enable-failover or disable-failover mode of the mc_ctl command.

4.1.2 Operations when the Server has Started Degrading after a Disconnection has Occurred

This section explains the operations when the server has started degrading after a disconnection has occurred.

Note

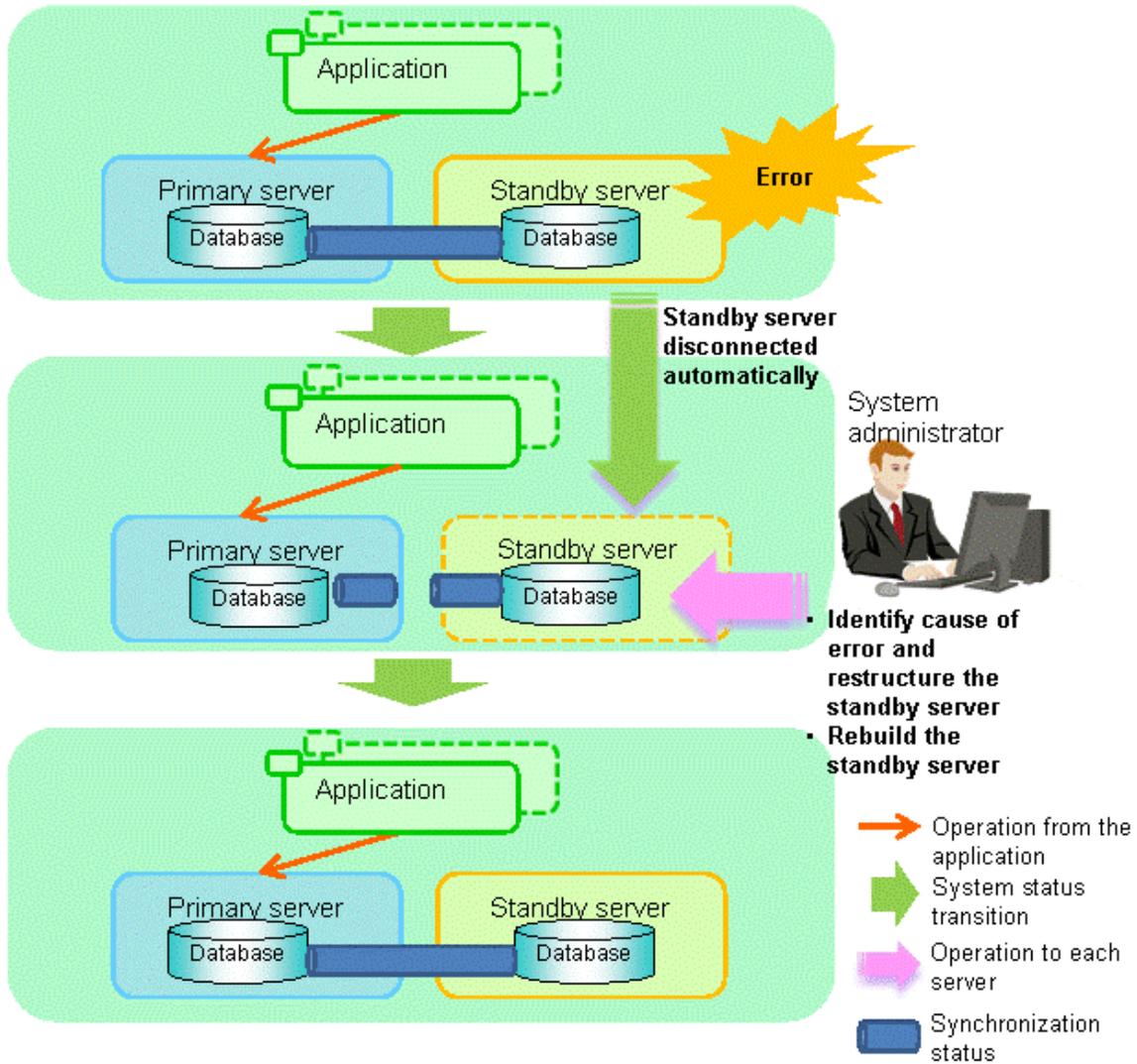
After a disconnection has occurred as a result of an abnormality on the standby server, the database will not have a multiplexed configuration until the standby server is rebuilt. Remove the cause of the error as quickly as possible, and then rebuild the standby server.

If the disconnection occurred and the server has started degrading, perform the following operations to recover the standby server and revert it to its original state:

- [Identify Cause of Error and Restore the Standby Server](#)
- [Rebuild the Standby Server](#)

The flow of these operations is shown in the figure below.

Figure 4.2 Flow of operations



4.1.2.1 Identify Cause of Error and Restore the Standby Server

Perform the recovery according to the following procedure:

1. [Stop Mirroring Controller](#)
2. [Recovery of the Mirroring Controller management directory](#)
3. [Identify cause of error and perform recovery](#)

4.1.2.1.1 Stop Mirroring Controller

Execute the `mc_ctl` command in stop mode for the standby server on which the error occurred.

If automatic start and stop of Mirroring Controller has been configured using `systemd`, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to ["2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances"](#) for details.

Example)

```
$ mc_ctl stop -M /mdir/inst1
```

This also stops the instance that is required to perform the recovery.

Note

If the instance does not stop, refer to "Actions in Response to Failure to Stop an Instance" in the Operation Guide, and then stop the instance. Then, specify the `-e` option in the above command to forcibly stop Mirroring Controller.

4.1.2.1.2 Recovery of the Mirroring Controller management directory

Copy the files in the Mirroring Controller management directory from the backup data, and then perform the recovery.

4.1.2.1.3 Identify cause of error and perform recovery

Refer to the system logs of the primary server and the standby server to identify the cause of the error, and then perform recovery.

Execute the `pg_basebackup` command to perform recovery by synchronizing data in the primary server with the standby server.

Example)

```
$ pg_basebackup -D /database/inst1 -X fetch --waldir=/transaction/inst1 --progress --verbose -R --  
dbname='application_name=standbyServerName' -h primaryServerHostName -p primaryServerPortNumber
```

See

This recovery procedure is the same as the procedure for setting up the standby server.

Refer to "2.5.2 Creating, Setting, and Registering the Standby Server Instance", and then perform the recovery.

4.1.2.2 Rebuild the Standby Server

Start the Mirroring Controller and the instance of the standby server, and rebuild the standby server.

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mdir/inst1 -F
```

Point

After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

4.1.3 Addressing Errors During Degrading Operation

This section explains how to address errors that may occur on the server on which operation is continuing during degrading operation triggered by a switch or disconnection.

If needing to recover from backup data

If it is necessary to recover the database using backup data due to data becoming corrupted from disk failure or user operation error, refer to the following for information on recovery to database multiplexing mode:

- [Action Required when All Database Servers or Instances Stopped](#)
- [Recovering from an Incorrect User Operation](#)

If a temporary error occurs

If a temporary error occurs, such as due to a high load on the server or insufficient system resources, remove the cause of the error and restart Mirroring Controller, and then refer to the following for details on recovery to database multiplexing mode:

- [Operations when the Server has Started Degrading after a Switch has Occurred](#)
- [Operations when the Server has Started Degrading after a Disconnection has Occurred](#)



See

Refer to "[3.2 Starting and Stopping Mirroring Controller](#)" for information on restarting Mirroring Controller.

4.2 Action Required when Automatic Switch Fails

If the system behavior is unstable, for example there are insufficient temporary system resources, the Mirroring Controller automatic switch may fail.

Perform the switch manually using one of the following methods:

- Refer to the procedures in "[3.4 Manually Switching the Primary Server](#)".
- In the standby server, execute the `mc_ctl` command in switch mode with the `-force` option specified to forcibly perform the switch.

Example)

```
$ mc_ctl switch -M /mdir/inst1 --force
```



Point

- Even if connection cannot be established between database servers, it is possible to fence the primary server and forcibly switch by executing the `mc_ctl` command in switch mode with the `--force` option specified.
- The primary server is not fenced in the cases below, so stop Mirroring Controller and instances of the primary server database in advance:
 - The `--no-fencing` option is specified when performing forced switch.
 - The `heartbeat_error_action` parameter in `serverIdentifier.conf` is set to "message" and the fencing command is not configured to be used (the `fencing_command` parameter is omitted in `serverIdentifier.conf`).
 - The `heartbeat_error_action` parameter in `serverIdentifier.conf` is set to "fallback".



See

Recovery to database multiplexing mode

Refer to "[4.1.1.2 Rebuild the Standby Server](#)" and "[4.1.1.3 Failback of the Primary Server](#)" for information on recovery to database multiplexing mode.

4.3 Action Required when Automatic Disconnection Fails

If the system behavior is unstable, for example there are insufficient system resources such as available memory or free disk space, automatic disconnection using Mirroring Controller may not be possible.

Perform the disconnection manually using one of the following methods:

- Refer to the procedures in "[3.5 Manually Disconnecting the Standby Server](#)".
- In the primary server, execute the mc_ctl command in detach mode to perform forced disconnection.

Example)

```
$ mc_ctl detach -M /mcdir/inst1
```

Point

- Even if connection cannot be established between database servers, it is possible to fence the standby server and forcibly disconnect by executing the mc_ctl command in detach mode.
- In the cases below, stop Mirroring Controller and instances of the standby server database in advance so that the standby server is not fenced:
 - The --no-fencing option is specified when performing forced disconnection.
 - The heartbeat_error_action parameter in *serverIdentifier.conf* is set to "message" and the fencing command is not configured to be used (the fencing_command parameter is omitted in *serverIdentifier.conf*).
 - The heartbeat_error_action parameter in *serverIdentifier.conf* is set to "fallback".

See

Recovery to database multiplexing mode

Refer to "[4.1.2.2 Rebuild the Standby Server](#)" for information on recovery to database multiplexing mode.

4.4 Action Required when All Database Servers or Instances Stopped

This section explains what happens when all database servers or instances on the database server have stopped, so jobs cannot continue.

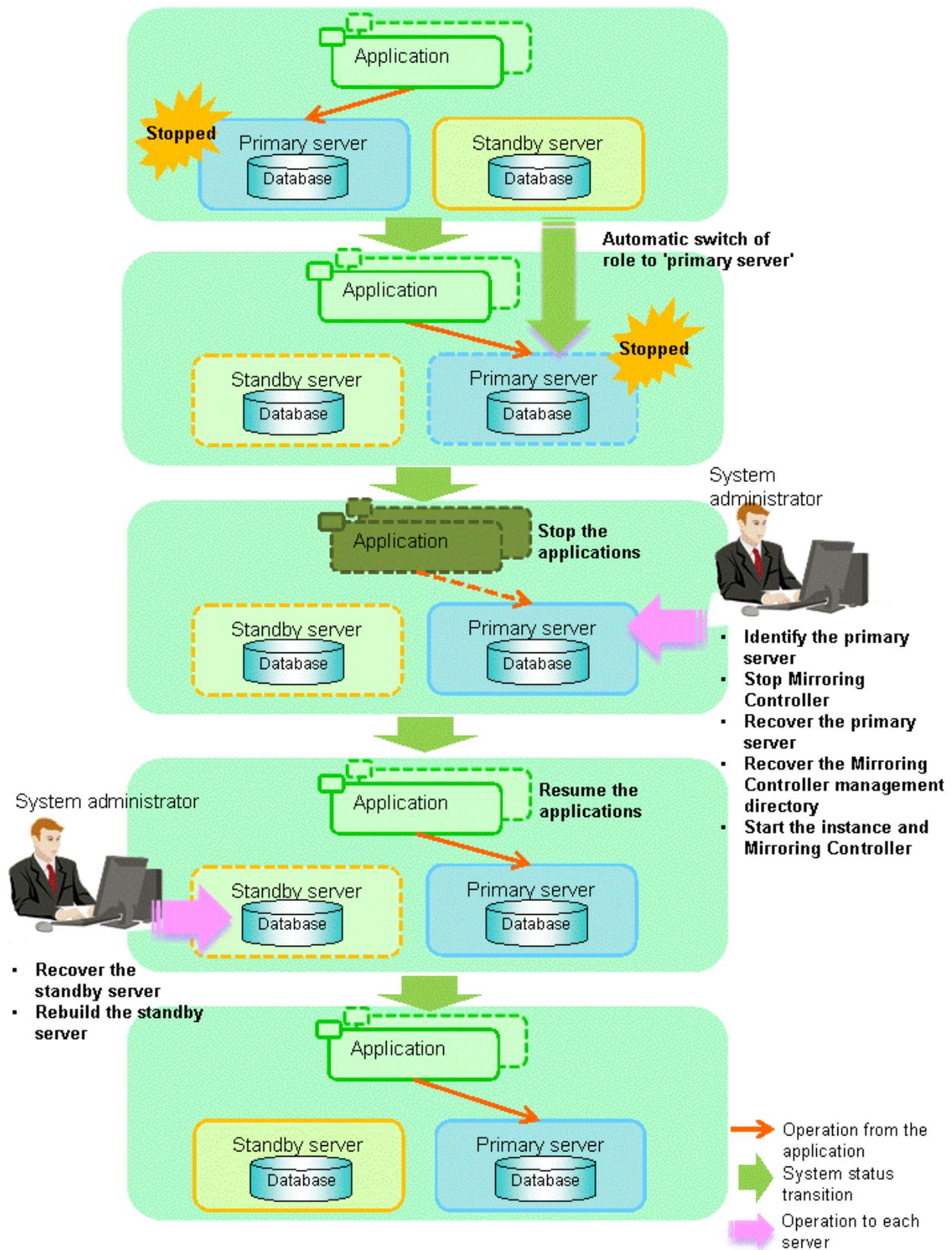
See

Recovery to database multiplexing mode

Refer to "[4.1.1.2 Rebuild the Standby Server](#)" and "[4.1.1.3 Failback of the Primary Server](#)" for information on recovery to database multiplexing mode.

The flow of these recovery operations is shown in the figure below.

Figure 4.3 Flow of operations



Perform the following procedure:

1. Stop the applications
Stop the applications from running.

2. Identify the primary server

Use one of the following methods to identify the primary server that was running before the servers or instances stopped:

- Refer to the system log on each server and identify the server where the following message was output.

Message:

```
MirroringControllerOpen[30017]: LOG: promotion processing completed (MCA00062)
```

- On each server, execute the `mc_ctl` command in status mode to search the servers for which "none(inactivated primary)" is displayed.

3. Stop Mirroring Controller on the primary server

Execute the `mc_ctl` command in stop mode on the primary server.

If automatic start and stop of Mirroring Controller has been configured using `systemd`, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

Example)

```
$ mc_ctl stop -M /mdir/inst1
```



Forcibly stopping Mirroring Controller

If Mirroring Controller does not stop, specify the `-e` option in the stop mode of the `mc_ctl` command and then execute the command.

Example)

```
$ mc_ctl stop -M /mdir/inst1 -e
```

4. Recover the primary server

First, refer to "Actions when an Error Occurs" in the Operation Guide, and then identify the cause of the error and perform recovery.

Next, recover the primary server using the recovery method that uses the `pgx_rcvall` command based on the backup data.

If the backup operation was performed using the `pgx_dmpall` command based on the instructions in "[2.14.2 Database Backup Operation](#)", perform the following procedure for the recovery:

- Perform the following operations on both the primary server and the standby server, and check the server containing the backup data and the archive log that show the latest date.
 - Execute the `pgx_rcvall` command with the `-l` option specified and identify the backup data that shows the latest date.
 - Identify the archive log that shows the latest date, as shown below.

Example)

```
$ ls -ltr backupDataStorageDir/*_wal
```

- If the latest backup data exists on the standby server, copy (*1) the backup data and overwrite (*2) it to each backup storage destination directory on the primary server.
- If the latest archive log and transaction log file exist on the standby server, copy (*1) the archive log and overwrite (*2) it to the backup storage destination directory on the primary server.
- Execute the `pgx_rcvall` command on the primary server, specifying the backup storage destination directory of the primary server.

Note

*1: The backup data may contain a symbolic link, so copy the backup data so that the symbolic link is not converted to an ordinary file (with the tar command, for example).

*2: If you can save a copy of the backup storage destination directory, do so without overwriting it.

See

Refer to "Actions when an Error Occurs" in the Operation Guide for information on the `pgx_rcvall` command.

5. Recover the Mirroring Controller management directory

Copy the files in the Mirroring Controller management directory from the backup data, and then perform the recovery.

6. Start the primary server instance and Mirroring Controller

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mdir/inst1 -F
```

Point

After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

7. Resume applications

Resume the applications.

8. Stop Mirroring Controller on the standby server

Execute the `mc_ctl` command in stop mode on the standby server.

If automatic start and stop of Mirroring Controller has been configured using `systemd`, do not use the `mc_ctl` command, but instead use the `systemctl` command. Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

Example)

```
$ mc_ctl stop -M /mdir/inst1
```

9. Recover the standby server

Refer to "[2.5.2 Creating, Setting, and Registering the Standby Server Instance](#)", and then recover (set up) the standby server from the primary server.

10. Rebuild the standby server

On the standby server, start Mirroring Controller and the instance.

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mcdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode with the `-F` option specified.

Example)

```
$ mc_ctl start -M /mcdir/inst1 -F
```



After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the `enable-failover` or `disable-failover` mode of the `mc_ctl` command.

4.5 Recovering from an Incorrect User Operation

This section describes how to recover an instance when data has been corrupted due to incorrect user operation.

For example, when data has been corrupted due to incorrect user operation, such as data being unintentionally changed or deleted by an application or command, it is necessary to restore the original data on the primary server and resynchronize with the standby server.

Use the following procedure to perform recovery.

1. Identify the primary server

Execute the `mc_ctl` command in status mode on each server, and search for a server for which "primary" or "none(inactivated primary)" is displayed.

2. Stop the applications and commands that caused the incorrect operation to occur

Stop applications and commands that are running on the primary server. This will minimize the impact caused by the incorrect data.

Also, if any applications used for reference by the standby server are running, stop them too.

3. Stop the instance and Mirroring Controller

Stop the instance and Mirroring Controller on both the primary server and standby server.

Example)

```
$ mc_ctl stop -a -M /mcdir/inst1
```

4. Recover the database on the primary server

Recover the database using the recovery method in which the `pgx_rcvall` command uses the backup data to recover the database to a restore point prior to the time when the incorrect operation was performed.



Refer to "Recovering from an Incorrect User Operation" in the Operation Guide for information on using the `pgx_rcvall` command to recover the database to a restore point, and then perform only the database recovery procedure while the instance is in a stop state.

5. Start the instance and Mirroring Controller

Start the instance and Mirroring Controller on the primary server.

Enabling automatic switch/disconnection

As the instance administrator user, execute the `mc_ctl` command in start mode.

Example)

```
$ mc_ctl start -M /mcdir/inst1
```

Disabling automatic switch/disconnection

As the instance administrator user, execute the mc_ctl command in start mode with the -F option specified.

Example)

```
$ mc_ctl start -M /mcdir/inst1 -F
```

Point

After Mirroring Controller is started, automatic switch/disconnection can be enabled or disabled using the enable-failover or disable-failover mode of the mc_ctl command.

6. Build the new standby server

Refer to "[2.5 Setting Up the Standby Server](#)" for information on building (setting up) a standby server from the primary server.

Chapter 5 Managing Mirroring Controller Using WebAdmin

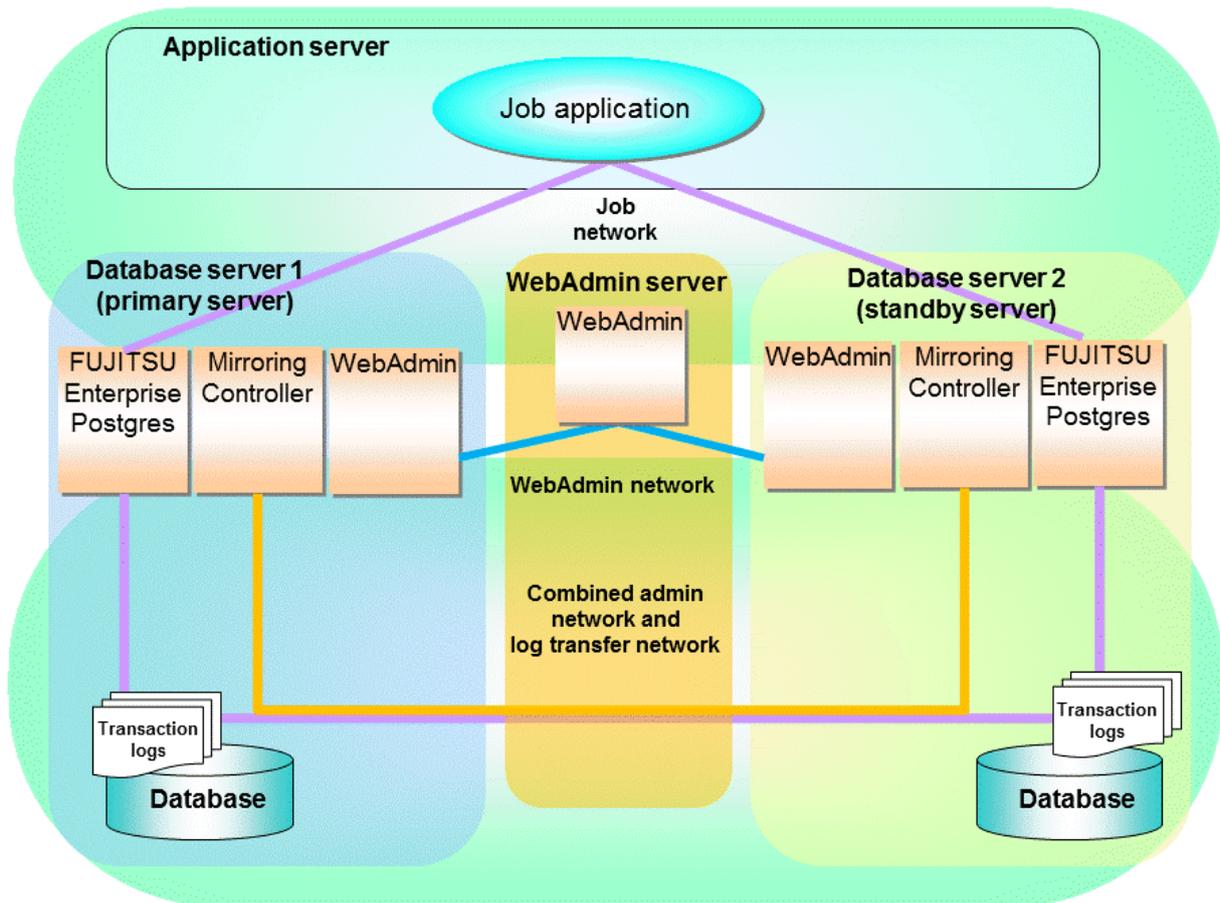
This chapter describes how to set up and manage Mirroring Controller in a streaming replication cluster using WebAdmin.

Mirroring Controller can be used to monitor a streaming replication cluster and perform automatic switching or disconnect synchronous replication when there is an error.

WebAdmin can be used to set up Mirroring Controller in an existing replication cluster. Mirroring Controller can be set up for either synchronous standby instances or asynchronous standby instances.

The configuration of the database multiplexing system built using WebAdmin is shown below:

Figure 5.1 Configuration of database multiplexing operation system using WebAdmin



Point

- If Mirroring Controller is set up to the replication cluster using WebAdmin, the network with the host name (or IP address) specified in [Host name] will be used as the admin network and the log transfer network.
- To use a network other than the job network as the log transfer network, before building the replication cluster specify a host name other than the job network one in [Host name].

Note

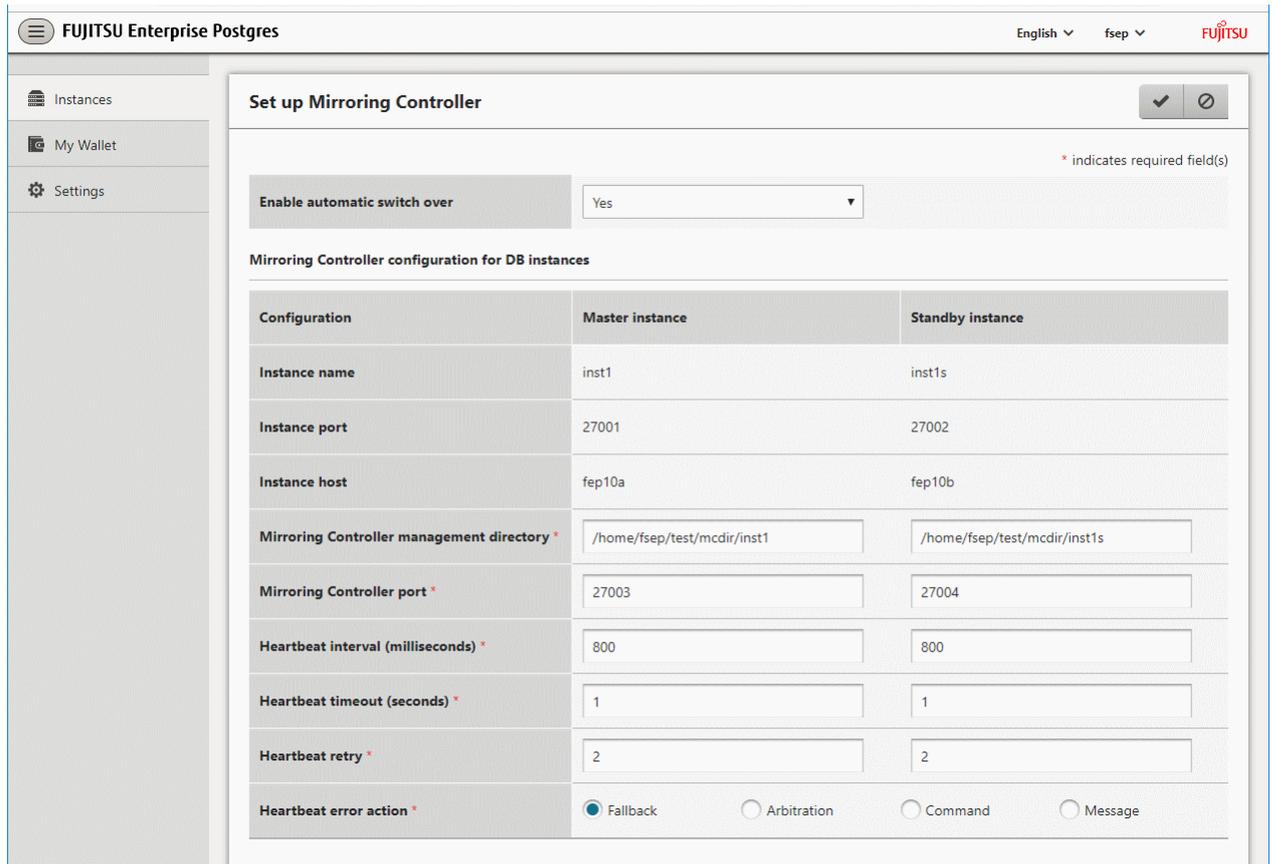
If you set up the arbitration server using WebAdmin, install WebAdmin on the arbitration server.

5.1 Mirroring Controller Setup

Perform the following procedure to set up Mirroring Controller in a streaming replication cluster.

1. In the [Instances] tab, select the standby instance on which Mirroring Controller needs to be set up.
2. Click .
3. Enter the information for the Mirroring Controller to be set up.

In the example below, Mirroring Controller is being set up for the replication cluster having master instance "inst1" and standby instance "inst1s".



The instance name, host address and port of the master and standby instances are displayed for easy reference.

Enter the following items on master instance and on standby instance fields for Mirroring Controller setup, as shown in the above screenshot:

- [Enable automatic switch over]: Toggles the automatic switch/disconnection functionality. Select "Yes". The default is "No".
- [Mirroring Controller management directory]: Directory where the Mirroring Controller configuration files will be stored. When the [Mirroring Controller management directory] is entered, WebAdmin will search the Mirroring Controller configuration files in the entered directory based on the [Data storage path] of the corresponding DB instance. If Mirroring Controller configuration files are found, the Mirroring Controller fields will be auto filled.
- [Mirroring Controller port]: Port number of Mirroring Controller.
- [Heartbeat interval (milliseconds)]: Number of milliseconds between two consecutive heartbeat checks. The default is "800".
- [Heartbeat timeout (seconds)]: Number of seconds for the heartbeat timeout. The default is "1".
- [Heartbeat retry]: Number of retries for heartbeat monitoring, before failover occurs. The default is "2".

- [Heartbeat error action]: Operation when a heartbeat abnormality is detected. The default is "Fallback".

When using FUJITSU Enterprise Postgres 11 instance created with previous versions, the instances will be in compatibility mode, and the "Fallback" is preselected and cannot be changed in the [Heartbeat error action] for Mirroring Controller setup.

When the [Heartbeat error action] is set to "Arbitration", the following extra items are displayed:

- [Arbitration network IP address]: IP address of the arbitration network.
- [Mirroring Controller Arbitration port]: Port number of Mirroring Controller for communicating with the arbitration server.

The [Arbitration server configuration] section is also displayed with the following items. The [Arbitration server configuration] will not be auto filled.

- [Location]: Location of the arbitration server. "Local" or "Remote" can be selected depending on your configuration.

If the arbitration server and WebAdmin server are located on the same server, you can select "Local" and the following items are displayed:

- [Arbitration management directory]: Directory where the arbitration server configuration files will be stored.
- [Arbitration server host or IP address]: Host name or IP address of the arbitration server.
- [Arbitration process port]: Port number for the arbitration process.
- [Fencing command]: Full path of the fencing command that fences a database server when an abnormality is detected.

If "Remote" is set for the item, the items below are displayed in addition to the above items.

- In the [Arbitration server configuration] section, [Operating system credential] is displayed where you can enter the following information:

[User name]: User name to access the arbitration server.

[Password]: Password to access the arbitration server.

- In the [Remote WebAdmin for Arbitration server] section, the following items are displayed:

[Remote WebAdmin address]: IP address of the remote WebAdmin installed on the arbitration server.

[Remote WebAdmin port]: Port number for the WebAdmin installed on the arbitration server.

When the [Heartbeat error action] is set to "Command", the following extra items are displayed:

- [Arbitration command]: Full path of the arbitration command to be executed when an abnormality is detected.
- [Fencing command]: Full path of the fencing command that fences a database server when an abnormality is detected.

4. Click to set up Mirroring Controller.

- Upon successful completion, Mirroring Controller will be started on master and standby instances.

In the [Instances] tab, select standby instance. The page below is displayed, in which you can check the Mirroring Controller status. In the example below, standby instance "inst1s" is used.

The screenshot shows the FUJITSU Enterprise Postgres WebAdmin interface. The left sidebar contains navigation options: Instances, My Wallet, and Settings. The main content area displays the configuration for instance 'inst1s' (server ID: fep10b:27002). The instance is highlighted in blue in the 'Instances' list. The configuration page for 'inst1s' includes a 'Summary' section with the following details:

Title	inst1s (fep10b:27002)
Server type	FUJITSU Enterprise Postgres AE Linux 64-bit
Version	PostgreSQL 12.1
Server up time	20 hours, 5 minutes, 4 seconds
Encoding	UTF8
Instance type	Synchronous Standby
Last WAL applied time	
Application name	inst1sapp
Mirroring Controller status	Running (switchable)
Heartbeat error action	fallback

Below the summary, there is a 'Storage summary' section and a 'Messages' section with the following log entries:

- 2019-09-05 12:07:23 Mirroring Controller has been added successfully.
- 2019-09-05 12:07:23 Mirroring Controller has been started successfully.
- 2019-09-05 12:07:18 Starting Mirroring Controller. Please wait...

After the Mirroring Controller has been set up, ([Edit Mirroring Controller] button) and ([Mirroring Controller Configuration] button) are available. These buttons are displayed only when FUJITSU Enterprise Postgres 11 and 12 instances are created with FUJITSU Enterprise Postgres WebAdmin 12.

When the [Heartbeat error action] is "Arbitration", the following information is displayed: whether the arbitration status is "online" or "offline", the arbitration server IP address and the arbitration process port.

Note

Operating system credential (User name, Password) should not contain hazardous characters. Refer to "[Appendix E WebAdmin Disallow User Inputs Containing Hazardous Characters](#)".

5.2 Edit Mirroring Controller Setup

Settings made in "[5.1 Mirroring Controller Setup](#)" can be updated in either the master instance or a standby instance using WebAdmin.

Perform the following procedure to edit Mirroring Controller configuration:

- In the [Instances] tab, select the instance for which the Mirroring Controller configuration is to be edited.
- Click .
- Enter the information for the Mirroring Controller to be updated. Refer to "[5.1 Mirroring Controller Setup](#)".
- Click to update the Mirroring Controller.
- Upon successful completion, Mirroring Controller will be started on master and standby instances.

Editing and saving the [Edit Mirroring Controller] page will reset all other settings that are not listed on this page to default values.

5.3 Mirroring Controller Configuration

The information related to Mirroring Controller monitoring and control (refer to "[A.4.1 Server Configuration File for the Database Servers](#)") and the information related to arbitration and control of the Mirroring Controller arbitration process (refer to "[A.4.2 Arbitration Configuration File](#)") can be set using WebAdmin. You can view and update the configuration on either the master instance or the standby instance.

Perform the following procedure:

1. In the [Instances] tab, select the instance for the Mirroring Controller configuration you want to view.
2. Click  to view the Mirroring Controller configuration.
3. Click  to show the editing page for the Mirroring Controller configuration. The Mirroring Controller configurations defined during [Mirroring Controller Setup] are read-only on this page. Refer to "[5.1 Mirroring Controller Setup](#)".

Additionally, refer to the "[Appendix A Parameters](#)" for information about the settings and the corresponding parameter names.

The items common to all [Heartbeat error action] are:

- Target DB
- Core file path
- Syslog facility
- Syslog identity
- Remote call timeout (milliseconds)
- Agent alive timeout (seconds)
- DB instance check interval (milliseconds)
- DB instance check timeout (seconds)
- DB instance check retry
- DB instance timeout action
- Disk check interval (milliseconds)
- Disk check retry
- Tablespace directory error action
- Post-switch command
- Post-promote command
(Post-promote command is replaced in FUJITSU Enterprise Postgres 12. The Post-promote command is still valid and will be displayed when it is used in the server configuration file of Mirroring Controller.)
- Post-attach command
- Pre-detach command
- State transition command timeout (seconds)
- Check synchronous standby names validation

When the [Heartbeat error action] is set to "Arbitration", the following extra items are displayed:

- Arbitration timeout (seconds)
- Arbiter alive interval (milliseconds)
- Arbiter alive retry

- Arbiter alive timeout (seconds)
- Arbiter connect interval (milliseconds)
- Arbiter connect timeout (seconds)
- Fencing command
- Fencing command timeout (seconds)
- Shutdown detached synchronous standby

When the [Heartbeat error action] is set to "Arbitration", the [Arbitration server configuration] section is displayed with the following items:

- Core file path
- Syslog facility
- Syslog identity
- Fencing command timeout (seconds)
- Heartbeat interval (milliseconds)
- Heartbeat timeout (seconds)
- Heartbeat retry

When the [Heartbeat error action] is set to "Command", the following extra items are available:

- Fencing command timeout (seconds)
- Arbitration command timeout (seconds)
- Shutdown detached synchronous standby

When the [Heartbeat error action] is set to "Message", the following extra items are available:

- Fencing command
- Fencing command timeout (seconds)

In addition, the following configurations are provided:

- DB instance JDBC connection SSL parameters
- DB instance libpq connection SSL parameters

4. Click  to update the Mirroring Controller configurations.

5.4 Stopping Mirroring Controller

Mirroring Controller can be stopped either in master instance or in standby instance using WebAdmin.

Perform the following procedure to stop Mirroring Controller.

1. In the [Instances] tab, select the instance where to stop Mirroring Controller.
2. Click .
3. In the confirmation dialog box, click [Yes].

Mirroring Controller will be stopped on the selected instance. The Mirroring Controller status will be updated, and a confirmation message entry will be displayed in the [Message] section.

5.5 Starting Mirroring Controller

Mirroring Controller can be started either in master instance or in standby instance using WebAdmin.

Perform the following procedure to start Mirroring Controller.

1. In the [Instances] tab, select the instance where to start Mirroring Controller.
2. Click .
3. In the confirmation dialog box, select the desired failover mode, and then click [Yes].

Mirroring Controller will be started on the selected instance. The Mirroring Controller status will be updated, and a confirmation message entry will be displayed in the [Message] section.

5.6 Disabling Failover Mode

Disabling failover mode in Mirroring Controller disables automatic switch/disconnection between master and standby instances.

Perform the following procedure to disable failover mode.

1. In the [Instances] tab, select the instance.
2. Click .
3. In the confirmation dialog box, click [Yes].

Failover mode will be disabled in Mirroring Controller. The Mirroring Controller status will be updated and a confirmation message entry will be displayed in the [Message] section.

5.7 Enabling Failover Mode

Enabling failover mode in Mirroring Controller enables automatic switch/disconnection between master and standby instances.

Perform the following procedure to enable failover.

1. In the [Instances] tab, select the instance.
2. Click .
3. In the confirmation dialog box, click [Yes].

Failover mode will be enabled in Mirroring Controller. The Mirroring Controller status will be updated and a confirmation message entry will be displayed in the [Message] section.

5.8 Deleting Mirroring Controller Setup

Deleting Mirroring Controller setup removes its setup from master and standby instances.

1. In the [Instances] tab, select the instance.
2. Click .
3. In the confirmation dialog box, click [Yes].

Mirroring Controller setup will be removed from the cluster. The cluster status will be updated and a confirmation message entry will be displayed in the [Message] section.

For the instances in FUJITSU Enterprise Postgres 12, WebAdmin does not delete the Mirroring Controller management directory and the configuration files.

5.9 Status Update after Failover

When Mirroring Controller performs a failover, standby instance will be promoted to standalone instance. The Mirroring Controller setup will be removed from both standby and master instances.

The following scenario describes one of the ways in which failover can be triggered, and the results achieved by the use of Mirroring Controller in WebAdmin.

1. In the [Instances] tab, select the master instance "inst1".
2. Click .
3. In the confirmation dialog box, the warning "This instance is being monitored by Mirroring Controller. Stopping the instance may result in cluster failover." is displayed.
4. Choose the stop mode and click [Yes].

In the server, the following takes place:

- a. The master instance is stopped.
 - b. Failover is triggered in Mirroring Controller.
 - c. The Mirroring Controller setup is removed from both master and standby instances
 - d. Standby instance is promoted to standalone.
5. When the instance is refreshed in WebAdmin, the latest status of the instances will be displayed.



When failover is performed, the Mirroring Controller setup is removed from both master and standby instances. Therefore, to manage the Mirroring Controller using WebAdmin again, create the standby instance and set up Mirroring Controller.

Refer to "Creating a Standby Instance" in the Operation Guide for details.

Refer to "[5.1 Mirroring Controller Setup](#)" for details.

5.10 Action Required when an Error Occurs in the Combined Admin Network and Log Transfer Network

Communication errors may temporarily occur in the network used as the admin network and log transfer network due to reasons such as high load on the server or insufficient system resources. Because of this, there is a risk of causing a split-brain situation by mistake even though the server has no issues.

Split brain is a phenomenon in which both servers temporarily operate as primary servers, causing data updates to be performed on both servers.

How to detect split brain using WebAdmin

If the conditions below are met, split brain may occur. Refer to "[Split-brain detection method](#)" and "[How to recover from a split-brain](#)" in "[Appendix D Notes on Performing Automatic Degradation Immediately after a Heartbeat Abnormality](#)" and take the actions described.

1. A standby instance is selected in the [Instances] tab, and
2. "Standalone" is displayed in [Instance type], and
3. A master instance is selected in the [Instances] tab, and
4. "Standalone" is displayed in [Instance type].



The admin network is important because Mirroring Controllers use it to confirm the status of each server.

The log transfer network is also important to maintain the data freshness.

Therefore, use network configurations resistant to faults for these networks by using the network redundancy channel bonding feature provided by the operating system or network driver vendor.

5.11 Performing Automatic Degradation Using the Arbitration Server

If database multiplexing is performed using WebAdmin, it is also possible to perform automatic degradation using the arbitration server. In such cases, it is necessary to perform tasks on the database server and the arbitration server after setting up Mirroring Controller in WebAdmin.

Tasks on the arbitration server

Perform setup of the arbitration server using Mirroring Controller commands.

1. Set up the arbitration server.

Refer to "2.3 Setting Up the Arbitration Server" in "Chapter 2 Setting Up Database Multiplexing Mode" for information on how to set up the arbitration server.

Tasks on the database server

Change some of the settings after setting up Mirroring Controller in WebAdmin.

1. Set up Mirroring Controller in WebAdmin.

Refer to "5.1 Mirroring Controller Setup" for details.

2. Use WebAdmin to stop Mirroring Controller on the master and standby instances.

Refer to "5.4 Stopping Mirroring Controller" for details.

3. Edit the network configuration file of the master and standby instances, and add the arbitration server information.

The network configuration file is network.conf, which exists in the Mirroring Controller management directory specified during Mirroring Controller setup. Refer to "A.3 Network Configuration File" for details.

A definition example of network.conf is shown below.

Example:

The port number of the database server to be used as the arbitration network is set to "27541". The ID of the server of the Mirroring Controller arbitration process is set to "arbiter", and its port number is set to "27541".

```
dbsvm27500 192.0.2.100,192.0.3.100 27540,27541 server
dbsvs27500 192.0.2.110,192.0.3.110 27540,27541 server
arbiter 192.0.3.120 27541 arbiter
```

Note

- Ensure that the port numbers set for the database server and the arbitration server do not conflict with other software. In addition, do not configure the same segment for the admin network and the arbitration network.
- If the server type is "server", two IP addresses or host names, and two port numbers need to be specified in the following order:
 - IP address or host name of the database server used as the admin network
 - IP address or host name of the database server used as the arbitration network
 - Port number of the database server used as the admin network
 - Port number of the database server used as the arbitration network

- If the server type is "arbiter", specify the IP address or host name set for the my_address parameter and the port number set for the port parameter in arbitration.conf of the arbitration server.
 - WebAdmin also support editing mirroring controller configuration via Use WebAdmin to edit Mirroring Controller configurations.
Refer to "[5.2 Edit Mirroring Controller Setup](#)" for details.
-

4. Edit the server configuration file of the master and standby instances, and add the parameters required for automatic degradation using the arbitration server.

The server configuration file is *instanceName.conf* or *instancePort.conf*, which exists in the Mirroring Controller management directory specified during Mirroring Controller setup.

To perform automatic degradation using the arbitration server, set the heartbeat_error_action parameter to "arbitration".

Refer to "[A.4.1 Server Configuration File for the Database Servers](#)" for information on other parameters.

5. Use WebAdmin to start Mirroring Controller on the master and standby instances.

Refer to "[5.5 Starting Mirroring Controller](#)" for details.

Common tasks

1. Use the Mirroring Controller command to check the connection status from the database server or the arbitration server.

Refer to "[2.8 Checking the Connection Status](#)" for information on how to check the connection status.

Appendix A Parameters

This appendix describes the configuration files and parameters required by the database multiplexing mode.



See

Refer to "Server Configuration" in the PostgreSQL Documentation for information on the postgresql.conf file.

A.1 Parameters Set on the Primary Server

The content for the parameters set in the postgresql.conf file of the primary server is shown in the table below.

Table A.1 postgresql.conf file

Parameter	Value set	Explanation
wal_level	replica or logical	Specify the output level for the transaction log. Specify "logical" when logical decoding is also to be used.
max_wal_senders	2 or more	Specify "2" when building a Mirroring Controller cluster system. When additionally connecting asynchronous standby servers to the cluster system, add the number of simultaneous connections from these standby servers.
synchronous_standby_names	'standbyServerName'	Use single quotation marks (') to enclose the name that will identify the standby server. Any name can be specified. Do not change this parameter while Mirroring Controller is running. Do not specify multiple names to this parameter as the Mirroring Controller can manage only one standby server.
hot_standby	on	Specify whether queries can be run on the standby server. Specify "on".
wal_keep_segments	Number of file segments	If a delay exceeding the value set in this parameter occurs, the WAL segment required later by the primary server may be deleted. Additionally, if you stop a standby server (for maintenance, for example), consider the stop time and set a value that will not cause the WAL segment to be deleted. Refer to "Estimating Transaction Log Space Requirements" in the Installation and Setup Guide for Server for information on estimating the WAL segment.
wal_log_hints	on	When using the pg_rewind command to recover a standby server, specify this parameter or enable checksums when executing the initdb command.
wal_sender_timeout	Timeout (milliseconds)	Specify the time period after which it is determined that the receiver process (walreceiver) of the transaction log is in an abnormal state on the primary server. The specified value must be larger than the value set for the wal_receiver_status_interval parameter set in the postgresql.conf file of the standby server.

Parameter	Value set	Explanation
		By aligning this value with the value for the database process heartbeat monitoring time, you can unify the time after which it is determined that an error has occurred.
wal_receiver_timeout	Timeout (milliseconds)	Specify the time period after which it is determined that an error has occurred when the transaction log was received on the standby server. By aligning this value with the value for the database process heartbeat monitoring time, you can unify the time after which it is determined that an error has occurred.
archive_mode	on	Specify the archive log mode.
archive_command	<code>'installDir/bin/pgx_walcopy.cmd "%p" "backupDataStorageDestinationDirectory/archived_wal/%f"</code>	Specify the command and storage destination to save the transaction log.
backup_destination	Backup data storage destination directory	Specify the name of directory where to store the backup data. Set the permissions so that only the instance administrator user can access the specified directory. Specify the same full path on all servers, so that the backup data of other servers can be used to perform recovery.
listen_addresses	Primary server IP address, host name, or "*"	Specify the IP address or host name of the primary server. Specify the IP address or corresponding host name that will be used to connect to the log transfer network. The content specified is also used to allow connections from client applications. To receive the connection and the transaction log from any client or standby server, specify "*". Refer to "Connections and Authentication" in the PostgreSQL Documentation for details.
max_connections	Number of simultaneous client connections to the instance + superuser_reserved_connections value	The value specified is also used to restrict the number of connections from client applications and the number of connections for the management of instances. Refer to "When an Instance was Created with the initdb Command" in the Installation and Setup Guide for Server, and "Connections and Authentication" in the PostgreSQL Documentation, for details.
superuser_reserved_connections	Add the number of simultaneous executions of mc_ctl status (*1) + 2	Specify the number of connections reserved for connections from database superusers. Add the number of connections from Mirroring Controller processes. Also reflect the added value in the max_connections parameter.
restart_after_crash	off	If "on" is specified, or the default value is used for this parameter, behavior equivalent to restarting FUJITSU Enterprise Postgres, including crash recovery, will be performed when some server processes end abnormally. However, when database multiplexing monitoring is used, a failover will occur after an error is detected when some server processes end abnormally, and the restart of those server processes is forcibly stopped. Specify "off" to

Parameter	Value set	Explanation
		prevent behavior such as this from occurring for no apparent reason.
synchronous_commit	on or remote_apply	Specify up to what position WAL send is to be performed before transaction commit processing returns a normal termination response to a client. The recommended value is "on" or "remote_apply" to prevent data loss caused by operating system or server down immediately after a switch or switch.
recovery_target_timeline	latest	Specify "latest" so that the new standby server (original primary server) will follow the new primary server when a switch occurs. This parameter is required when the original primary server is incorporated as a new standby server after the primary server is switched.

*1: Number of simultaneous executions of the mc_ctl command in the status mode.

A.2 Parameters Set on the Standby Server

This section explains the content of the file and parameters set on the standby server. After editing postgresql.conf file, start the instance. The content for the parameters specified in postgresql.conf file is shown in the table below.

Table A.2 postgresql.conf file

Parameter	Value set	Explanation
wal_level	replica or logical	Specify the output level for the transaction log. Specify "logical" when logical decoding is also to be used.
max_wal_senders	2 or more	Specify "2" when building a Mirroring Controller cluster system. When additionally connecting asynchronous standby servers to the cluster system, add the number of simultaneous connections from these standby servers.
synchronous_standby_names	' <i>primaryServerName</i> '	Use single quotation marks (') to enclose the name that will identify the primary server. Any name can be specified. This name will be required to rebuild the original primary server as the new standby server after the primary server was switched. Do not change this parameter while Mirroring Controller is running. Do not specify multiple names to this parameter as the Mirroring Controller can manage only one standby server.
hot_standby	on	Specify whether queries can be run on the standby server. Specify "on".
wal_keep_segments	Number of file segments	If a delay exceeding the value set in this parameter occurs, the WAL segment required later by the standby server may be deleted by the primary server.

Parameter	Value set	Explanation
		<p>Additionally, if you stop a standby server (for maintenance, for example), consider the stop time and set a value that will not cause the WAL segment to be deleted.</p> <p>Refer to "Estimating Transaction Log Space Requirements" in the Installation and Setup Guide for Server for information on estimating the WAL segment.</p>
wal_log_hints	on	When using the pg_rewind command to recover a standby server, specify this parameter or enable checksums when executing the initdb command.
wal_sender_timeout	Timeout (milliseconds)	<p>Specify the time period after which it is determined that the receiver process (walreceiver) of the transaction log is in an abnormal state on the primary server.</p> <p>The specified value must be larger than the value set for the wal_receiver_status_interval parameter set in the postgresql.conf file of the standby server.</p> <p>By aligning this value with the value for the database process heartbeat monitoring time, you can unify the time after which it is determined that an error has occurred.</p>
wal_receiver_timeout	Timeout (milliseconds)	<p>Specify the time period after which it is determined that an error has occurred when the transaction log was received on the standby server.</p> <p>By aligning this value with the value for the database process heartbeat monitoring time, you can unify the time after which it is determined that an error has occurred.</p>
backup_destination	Backup data storage destination directory	<p>Specify the name of the backup data storage directory.</p> <p>Set the permissions so that only the instance administrator user can access the specified directory.</p> <p>Specify the same full path on all servers so that the backup data of other servers can be used to perform recovery.</p>
archive_mode	on	Specify the archive log mode.
archive_command	'installDir/bin/pgx_walcopy.cmd "%p" "backupDataStorageDestinationDirectory/archived_wal/%f"'	Specify the command and storage destination to save the transaction log.
listen_addresses	Standby server IP address, host name, or "*"	<p>Specify the IP address or host name of the standby server. Specify the IP address or corresponding host name that will be used to connect to the log transfer network.</p> <p>The content specified is also used to allow connections from client applications.</p> <p>To receive the connection and the transaction log from any client or standby server, specify "*".</p> <p>Refer to "Connections and Authentication" in the PostgreSQL Documentation for details.</p>

Parameter	Value set	Explanation
max_connections	Number of simultaneous client connections to the instance + superuser_reserved_connections value	The value specified is also used to restrict the number of connections from client applications and the number of connections for the management of instances. Refer to "When an Instance was Created with the initdb Command" in the Installation and Setup Guide for Server, and "Connections and Authentication" in the PostgreSQL Documentation, for details.
superuser_reserved_connections	Add the number of simultaneous executions of mc_ctl status (*1) + 2	Specify the number of connections reserved for connections from database superusers. Add the number of connections from Mirroring Controller processes. Also reflect the added value in the max_connections parameter.
restart_after_crash	off	If "on" is specified, or the default value is used for this parameter, behavior equivalent to restarting FUJITSU Enterprise Postgres, including crash recovery, will be performed when some server processes end abnormally. However, when database multiplexing monitoring is used, a failover will occur after an error is detected when some server processes end abnormally, and the restart of those server processes is forcibly stopped. Specify "off" to prevent behavior such as this from occurring for no apparent reason.
synchronous_commit	on or remote_apply	Specify up to what position WAL send is to be performed before transaction commit processing returns a normal termination response to a client. The recommended value is "on" or "remote_apply" to prevent data loss caused by operating system or server down immediately after a switch or switch.
primary_conninfo	' <i>streamingReplication</i> <i>ConnectionDestinationInfo</i> '	Use single quotation marks (') to enclose the connection destination information of the streaming replication. The default value of this parameter is automatically set to postgresql.auto.conf in the procedure to run pg_basebackup for instance setup.
recovery_target_timeline	latest	Specify "latest" so that the new standby server (original primary server) will follow the new primary server when a switch occurs. This parameter is required when the original primary server is incorporated as a new standby server after the primary server is switched.

A.3 Network Configuration File

This section explains the network configuration file (network.conf) to be defined individually for the database servers and the arbitration server. Define the same content on the primary server and standby server.

For database multiplexing mode, define the network configuration for the following in network.conf.

- Integration between Mirroring Controller processes
- Integration between a Mirroring Controller process and the Mirroring Controller arbitration process

Items to be defined in network.conf

Format :

```
serverIdentifier hostName[,hostName] portNum[,portNum] [serverType]
Or,
serverIdentifier ipAddr[,ipAddr] portNum[,portNum] [serverType]
```

Specify the server identifier, IP address or host name, port number, and server type, using a space as the delimiter.

The items are explained in the table below.

Table A.3 network.conf file

Item	Description
<i>serverIdentifier</i>	Specify any identifier for the server. The maximum length is 64 bytes. Use ASCII characters excluding spaces and number signs (#) to specify this parameter.
<i>ipAddrOrHostName</i>	Specify the IP address or its corresponding host name that will connect to the admin network that performs communication between the database servers, and to the arbitration network that performs communication between a database server and the arbitration server. When specifying two IP addresses or host names delimited by a comma, do not insert a space after the comma. Use ASCII characters excluding spaces to specify the host name.
<i>portNum</i>	A port number cannot be specified if it exceeds the range 0 to 65535. Ensure that the port number does not conflict with other software. Do not specify an ephemeral port that may temporarily be assigned by another program. Note that the value specified in this parameter must also be set in the services file. When specifying two port numbers delimited by a comma, do not insert a space after the comma.
<i>serverType</i>	Specify "server" for a database server ("server" can be omitted), or "arbiter" for the arbitration server.

Content to be defined on the database servers

This section explains the network.conf content to be defined on the database servers.

The content to be defined depends on the operation settings at the time a heartbeat abnormality is detected.

When automatic degradation by the arbitration server is selected

- Specify definitions related to the admin network and arbitration network.
- Specify the IP address or host name and port number according to the server type (database server or arbitration server) as shown in the table below.

Server type	IP address or host name		Port number	
	First	Second	First	Second
server	IP address or host name used as the admin network	IP address or host name used as the arbitration network (*1)	Port number used as the admin network	Port number used as the arbitration network (*1)
arbiter	IP address or host name of the arbitration server Specify the same value as that specified in the my_address parameter of arbitration.conf on the arbitration server.	Not required	Port number on the arbitration server Specify the same value as that specified in the port parameter of arbitration.conf on the arbitration server.	Not required

*1: This value can be omitted from definitions not related to the local server. If it is omitted, network.conf must be created on both the primary server and standby server.

Example)

IPv4

```
server1 192.0.2.100,192.0.3.100 27540,27541 server
server2 192.0.2.110,192.0.3.110 27540,27541 server
arbiter 192.0.3.120 27541 arbiter
```

IPv6

```
server1 2001:258:8404:1217:250:56ff:fea7:559f,2001:258:8404:1217:250:56ff:fea8:559f
27540,27541 server
server2 2001:258:8404:1217:250:56ff:fea7:55a0,2001:258:8404:1217:250:56ff:fea8:55a0
27540,27541 server
arbiter 2001:258:8404:1217:250:56ff:fea8:55a0 27541 arbiter
```

When operation other than automatic degradation by the arbitration server is selected

- Specify definitions related to the admin network.
- Define the same content on the primary server and standby server.
- Define lines for database servers only.
- Specify only one IP address or host name and port number.

IP address or host name		Port number	
First	Second	First	Second
IP address or host name to be used as the admin network	Not required	Port number used as the admin network	Not required

Example)

The literal space represents a space.

IPv4

```
server1 192.0.2.100 27540
server2 192.0.2.110 27540
```

IPv6

```
server1 2001:258:8404:1217:250:56ff:fea7:559f 27540
server2 2001:258:8404:1217:250:56ff:fea7:55a0 27540
```

Content to be defined on the arbitration server

This section explains the network.conf content to be defined on the arbitration server.

- Specify definitions related to the arbitration network.
- Define lines for database servers only.
- For the IP address or host name, specify the same value as the second IP address or host name specified in the database server line in network.conf of the database server.

- For the port number, specify the same value as the second port number specified in the database server line in network.conf of the database server.

Example)

The literal space represents a space.

IPv4

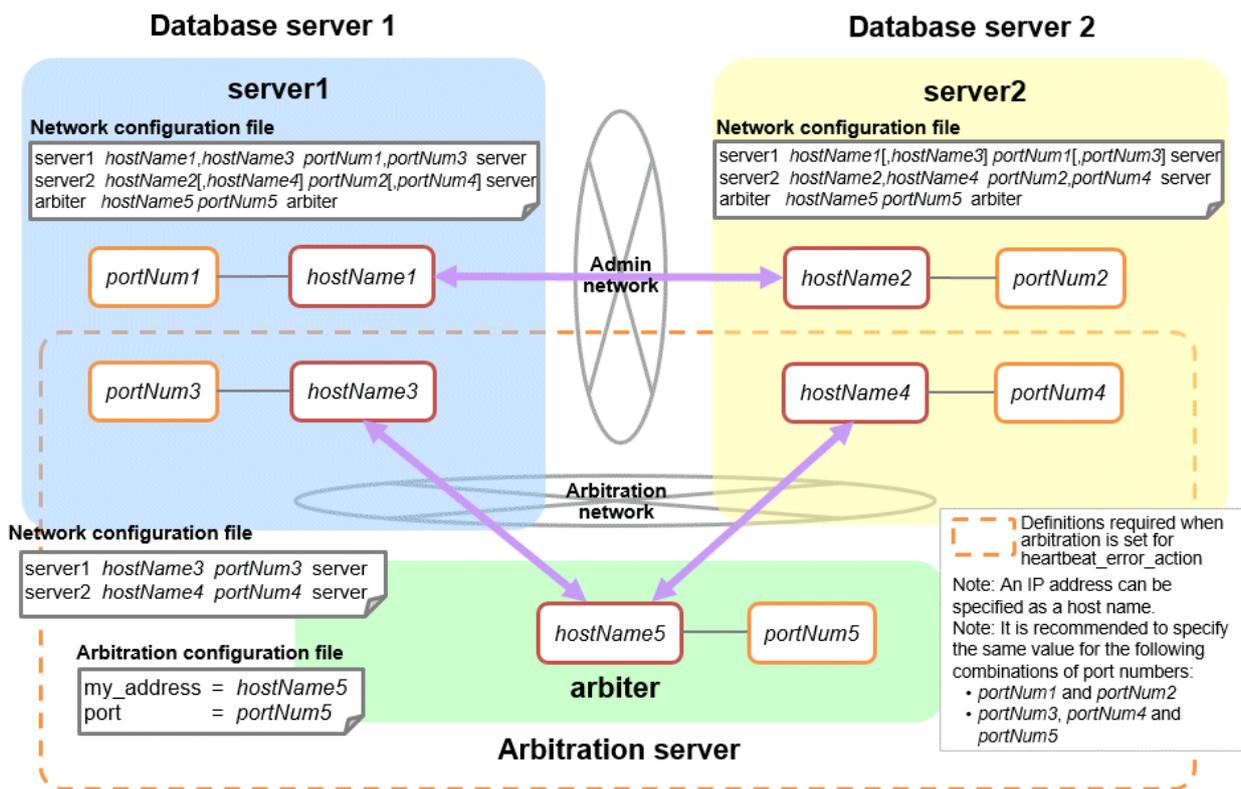
```
server1 192.0.3.100 27541
server2 192.0.3.110 27541
```

IPv6

```
server1 2001:258:8404:1217:250:56ff:fea8:559f 27541
server2 2001:258:8404:1217:250:56ff:fea8:55a0 27541
```

Relationship between network-related definitions

Refer to the diagram below for the relationship between the host names and IP addresses or port numbers specified in the network configuration file (network.conf) and arbitration configuration file (arbitration.conf).



A.4 Server Configuration File

A.4.1 Server Configuration File for the Database Servers

Define the information related to Mirroring Controller monitoring and control in the serverIdentifier.conf file. The maximum length of the server identifier is 64 bytes. Use ASCII characters excluding spaces to specify this parameter.

If the primary server and standby server environments are different, define content that is different, according to the environment.

Table A.4 serverIdentifier.conf file

Parameter	Value set	Explanation
db_instance	'dataStorageDestinationDir' [Example] db_instance = '/database1/inst1'	Specify using single quotation marks (') to enclose the data storage destination directory used to identify the monitoring target instance. Use ASCII characters to specify this parameter.
target_db	postgres or template1	Specify the name of the database to be connected to the database instance. The default is "postgres".
db_instance_username	'usernameToConnectToDbInstance'	Specify the username to connect to the database instance. Use ASCII characters to specify this parameter. Specify this parameter if the database administrator user is different from the operating system user who starts Mirroring Controller. Enclose the username of the database superuser in single quotation marks ('). The maximum length of the username is 63 bytes. The default is the operating system user who starts Mirroring Controller.
db_instance_password	'passwordOfInstanceAdminUser'	Specify the password used when Mirroring Controller connects to a database instance, enclosed in single quotation marks ('). Use ASCII characters to specify this parameter. If password authentication is performed, you must specify this parameter in the settings used when Mirroring Controller connects to a database instance. If you specify this parameter when password authentication is not performed, the parameter will be ignored. If the specified value of this parameter includes ' or \, write \' or \\, respectively.
enable_hash_in_password	on or off	Specify on to treat the # in the db_instance_password specification as a password character, or off to treat it as a comment. The default is "off".
core_file_path	'coreFileOutputDir'	Specify the directory to which the core file is to be output, enclosed in single quotation marks ('). Use ASCII characters to specify this parameter. If this parameter is omitted, it will be assumed that the Mirroring Controller management directory was specified.
syslog_facility	Specify LOCAL0, LOCAL1, LOCAL2, LOCAL3, LOCAL4, LOCAL5, LOCAL6, or LOCAL7.	When the import of logs to the syslog is enabled, the value of this parameter will be used for "facility" of the syslog. The default is "LOCAL0".
syslog_ident (*1)	'programName'	Specify using single quotation marks (') to enclose the program name used to identify the Mirroring Controller message in the system log.

Parameter	Value set	Explanation
		Use ASCII characters excluding spaces to specify this parameter. The default is 'MirroringControllerOpen'.
remote_call_timeout	Admin communication timeout	Specify the timeout value (milliseconds) of the Mirroring Controller agent process for communication between servers. Specify a value between 0 and 2147483647 to be less than the operation system TCP connection timeout (*2). The value 0 indicates that there is no timeout limit. The default is 70000 milliseconds (70 seconds).
agent_alive_timeout	Timeout for Mirroring Controller process heartbeat monitoring (seconds)	If there is no response for at least the number of seconds specified, the Mirroring Controller process is restarted. Specify 0 or a value between 2 and 2147483647. The value 0 indicates that there is no timeout limit. The default is 0 seconds.
heartbeat_error_action	Operation when a heartbeat abnormality is detected using operating system or server heartbeat monitoring	arbitration: Perform automatic degradation using the arbitration server. command: Call a user command to determine degradation, and perform automatic degradation if required. message: Notify messages. fallback: Perform automatic degradation unconditionally. The default is "arbitration". Set the same value on the primary server and standby server.
heartbeat_interval	Interval time for abnormality monitoring during heartbeat monitoring of the operating system or server (milliseconds)	Abnormality monitoring of the operating system or server is performed at the interval specified in heartbeat_interval. If an error is detected, operation will conform to the value specified for heartbeat_error_action. If "arbitration" is specified in heartbeat_error_action, the error detection time during monitoring of the operating system or server becomes longer than when the arbitration server is not used, by up to the value specified for arbitration_timeout. Specify a value between 1 and 2147483647. The specified value is used as the default for db_instance_check_interval and disk_check_interval. The default is 800 milliseconds.
heartbeat_timeout	Timeout for abnormality monitoring during heartbeat monitoring of the operating system or server (seconds)	If there is no response for at least the number of seconds specified, it will be assumed that an error has occurred that requires the primary server to be switched, or the standby server to be disconnected. If an error is detected, operation will conform to the value specified for heartbeat_error_action. If "arbitration" is specified in heartbeat_error_action, the error detection time during monitoring of the operating system or server becomes longer than when the arbitration server is not used, by up to the value specified for arbitration_timeout.

Parameter	Value set	Explanation
		<p>Specify a value between 1 and 2147483647.</p> <p>The specified value is used as the default for <code>db_instance_check_timeout</code>.</p> <p>The default is 1 second.</p>
<code>heartbeat_retry</code>	Number of retries for abnormality monitoring during heartbeat monitoring of the operating system or server (number of times)	<p>Specify the number of retries to be performed when an error has been detected that requires the primary server to be switched, or the standby server to be disconnected. If an error is detected in succession more than the specified number of times, switch or disconnection will be performed.</p> <p>If an error is detected, operation will conform to the value specified for <code>heartbeat_error_action</code>. If "arbitration" is specified in <code>heartbeat_error_action</code>, the error detection time during monitoring of the operating system or server becomes longer than when the arbitration server is not used, by up to the value specified for <code>arbitration_timeout</code>.</p> <p>Specify a value between 0 and 2147483647.</p> <p>The specified value is used as the default for <code>db_instance_check_retry</code> and <code>disk_check_retry</code>.</p> <p>The default is 2 times.</p>
<code>db_instance_check_interval</code>	Database process heartbeat monitoring interval (milliseconds)	<p>Heartbeat monitoring of the database process is performed at the interval specified in <code>db_instance_check_interval</code>.</p> <p>This parameter setting is also used for abnormality monitoring of streaming replication.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is the value set for <code>heartbeat_interval</code>.</p>
<code>db_instance_check_timeout</code>	Database process heartbeat monitoring timeout (seconds)	<p>If there is no response for at least the number of seconds specified, it will be assumed that an error has occurred that requires the primary server to be switched, or the standby server to be disconnected.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is the value set for <code>heartbeat_timeout</code>.</p>
<code>db_instance_check_retry</code>	Number of retries for database process heartbeat monitoring (number of times)	<p>Specify the number of retries to be performed when an error has been detected that requires the primary server to be switched, or the standby server to be disconnected. If an error is detected in succession more than the specified number of times, switch or disconnection will be performed. However, if it detects that the database process is down, it will immediately switch or disconnect regardless of the setting of this parameter.</p> <p>This parameter setting is also used for abnormality monitoring of streaming replication.</p> <p>Specify a value between 0 and 2147483647.</p> <p>The default number of retries is the value set for <code>heartbeat_retry</code>.</p>
<code>db_instance_timeout_action</code>	none, message, or failover	Specify the behavior for no-response monitoring of the instance.

Parameter	Value set	Explanation
		<p>none: Do not perform no-response monitoring.</p> <p>message: Notify messages if an error is detected during no-response monitoring.</p> <p>failover: Perform automatic degradation if an error is detected during no-response monitoring.</p> <p>The default is "failover".</p>
disk_check_interval	Interval time for disk abnormality monitoring (milliseconds)	<p>Abnormality monitoring of disk failure is performed at the interval specified in disk_check_interval. If the file cannot be created, it will be assumed that an error has occurred that requires the primary server to be switched, or the standby server to be disconnected.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is the value set for heartbeat_interval.</p>
disk_check_retry	Number of retries for disk abnormality monitoring (number of times)	<p>Specify the number of retries to be performed when an error has been detected that requires the primary server to be switched, or the standby server to be disconnected.</p> <p>If an error is detected in succession more than the specified number of times, switch or disconnection will be performed.</p> <p>Specify a value between 0 and 2147483647.</p> <p>The default number of retries is the value set for heartbeat_retry.</p>
tablespace_directory_error_action	message or failover	<p>Specify the behavior to be implemented if an error is detected in the tablespace storage directory.</p> <p>message: Notify messages.</p> <p>failover: Perform automatic degradation.</p> <p>The default is "failover".</p>
arbiter_alive_interval	Interval time for monitoring connection to the Mirroring Controller arbitration process (milliseconds)	<p>A heartbeat is sent to the Mirroring Controller arbitration process at the specified interval.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 16000 milliseconds.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
arbiter_alive_timeout	Timeout for monitoring connection to the Mirroring Controller arbitration process (seconds)	<p>If the heartbeat does not respond within the specified number of seconds, the Mirroring Controller arbitration process is determined to have been disconnected, a message is output, and reconnection is attempted.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 20 seconds.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
arbiter_alive_retry	Number of retries for monitoring connection to the Mirroring Controller arbitration process (number of times)	<p>Specify the number of heartbeat retries to be performed if an error is detected in the heartbeat to the Mirroring Controller arbitration process. If the heartbeat does not respond within the specified number of retries, the</p>

Parameter	Value set	Explanation
		<p>Mirroring Controller arbitration process is determined to have been disconnected.</p> <p>Specify a value between 0 and 2147483647.</p> <p>The default is 0 times.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
arbiter_connect_interval	Attempt interval for connection to the Mirroring Controller arbitration process (milliseconds)	<p>Reconnection is attempted at the specified interval if connection fails at startup of the Mirroring Controller process or if the Mirroring Controller arbitration process is disconnected.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 16000 milliseconds.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
arbiter_connect_timeout	Timeout for connection to the Mirroring Controller arbitration process (seconds)	<p>If reconnection at startup of the Mirroring Controller process or after disconnection of the Mirroring Controller arbitration process does not succeed within the specified number of seconds, connection to the Mirroring Controller arbitration process is determined to have failed and reconnection is attempted.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 20 seconds.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
fencing_command	<p><i>'fencingCmdFilePath'</i></p> <p>[Setting example]</p> <p>fencing_command='/mc/fencing_dir/ execute_fencing.sh'</p>	<p>Specify the full path of the fencing command that fences a database server where an error is determined to have occurred.</p> <p>Enclose the path in single quotation marks (').</p> <p>Specify the path using less than 1024 bytes.</p> <p>This parameter must be specified when "command" is set for heartbeat_error_action.</p>
fencing_command_timeout	Fencing command timeout (seconds)	<p>If the command does not respond within the specified number of seconds, fencing is determined to have failed and a signal (SIGTERM) is sent to the fencing command execution process.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 20 seconds.</p>
arbitration_timeout	Arbitration processing timeout in the Mirroring Controller arbitration process (seconds)	<p>The specified value must be at least equal to the value of fencing_command_timeout in the arbitration configuration file, which is the heartbeat monitoring time of the operating system or server.</p> <p>If there is no response for at least the number of seconds specified, the primary server will not be switched and the standby server will not be disconnected. Therefore, perform degradation manually.</p> <p>If the heartbeat_interval, heartbeat_timeout, and heartbeat_retry values are specified in arbitration.conf for</p>

Parameter	Value set	Explanation
		<p>the arbitration server, use the arbitration server values to design arbitration_timeout.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 30 seconds.</p> <p>This parameter does not need to be set for operation that does not use the arbitration server.</p>
arbitration_command	<p><i>'arbitrationCmdFilePath'</i></p> <p>[Setting example]</p> <p>arbitration_command = '/mc/ arbitration_dir/ execute_arbitration_command.sh'</p>	<p>Specify the full path of the arbitration command to be executed when an abnormality is detected during heartbeat monitoring of the operating system or server. Enclose the path in single quotation marks (').</p> <p>Specify the path using less than 1024 bytes.</p> <p>This parameter must be specified when "command" is set for heartbeat_error_action.</p>
arbitration_command_timeout	<p>Arbitration command timeout (seconds)</p>	<p>If the arbitration command does not respond within the specified number of seconds, it is determined that execution of the arbitration command has failed and a signal (SIGTERM) is sent to the arbitration command execution process.</p> <p>Specify a value between 1 and 2147483647.</p> <p>The default is 30 seconds.</p> <p>This parameter can be specified only when "command" is set for heartbeat_error_action.</p>
shutdown_detached_synchronous_standby	<p>on or off</p>	<p>Specify whether to forcibly stop the instance on the standby server when the standby server is disconnected.</p> <p>on: Stop the instance.</p> <p>off: Do not stop the instance.</p> <p>If "on" is specified and the pre-detach command was created, the pre-detach command is executed and then the instance is stopped.</p> <p>The default is "off".</p>
post_switch_command	<p><i>'postSwitchCmdFilePath'</i></p> <p>[Setting example]</p> <p>post_switch_command = '/mc/ status_change/ execute_post_switch.sh'</p>	<p>Specify the full path of the command to be called by Mirroring Controller after a new primary server is promoted during a failover of the primary server.</p> <p>Enclose the path in single quotation marks (').</p> <p>Specify the path using less than 1024 bytes.</p>
post_attach_command	<p><i>'postAttachCmdFilePath'</i></p> <p>[Setting example]</p> <p>post_attach_command = '/mc/ status_change/ execute_post_attach.sh'</p>	<p>Specify the full path of the command to be called by Mirroring Controller after the standby server is attached to the cluster system.</p> <p>Enclose the path in single quotation marks (').</p> <p>Specify the path using less than 1024 bytes.</p>
pre_detach_command	<p><i>'preDetachCmdFilePath'</i></p> <p>[Setting example]</p> <p>pre_detach_command = '/mc/ status_change/execute_pre_detach.sh'</p>	<p>Specify the full path of the command to be called by Mirroring Controller before the standby server is disconnected from the cluster system.</p> <p>Enclose the path in single quotation marks (').</p> <p>Specify the path using less than 1024 bytes.</p>

Parameter	Value set	Explanation
status_change_command_timeout	State transition command timeout (seconds)	Specify the timeout value of the post-switch command, post-attach command, and pre-detach command. If the command does not respond within the specified number of seconds, a signal (SIGTERM) is sent to the execution process of the status change command. Specify a timeout between 1 and 2147483647. The default is 20 seconds.
check_synchronous_standby_names_validation	on or off	Specify whether Mirroring Controller is to periodically check during operations whether the synchronous_standby_names parameter in postgresql.conf was changed by an incorrect user operation. However, it is not recommended to enable this parameter, because performing this check causes Mirroring Controller to use the CPU of the database server redundantly and execute SQL statements at high frequency. The default is "off".
db_instance_ext_pq_conninfo	<i>'libpqConnectionSSLParamToConnectToDbinstance'</i>	Specify, in key-value form, the connection parameter for libpq that Mirroring Controller adds when connecting to a database. The connection parameters you can specify are those related to SSL. Use ASCII characters to specify this parameter. The connection parameter specified in this parameter must also be specified in the db_instance_ext_jdbc_conninfo.
db_instance_ext_jdbc_conninfo	<i>'JDBCConnectionSSLParamToConnectToDbinstance'</i>	Specify, in URI form, the connection parameter for JDBC that Mirroring Controller adds when connecting to a database. The connection parameters you can specify are those related to SSL. Use ASCII characters to specify this parameter. The connection parameter specified in this parameter must also be specified in the db_instance_ext_pq_conninfo.

*1: By specifying the syslog_ident parameter of the postgresql.conf file, the Mirroring Controller output content can be referenced transparently, so log reference is easy.

*2: The operating system TCP connection timeout period is determined by the kernel parameter tcp_syn_retries. The remote_call_timeout parameter must be set to a value that is shorter than the timeout period for the operating system TCP connection timeout, so change either parameter as necessary.

The availability of some parameters depends on the value set for the heartbeat_error_action parameter that sets the operation to be performed if heartbeat monitoring of the operating system or server detects a heartbeat abnormality.

Table A.5 Parameter availability depending on the value set for the heartbeat_error_action parameter

Parameter	Value set			
	arbitration	command	message	fallback
arbiter_alive_interval	Y	N	N	N
arbiter_alive_timeout	Y	N	N	N
arbiter_alive_retry	Y	N	N	N
arbiter_connect_interval	Y	N	N	N
arbiter_connect_timeout	Y	N	N	N
arbitration_timeout	Y	N	N	N

Parameter	Value set			
	arbitration	command	message	fallback
arbitration_command	N	R	N	N
arbitration_command_timeout	N	Y	N	N
fencing_command	Y	R	Y	N
fencing_command_timeout	Y	Y	Y	N
shutdown_detached_synchronous_standby	Y	Y	N	N

R: Required

Y: Can be specified

N: Cannot be specified

A.4.2 Arbitration Configuration File

In `arbitration.conf`, define the information related to arbitration and control of the Mirroring Controller arbitration process.

Table A.6 `arbitration.conf` file

Parameter	Value set	Description
port	Port number of the Mirroring Controller arbitration process	The specified value must not exceed the range 0 to 65535. Ensure that the port number does not conflict with other software. Do not specify an ephemeral port that may temporarily be assigned by another program. For the port number of the arbitration server to be specified in <code>network.conf</code> on the database server, specify the same value as the port number specified in this parameter.
my_address	<i>'ipAddrOrHostNameThatAcceptsConnectionFromMirroringControllerProcessOnDbServer'</i> [Setting example] my_address = '192.0.3.120'	For the IP address or host name of the arbitration server to be specified in <code>network.conf</code> on the database server, specify the same value as the IP address or host name specified in this parameter. IPv4 and IPv6 addresses can be specified. Specify the IP address or host name, enclosed in single quotation marks (').
core_file_path	<i>'coreFileOutputDir'</i>	Specify the directory to which the core file is to be output, enclosed in single quotation marks ('). Use ASCII characters to specify this parameter. If this parameter is omitted, it will be assumed that the Mirroring Controller arbitration process management directory was specified.
syslog_facility	Specify LOCAL0, LOCAL1, LOCAL2, LOCAL3, LOCAL4, LOCAL5, LOCAL6, or LOCAL7.	When the import of logs to the syslog is enabled, the value of this parameter will be used for "facility" of the syslog. The default is "LOCAL0".
syslog_ident	<i>'programName'</i>	Specify using single quotation marks (') to enclose the program name used to identify the Mirroring Controller arbitration process message in the system log. Use ASCII characters excluding spaces to specify this parameter.

Parameter	Value set	Description
		The default is 'MirroringControllerArbiter'.
fencing_command	' <i>fencingCmdFilePath</i> ' [Setting example] fencing_command = '/arbiter/ fencing_dir/execute_fencing.sh'	Specify the full path of the fencing command that fences a database server where an error is determined to have occurred. Enclose the path in single quotation marks ('). Specify the path using less than 1024 bytes.
fencing_command_timeout	Fencing command timeout (seconds)	If the command does not respond within the specified number of seconds, fencing is determined to have failed and a signal (SIGTERM) is sent to the fencing command execution process. Specify a value between 1 and 2147483647. The default is 20 seconds.
heartbeat_interval(*1)	Interval time for heartbeat monitoring of the operating system or server (milliseconds)	The heartbeat monitoring of the database server is checked at the specified interval and arbitration is performed. Specify a value between 1 and 2147483647. The default is the value specified in <i>serverIdentifier.conf</i> of the database server. Specify this parameter to perform optimization taking into account differences in the line load to the admin network and the reduction in the time it takes to degrade.
heartbeat_timeout	Timeout for heartbeat monitoring of the operating system or server (seconds)	If there is no response for at least the number of seconds specified, it will be assumed that an error has occurred that requires the primary server or standby server to be fenced. Specify a value between 1 and 2147483647. The default is the value specified in <i>serverIdentifier.conf</i> of the database server. Specify this parameter to perform optimization taking into account differences in the line load to the admin network and the reduction in the time it takes to degrade.
heartbeat_retry	Number of retries for heartbeat monitoring of the operating system or server (number of times)	Specify the number of retries to be performed when an error has been detected that requires the primary server or standby server to be fenced. If an error is detected in succession more than the specified number of times, fencing will be performed. Specify a value between 0 and 2147483647. The default is the value specified in <i>serverIdentifier.conf</i> of the database server. Specify this parameter to perform optimization taking into account differences in the line load to the admin network and the reduction in the time it takes to degrade.

*1:Refer to "[2.11.4 Tuning for Optimization of Degradation Using Abnormality Monitoring](#)" for information on the tuning parameters for operating system or server abnormality monitoring when using an arbitration server.

Appendix B Supplementary Information on Building the Primary Server and Standby Server on the Same Server

The primary server and standby server can be pseudo-configured on the same server for system testing, for example. Out of consideration for performance and reliability, do not use this type of configuration for any other purposes. For this reason, do not use this type of configuration in a production environment.

Note that the setup and operations is the same as if the primary and standby servers are built on different servers.

This appendix provides supplementary information explaining how to configure the primary server and standby server on the same server.



Even if automatic degradation by an arbitration server is set when the primary server and standby server are configured on the same server, there will be no effect of it.

B.1 Backup Data Storage Destination Directory

It is not a problem if the same backup data storage destination directory is used on the primary server and standby server.

B.2 How to Execute the mc_ctl Command

When executing the mc_ctl command, specify the server identifier in the --local-server option in order to identify the operation destination server.

Below is an example of starting Mirroring Controller of the server "server1" defined in the network.conf file. For mc_ctl command operations using another mode, also specify the --local-server option.

Define two server identifiers for the same IP address with different port numbers in the network.conf file.

Example)

```
server1 192.0.2.100 27540
server2 192.0.2.100 27541
```

Ensure that the port numbers of both primary server and standby server do not conflict with any other software.

Enabling automatic switch/disconnection

Start Mirroring Controller of the server "server1":

Example)

```
$ mc_ctl start -M /mcdire/inst1 --local-server server1
```

Stop Mirroring Controller of the server "server1":

Example)

```
$ mc_ctl stop -M /mcdire/inst1 --local-server server1
```

Disabling automatic switch/disconnection

Start Mirroring Controller of the server "server1":

Example)

```
$ mc_ctl start -M /mcdire/inst1 -F --local-server server1
```

Stop Mirroring Controller of the server "server1":

Example)

```
$ mc_ctl stop -M /mcdir/inst1 --local-server server1
```

Note

If using an rc script

Append the --local-server option to the mc_ctl command call defined in the automatic start shell script.

If using systemd

Add the --local-server option to the mc_ctl option specification for ExecStart and ExecStop of the unit file for systemd.

Refer to "[2.12 Setting Automatic Start and Stop of Mirroring Controller and Multiplexed Instances](#)" for details.

Appendix C User Commands

This appendix describes three categories of commands:

- Fencing command
- Arbitration command
- State transition commands

This appendix describes each category of user command.

C.1 Fencing Command

Format

The syntax for calling the fencing command from the Mirroring Controller process or the Mirroring Controller arbitration process is described below.

Fencing command of the database server

```
fencingCmd executionMode mcDegradationOper cmdServerId targetServerId primarycenter
```

Fencing command of the arbitration server

```
fencingCmd executionMode mcDegradationOper targetServerId
```

Input

Fencing command of the database server

Execution mode

monitor: Detect issues via automatic monitoring of the Mirroring Controller process

command: Mirroring Controller command execution (switch mode or detach mode of the mc_ctl command)

Degradation operation to be performed by Mirroring Controller

switch: Switch

detach: Disconnect

cmdServerId

ID of the database server that called the command

targetServerId

ID of the database server to be fenced

primarycenter

Fixed value

Fencing command of the arbitration server

Execution mode

monitor: Detect issues via automatic monitoring of the Mirroring Controller process

command: Mirroring Controller command execution (switch mode or detach mode of the mc_ctl command)

Degradation operation to be performed by Mirroring Controller

switch: Switch

detach: Disconnect

targetServerId

ID of the database server to be fenced

Output

Return value

0: Mirroring Controller will continue the degradation process.

Other than 0: Mirroring Controller will cancel the degradation process.

Description

Identifies the database server targeted for fencing based on the input server identifier, and implements the process that isolates it from the cluster system.

Notes

- The command is executed by the operating system user who started Mirroring Controller or the Mirroring Controller arbitration process. Therefore, if the command is to be executed by a specific operating system user, change the executing user of the command accordingly.
- The operating system user who started Mirroring Controller or the Mirroring Controller arbitration process must have execution privileges to the command. Otherwise, the degradation process will be canceled.
- From a security point of view, set the access privileges as necessary so that the fencing command is not overwritten and unauthorized operations are not performed by unintended operating system users.
- If the fencing command returns a value other than 0, Mirroring Controller will cancel the degradation process, so it is necessary for the user to check the status of the server, and switch or disconnect it manually.
- Before executing the fencing command, check if the server is already fenced, to avoid the command terminating abnormally.
- If the command times out, Mirroring Controller will stop the command, output an error message, and cancel the degradation process.

Information

The fencing command can be implemented by simply stopping the operating system or server. For example, if stopping the power for the database server, it is possible to use a utility to control the hardware control board in environments equipped with boards compatible with IPMI hardware standard.

Below is a sample script of a fencing command that powers off the database server using the IPMI tool.

Sample shell script

```
/installDir/share/mcarb_execute_fencing.sh.sample
```

C.2 Arbitration Command

Format

The syntax for calling the arbitration command from the Mirroring Controller process is described below.

```
arbitrationCmd cmdServerId targetServerId primarycenter
```

Input

cmdServerId

ID of the database server that called the command

targetServerId

ID of the database server to arbitrate

primarycenter

Fixed value

Output

Return value

0: The database server to arbitrate has an issue, and Mirroring Controller will continue the degradation process.

Other than 0: The database server to arbitrate is normal, and Mirroring Controller will cancel the degradation process.

Description

Identifies the database server to arbitrate based on the input server identifier, and checks the status of the server.

Notes

- The command is executed by the operating system user who started Mirroring Controller.
- The operating system user who started Mirroring Controller must have execution privileges to the command. Otherwise, the command will not be called, and the degradation process will be canceled.
- If the command times out, Mirroring Controller will stop the command, output an error message, and cancel the degradation process.

C.3 State Transition Commands

State transition commands include the three types of user commands below. Any of the commands can be implemented by Mirroring Controller in conjunction with database server status transitions.

- Post-switch command
- Pre-detach command
- Post-attach command

C.3.1 Post-switch Command

Format

The syntax for calling the post-switch command from the Mirroring Controller process is described below.

```
postswitchCmd serverIdentifier primarycenter
```

Input

serverIdentifier

ID of the database server (new primary server) that was switched

primarycenter

Fixed value

Output

Return value

None

Notes

- The command is executed by the operating system user who started Mirroring Controller.
- The operating system user who started Mirroring Controller must have execution privileges to the command. Otherwise, the command will not be called.
- If the command times out, Mirroring Controller will stop the command, output an error message, and cancel the process.

C.3.2 Pre-detach Command

Format

The syntax for calling the pre-detach command from the Mirroring Controller process is described below.

```
predetachCmd cmdServerId serverRole targetServerId primarycenter
```

Input

cmdServerId

ID of the database server that called the command

Server role

Role of the database server that called the command

primary: Primary

standby: Standby

targetServerId

ID of the standby server to be disconnected from the cluster system

primarycenter

Fixed value

Output

Return value

None

Notes

- The command is executed by the operating system user who started Mirroring Controller.
- The operating system user who started Mirroring Controller must have execution privileges to the command. Otherwise, the command will not be called, however, Mirroring Controller will output an error message and continue the process.
- If the command times out, Mirroring Controller will stop the command, output an error message, and cancel the process.

C.3.3 Post-attach Command

Format

The syntax for calling the post-attach command from the Mirroring Controller process is described below.

```
postattachCmd cmdServerId serverRole targetServerId primarycenter
```

Input

cmdServerId

ID of the database server that called the command

Server role

Role of the database server that called the command

primary: Primary

standby: Standby

targetServerId

ID of the standby server to be attached to the cluster system

primarycenter

Fixed value

Output

Return value

None

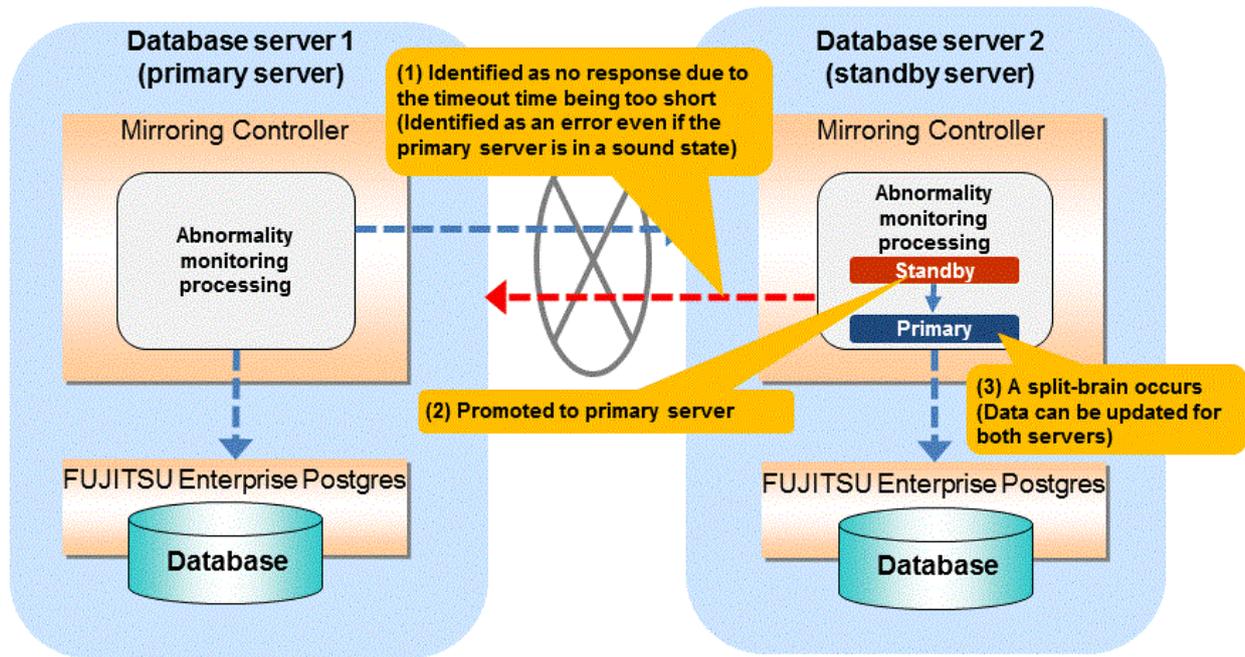
Notes

- The command is executed by the operating system user who started Mirroring Controller.
- The operating system user who started Mirroring Controller must have execution privileges to the command. Otherwise, the command will not be called.
- If the command times out, Mirroring Controller will stop the command, output an error message, and cancel the process.

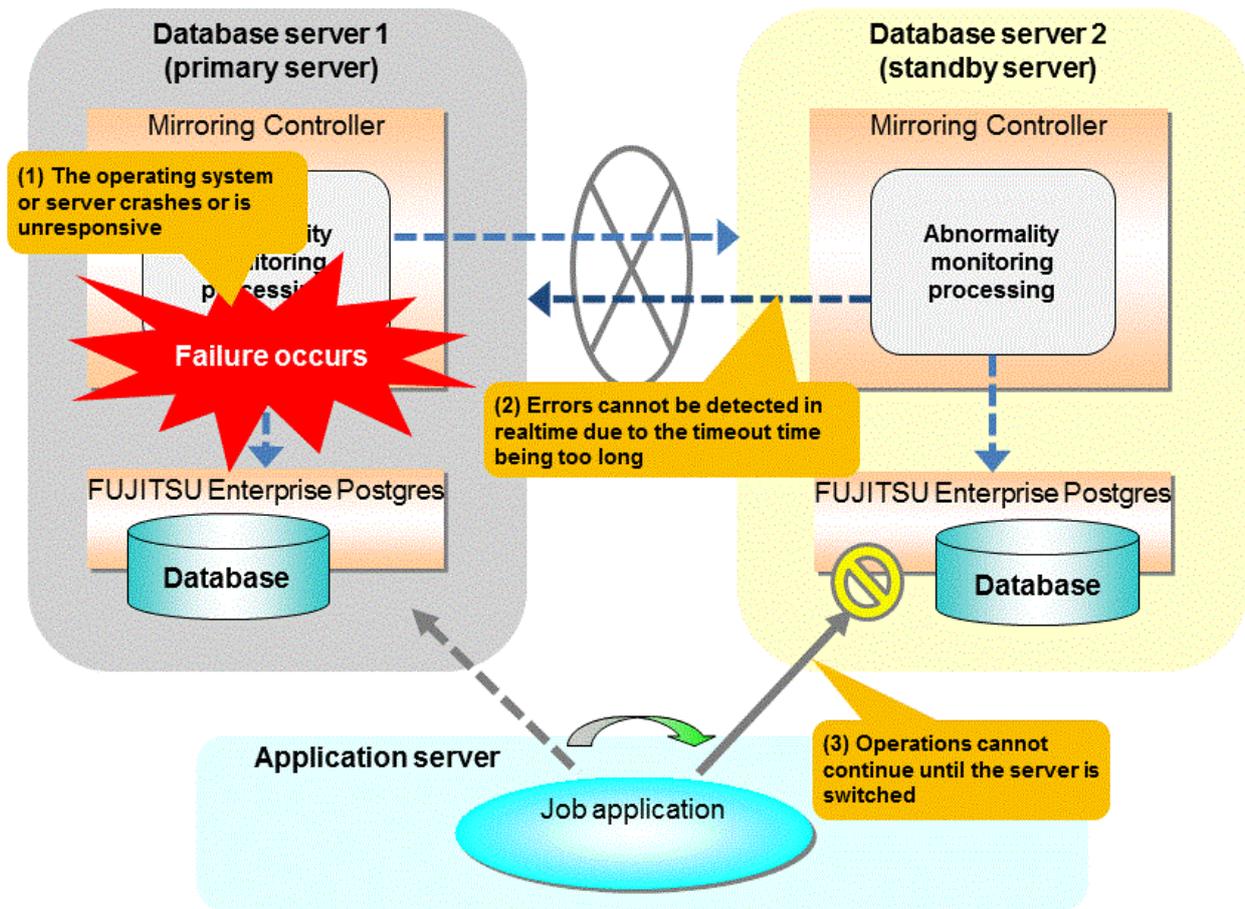
Appendix D Notes on Performing Automatic Degradation Immediately after a Heartbeat Abnormality

The type of issue below occurs if automatic degradation is performed unconditionally after an issue is detected during heartbeat monitoring of an operating system or server, and heartbeat monitoring was not properly tuned.

- If the timeout time is too short



● If the timeout time is too long



Notes on monitoring when the operating system or server crashes or is unresponsive

As illustrated in the diagram above, timeout is used to monitor whether the operating system or server crashes or is unresponsive. Therefore, if tuning has not been performed correctly, there is a risk of a split-brain mistakenly occurring even if the server is in a sound state.

Split-brain is a phenomenon in which both servers temporarily operate as primary servers, causing data updates to be performed on both servers.

Split-brain detection method

It can be confirmed that split-brain occurs under the following conditions:

1. When the mc_ctl command is executed in status mode on both servers, the "host_role" of both servers is output as "primary", and
2. The following message is output to the system log of one of the servers:

```
promotion processing completed (MCA00062)
```

How to recover from a split-brain

Use the procedure described below. Note that the new primary server is the server that was confirmed in step 2 of the aforementioned detection method.

1. Stop all applications that are running on the old and new primary servers.
2. Investigate and recover the database.
Investigate the update results that have not been reflected to the new primary server from the database of the old primary server, and apply to the new primary server as necessary.
3. Stop the old primary server instance and the Mirroring Controller.

4. Resume the applications that were stopped in step 1.
5. Recover the old primary server.
While referring to "[2.5 Setting Up the Standby Server](#)", build (set up) the old primary server as the new standby server, from the new primary server.

Appendix E WebAdmin Disallow User Inputs Containing Hazardous Characters

WebAdmin considers the following as hazardous characters, which are not allowed in user inputs.

- | (pipe sign)
- & (ampersand sign)
- ; (semicolon sign)
- \$ (dollar sign)
- % (percent sign)
- @ (at sign)
- ' (single apostrophe)
- " (quotation mark)
- \ ' (backslash-escaped apostrophe)
- \ " (backslash-escaped quotation mark)
- <> (triangular parenthesis)
- () (parenthesis)
- + (plus sign)
- CR (Carriage return, ASCII 0x0d)
- LF (Line feed, ASCII 0x0a)
- ,
- \ (backslash)

Appendix F Collecting Failure Investigation Data

If the cause of an error that occurs while building the environment or during operations is unclear, data must be collected for initial investigation.

This appendix describes how to collect data for initial investigation.

Use the `pgx_fjqssinf` command to collect data for initial investigation.



See

.....
Refer to the Reference for information on the `pgx_fjqssinf` command.
.....

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Connection Manager User's Guide

Preface

Purpose of this document

This document describes the Connection Manager features of FUJITSU Enterprise Postgres.

Intended readers

This document is aimed at people who use the Connection Manager features.

Readers of this document are also assumed to have general knowledge of:

- FUJITSU Enterprise Postgres
- PostgreSQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Connection Manager Features](#)

Explains the features and Mechanisms of the Connection Manager.

[Chapter 2 Setting Up](#)

Explains setting up the Connection Manager.

[Chapter 3 Using from an Application](#)

Explains how to use the Connection Manager from an application.

[Appendix A System Views](#)

Explains the system view of Connection Manager.

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Chapter 1 Connection Manager Features

The Connection Manager provides the following features:

Heartbeat monitoring feature

Detects kernel panics between the server running the client and the server running the PostgreSQL instance (hereinafter referred to as instance), physical server failures, and inter-server network link downs, and notifies the client or instance. The client is notified as an error event through the SQL connection, and the instance will be notified in the form of a force collection of SQL connections with clients that are out of service.

Transparent connection support feature

When an application wants to connect to an instance of an attribute in a set of instances configured for replication, it can connect to that instance without being aware of which server it is running on.

Information

- The available client drivers for Connection Manager are libpq (C language library) and ECPG (embedded SQL in C).

Each function is described below.

1.1 Heartbeat Monitoring Feature

Describes the Connection Manager's heartbeat monitoring feature.

Note

The Connection Manager does not monitor for delays, such as CPU busy occurring in the postmaster process or in the backend processes to which the application connects directly, or for no response, such as due to a software bug. It also does not monitor application downtime or unresponsiveness. To detect these, use various timeout features provided by PostgreSQL or the client drivers.

1.1.1 Difference from TCP keepalive

A peer of TCP connections cannot automatically detect a link down or server down.

There are two main methods to detect it. One is the operating system (Not all operating systems support it) TCP keepalive feature, and the other is the keepalive-equivalent timeout function implemented at the application layer. Connection Manager's heartbeat monitoring capabilities are categorized as the latter.

The operating system TCP keepalive feature has the following disadvantages, but the Connection Manager's heartbeat monitoring feature does not:

- The keepalive does not work when the TCP layer cannot receive an acknowledgement (ACK) and retransmits the packet repeatedly. This means that it is not possible to detect a down (For example, if a network goes down,) before sending some data and receiving ACK from the other side. There is also a parameter to interrupt retransmissions, which is not supported by some operating systems. The Connection Manager's heartbeat monitoring feature does not have this disadvantage because it is timeout monitoring at the application layer.
- The periodic packets for keepalive are sent per-TCP socket. If an instance accepts too many (For example, a few thousand clients) SQL connections, the load on the instance side cannot be ignored. The Connection Manager's heartbeat monitoring feature greatly reduces the load by allowing packets to be sent to the instance on a per-server basis on which the client runs.

1.1.2 Mechanism of Heartbeat Monitoring Feature

On the client side, the user must start one monitoring process using the `cm_ctl` command for the set of the instances to be monitored. This process, called the "conmgr process", can only be started by a user who is not an administrator (e.g. `superuser(root)` on Linux). An instance set is a collection of one or more instances that make up replication. One configuration file (`conmgr.conf`) for each conmgr process is used to set the information about the set of the instances being monitored and the parameters for monitoring.

On the server side, by installing PostgreSQL's EXTENSION that is called "watchdog", the postmaster will start two processes as background workers at instance startup.

One is the process for sending and receiving packets to and from the conmgr process for heartbeat monitoring. It is called "watchdog process". The other is the process for forcibly terminating SQL connections of the clients for which the watchdog process detects a failure on heartbeat monitoring. It is called "terminator process". SQL connections that do not use Connection Manager is also terminated, because the terminator process terminates them by IP address as key.



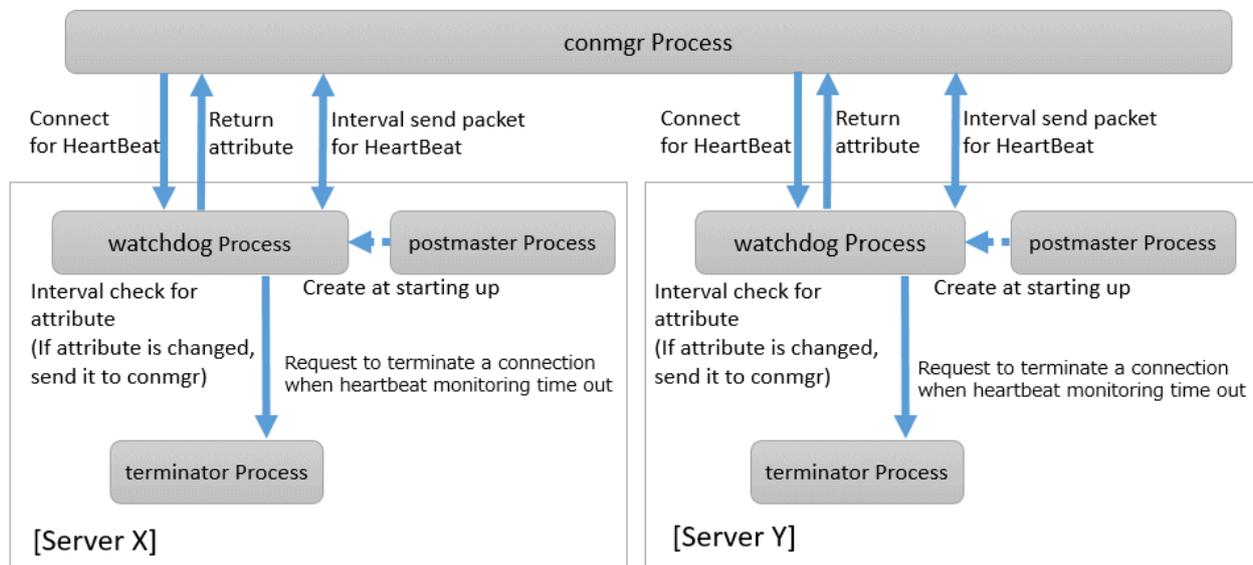
Note

System Configuration Notes

For replication, it is recommended that the instance that connects to the upstream instance of replication and the conmgr process that regards the upstream instance as an instance to be monitored for heartbeat (specified in `backend_host` parameter or `backend_hostaddr` parameter that is a configuration parameter of conmgr process) be not placed on the same server. This is because if the conmgr process stops normally or abnormally, the terminator process in the upstream instance will also kill the replication connection. The replication connection will reconnect automatically even if it is forcibly disconnected, so replication will continue without any problems. However, this can be a problem when the replication load is high or on systems that are sensitive to replication delays.

Note that the replication connection have different monitoring feature than the Connection Manager, so there is no need to monitor the Connection Manager for heartbeat. Refer to PostgreSQL documentation for details.

The process relationship is as follows:



See

Refer to "`cm_ctl`" in the Reference for information on `cm_ctl` command.

1.2 Transparent Connection Support Feature

The features similar to Connection Manager's transparent connection support feature can be found in PostgreSQL's libpq and other client drivers.

Using libpq as an example, the connection parameter to use that feature is `target_session_attrs` parameter. If this parameter is used not through Connection Manager, libpq will attempt to find the required instance by connecting sequentially to all instances of the set of instance requested by the `host` parameter or `hostaddr` parameter. In the worst case, libpq may find the promoted primary at the connection to the last instance of instance set. This means that you cannot predict how long it will take to complete the switch.

However, when combined with the Connection Manager, the `conmgr` process obtains its attributes via the `watchdog` process from all servers in a set of servers in advance, so that the connections to that server can be initiated as soon as the application requests it.

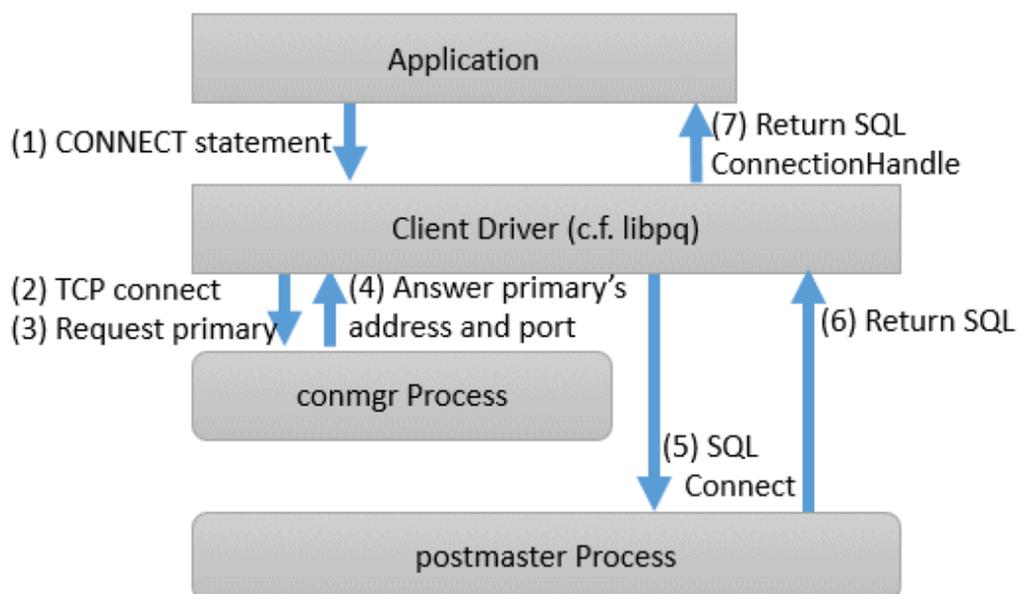
1.2.1 Mechanism of Connections using Transparent Connection Support Feature

A connection using this mechanism actually consists of two steps, but from the perspective of the application, it looks like a single SQL connection. In the application's connection string, specify the IP address or host name (In most cases it is "localhost") and port number where the `conmgr` process listens, and `target_session_attrs` parameter. You do not need to explicitly state that the connection is to the `conmgr` process. This is because the client driver can automatically determine whether the connection is to a instance or a `conmgr` process.

In the first phase of the connection, the client driver receives a connection request from the application and connects to the location specified in the connection string. Initially, it uses the protocol PostgreSQL requests, and if it learns in the middle that the connection is to a `conmgr` process, it asks the `conmgr` process for the IP address and port number that the instance with the attributes specified in the connection parameter `target_session_attrs` is listening for. If the destination is a backend process rather than a `conmgr` process, the connection process completes immediately and continues to send and receive data for normal SQL execution. The first stage of processing falls within the scope of timeout monitoring for SQL connection processing by each client driver. For example, the `connection_timeout` parameter of libpq.

In the second phase of the connection, the client driver connects to the instance using the IP address and port number from the `conmgr` process. Thereafter, the client driver and the instance directly send and receive the data for SQL execution. This ensures that the Connection Manager does not affect the performance of the SQL execution.

When the client driver is waiting to receive data after the second stage is completed, it monitors the reception of data to the two sockets obtained at each stage of the connection. This allows the client driver to know when, for example, the `conmgr` process notifies the client of a network link down.



Chapter 2 Setting Up

Describes setting up the Connection Manager.

2.1 Setting Up the Client Side

On the client side, configure settings for the conmgr process.

2.1.1 Creating a Directory for the conmgr Process

You need one conmgr process for each set of instances that you want to configure for replication. Assign a dedicated directory to each conmgr process. This directory must assign read, execute, and write permissions for the user who starts the conmgr process.

This directory is specified when you run the `cm_ctl` command, which starts and stops the conmgr process. To specify a directory in the `cm_ctl` command, set it in the environment variable `CMDATA` or specify it in the `-D` option.

2.1.2 Configuring `conmgr.conf`

Place the configuration file `conmgr.conf` in the directory for the conmgr process.

Syntax for `conmgr.conf`

- In `conmgr.conf`, after the symbol(`#`) are considered comments.
- The parameter name = value" is a set of settings and must be written on one line.
- Set the value in a format that matches the type of each parameter. The types and formats are:
 - integer: Numeric type. Express as a sequence of numbers in decimal number.
 - string: String type. You can also include spaces by enclosing them in quotation marks(`'`). If you include quotation marks, escape them.
 - enum: Enumeration type. Possible values are determined.

Parameters to Set

port (integer)

Specify the port number on which the conmgr process listens for connections from the applications.

The value must be greater than or equal to 1 and less than or equal to 65535. The default is 27546. You must restart conmgr process for this parameter change to take effect.

backend_host* (string)

Specify the host name or IP address of the instance.

You can also use IPv6 address. If you specify the IP address directly, you can save time by using `backend_hostaddr` parameter. If `backend_host` parameter and `backend_hostaddr` parameter are both specified, `backend_hostaddr` parameter is used. You must restart conmgr process for this parameter change to take effect.

To distinguish multiple instances, append a zero-based number immediately after the parameter name, such as `backend_host0`, `backend_host1`,... This number is called the instance number. A parameter identified by the same instance number configures the settings of a single instance. If you want to exclude some instances from your replication configuration, you can simply remove the settings for that instance.



Refer to "System Configuration Notes" in "[1.1.2 Mechanism of Heartbeat Monitoring Feature](#)" for details.

For example, if two instances are listening on "host name:host0, port number:5432" and "host name:host1, port number:2345", write as follows.

```
backend_host0='host0'  
backend_port0=5432  
backend_host1='host1'  
backend_port1=2345
```

You can also mix different instance number settings:

```
backend_host0='host0'  
backend_host1='host1'  
backend_port0=5432  
backend_port1=2345
```

It does not matter if the instance number is missing as in the following (instance number 1):

```
backend_host0='host0'  
backend_host2='host2'  
backend_port0=5432  
backend_port2=2345
```

If the host name is omitted even if the port is specified, as in the following instance number 1, it is regarded as a missing number.

```
backend_host0='host0'  
backend_host2='host2'  
backend_port0=5432  
backend_port1=5555  
backend_port2=2345
```

backend_hostaddr*(string)

Same as `backend_host` parameter except no name resolution is used.

backend_port* (integer)

Specify the port number the postmaster of the instance will listen on.

The value must be greater than or equal to 1 and less than or equal to 65535. The default is 27500. Append the instance number as you would for `backend_host` parameter. You must restart `conmgr` process for this parameter change to take effect.

watchdog_port* (integer)

Specify the port number on which the watchdog process listens.

The `conmgr` process connects to this port, but the user application does not. you must set it to the same value as `watchdog.port` parameter in `postgresql.conf`. The value must be greater than or equal to 1 and less than or equal to 65535. The default is 27545. Append the instance number as you would for `backend_host` parameter. You must restart `conmgr` process for this parameter change to take effect.

heartbeat_interval (integer)

Specify the interval at which heartbeat packets are sent for heartbeat monitoring.

Used in conjunction with `heartbeat_timeout` parameter. Connection Manager heartbeat monitoring always continues to send packets periodically from both ends of the connection. If a packet is not received from the other side within a certain period of time, the link is considered down.

Note that this method is different from TCP keepalive. TCP keepalive send a keepalive packet only when there is a certain amount of inactivity (idle), and expects to receive an ACK for that packet. If TCP keepalive does not receive an ACK, it repeats this a specified number of times and then assumes that the link is down.

The `heartbeat_interval` parameter and `heartbeat_timeout` parameter are propagated from the `conmgr` process to the watchdog process, and also apply to the interval between the transmissions of heartbeat packets from the watchdog process. If a watchdog process is connected from both a `conmgr` process with a `heartbeat_interval` parameter of 3 seconds and a `conmgr` process with a `heartbeat_interval` of 5 seconds, it sends heartbeat packets every 3 seconds to the former process and every 5 seconds to the latter process. The unit is seconds. Specify a value equal to or more than 1 second. The default is 10 seconds. You must restart `conmgr` process for this parameter change to take effect.

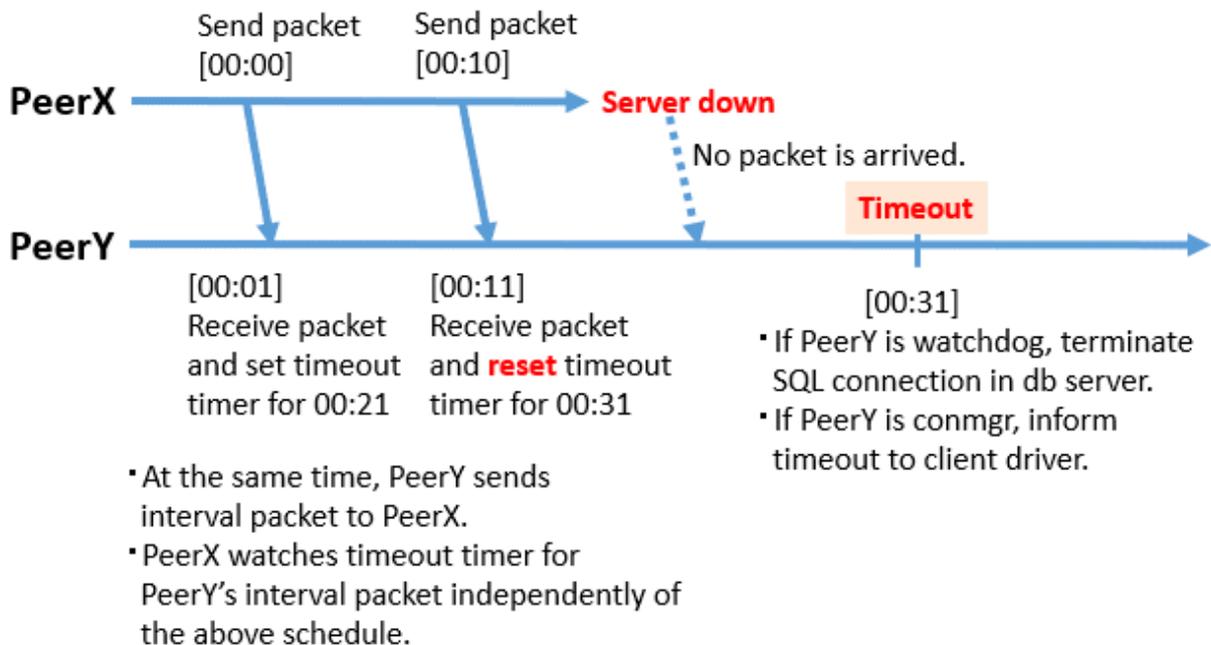
heartbeat_timeout (integer)

If a heartbeat packet for heartbeat monitoring cannot be received for more than the time specified by this parameter, an error is assumed to have occurred and the application is notified of the error.

This parameter should be decided on the basis of the heartbeat_interval parameter. No error occurs when the configuration file is loaded, but it is always considered abnormal by heartbeat monitoring if it is at least not greater than the heartbeat_interval parameter. The unit is seconds. Specify a value equal to or more than 1 second. The default is 20 seconds. You must restart the conmgr process for this parameter change to take effect.

Refer to the following figure for the relationship between the heartbeat_interval parameter and heartbeat_timeout parameter settings and the heartbeat timeout.

[Configuration: heartbeat_interval=10, heartbeat_timeout=20]



heartbeat_connect_interval (integer)

Specify the interval between attempts to establish heartbeat monitoring again after detecting an abnormality.

This parameter is useful when only the database server is started, but not the instance. In such a situation, the TCP connection fails immediately, and retries cannot be attempted without an interval. If you specify an excessively long value, you may delay noticing the start of the instance. If a connection attempt fails for a long time, it will attempt the next connection after the time specified by heartbeat_connect_interval parameter has elapsed. The unit is seconds. Specify a value equal to or more than 1 second. The default is 1 second. You must restart conmgr for this parameter change to take effect.

heartbeat_connect_timeout (integer)

Specify the connection timeout for establishing heartbeat monitoring.

The connection includes the time it takes to send the TCP connection and the first heartbeat packet to the watchdog process and receive a reply from the watchdog process. This parameter is particularly needed when the other server is down or the network is disconnected. This is because TCP connections are attempted over a long period of time, depending on the operating system configuration, and the connection takes a long time to fail. The unit is seconds. Specify a value equal to or more than 1 second. The default is 10 seconds. You must restart conmgr process for this parameter change to take effect.

log_destination (string)

Specify the destination of the message.

You can specify multiple destinations. Use commas to separate multiple entries and enclose all in single quotation marks. "stderr" and "syslog" can be specified. The default is to print only to stderr. You must restart conmgr process for this parameter change to take effect.

syslog_facility (enum)

Specify the syslog facility.

Valid only if log_destination parameter includes "syslog". LOCAL0, LOCAL1, LOCAL2, LOCAL3, LOCAL4, LOCAL5, LOCAL6, or LOCAL7 can be specified.

The default is "LOCAL0". You must restart conmgr process for this parameter change to take effect.

syslog_ident (string)

Specify the program name used to identify the output from the conmgr process.

The default is "conmgr". You must restart conmgr process for this parameter change to take effect.

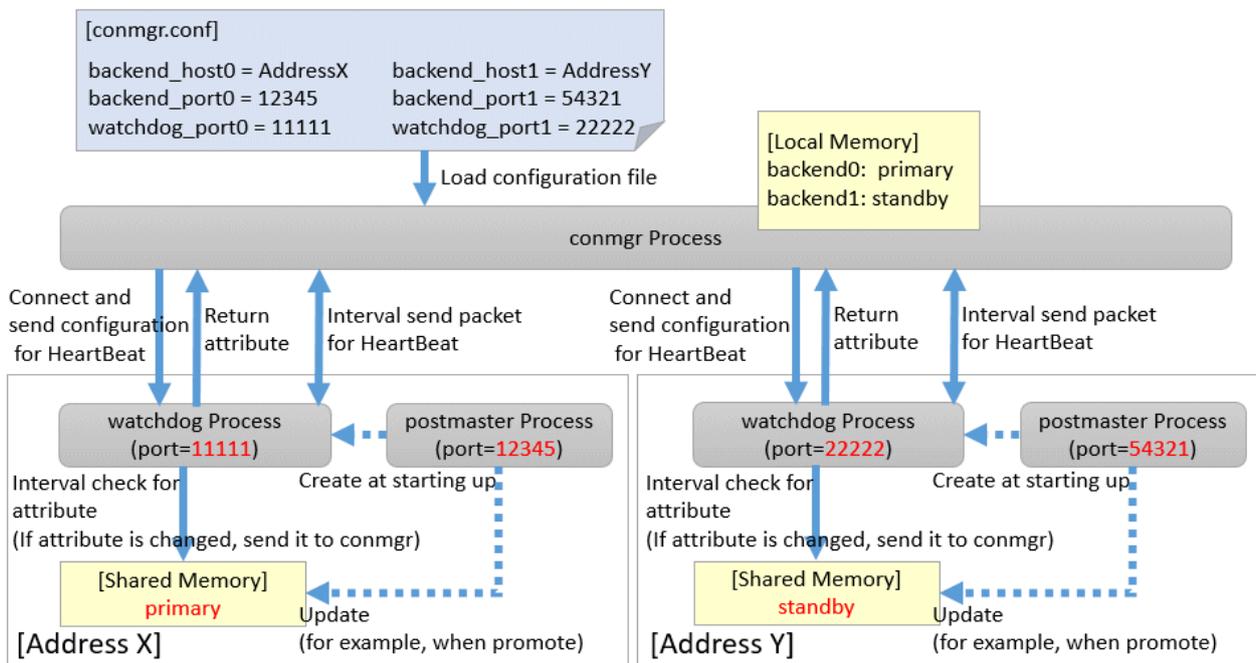
log_min_messages (enum)

Specifies the level of messages to output.

It can be DEBUG, INFO, NOTICE, WARNING, ERROR, LOG, FATAL, or PANIC. Messages below the specified level are not output. The default is "WARNING". You must restart conmgr process for this parameter change to take effect.

Overview of connections definitions

The following figure shows the relationship between the IP address or host name and the port number set in conmgr.conf and the processes.



2.2 Setting Up the Server Side

On the server side, configure settings for the watchdog process.

2.2.1 Configuring postgresql.conf

Describes the postgresql.conf parameters that must be set when using the Connection Manager.

Parameters to Set

max_connections

An existing PostgreSQL parameter. Add 2 to the value already set.

Connection to the instance is maintained from the time the instance is started to do the following:

- The watchdog process checks the state of the instance.

- The terminator process forces the client to terminate the SQL connection.

shared_preload_libraries

An existing PostgreSQL parameter. Add a watchdog.

The watchdog process and terminator process start when you add watchdog and restart the instance.

watchdog.port (integer)

Specify the port number on which the watchdog process accepts connections for heartbeat monitoring from the conmgr process.

The value must be greater than or equal to 1 and less than or equal to 65535. The default is 27545. The instance must be restarted for this parameter change to take effect.

watchdog.check_status_interval (integer)

Specify the interval between checking the attributes of a instance.

watchdog process immediately notifies the conmgr process if the attribute changes.

The unit is milliseconds. Specify a value equal to or more than 1 millisecond. The default is 1000 milliseconds. The instance must be restarted for this parameter change to take effect.

watchdog.max_hb_connections (integer)

Specify the maximum number of conmgr processes that connect to watchdog process.

The default is the value specified in max_connections of postgresql.conf.

There is no upper limit, but about 200 bytes of memory are consumed for 1 connection when PostgreSQL is started.

2.2.2 Introducing the watchdog extension

Execute the CREATE EXTENSION statement with watchdog.

Example)

```
postgres=# CREATE EXTENSION watchdog;  
CREATE EXTENSION
```

This allows you to see the [pgx_stat_watchdog view](#) for information about the watchdog process.

2.3 Removing Setup

No work is required on the client side.

On the server side, drop watchdog extension by DROP EXTENSION statement and remove it from shared_preload_libraries.

Example)

```
postgres=# DROP EXTENSION watchdog;  
DROP EXTENSION
```

Chapter 3 Using from an Application

Describes how to use the Connection Manager from an application.

3.1 Connection Method

When connecting to the instance using ConnectionManager, specify the following values in the connection parameters of the application. Application connection parameters are parameters that specify the database IP address, host name, port number, etc., which are originally specified when connecting to the database from the application. For example, when using libpq, specify "localhost" for the host parameter and specify the port number on which the conmgr process listens for the port parameter.

Connection parameters not shown here are used directly by the instance in the second stage of the connection, connecting to the instance (connecting to an instance without the Connection Manager), and the conmgr process does not check or use it.

Connection destination address

Specify "localhost". Unix domain sockets are not allowed.

It is possible to connect to a remote conmgr process, but it should not be used for other purposes expect such as testing. This is because there is no mechanism between the application and the conmgr process to detect the remote server down or the network link down, making the Connection Manager meaningless.

Port number

Specify the value specified for the port parameter in conmgr.conf.

Connection destination instance attributes

Follow the "Target server" in the application connection switch feature. Refer to "Target server" in "Connection Information for the Application Connection Switch Feature" in the "Application Development Guide" for information on the target server in the application connection switch feature.

3.2 How to Detect Instance Errors

Only special if you are using libpq's asynchronous communication method. For additional discovery methods, refer to "Errors when an Application Connection Switch Occurs and Corresponding Actions" of the for each client driver in the "Application Development Guide". If the conmgr process goes down while accessing it, or if the conmgr process tries to establish a SQL connection while it is down, the same error is returned as if the instance went down.

3.3 How to Use in libpq

libpq provides very detailed communication control. Therefore, to detect a heartbeat error through the conmgr process, you may need to modify the existing application logic.



See

Refer to "libpq - C Library" in the PostgreSQL Documentation on functions described below.

3.3.1 How to Specify Multiple Connection Destinations

The host parameter or hostaddr parameter in the connection string not only specifies the destination of one conmgr process, but can also be a mixture of destinations of other conmgr processes and postmaster. In this case, the connections are tried in the order listed.

For example, if the connection string specifies conmgr1, conmgr2 in that order, and if conmgr1 does not know the server for the attribute specified in target_session_attrs parameter, it queries conmgr2 for the destination. And, for example, if postmaster1, conmgr1 is specified, it will attempt to connect directly to the database instance pointed to by postmaster1. If this fails, query conmgr1 for a connection.

3.3.2 Using the Asynchronous Connection Method

An asynchronous connection method is to use a function like `PQconnectStart()` instead of a function like `PQconnectdb()`. `PQconnectStart()` returns without synchronizing the completion of the connection to the database. The user application must then monitor the sockets returned by `PQsocket()` to be readable or writable, for example by using the `poll()` system call, according to the values required by the return value of `PQconnectPoll()`.

With the Connection Manager, the socket returned by `PQsocket()` may change after a call to `PQconnectPoll()`, so be sure to reacquire the socket that you want to give to the `poll()` system call using `PQsocket()`. This behavior is similar to simply specifying multiple hosts in the connection string without using the Connection Manager.

3.3.3 Using an Asynchronous Communication Method

An asynchronous communication method is one in which the application returns control without waiting for a response from the database, and `PQsetnonblocking()` is used to asynchronize completion of transmission or completion of receipt of all results. Instead of using a function like `PQexec()`, use a function like `PQsendQuery()`. In this method, the user application monitors the socket that connects to the database returned by `PQsocket()`, for example, by using the `poll()` system call.

For example, if the link to the database goes down, simply monitoring the socket returned by `PQsocket` with the `poll()` system call will not detect it.

However, it is possible to detect the reception of database anomaly detection packets sent from the `conmgr` process, for example, by monitoring the reception of data on the socket (`POLLIN`) connecting to the `conmgr` process returned by `PQcmSocket()`. Once a reception is detected, the user application need not directly manipulate the packet. By calling something like `PQgetResult()` or `PQconsumeInput()` according to the existing application logic, it behaves as if the connection were disconnected. Refer to "Errors when an Application Connection Switch Occurs and Corresponding Actions" in the Application Development Guide on `SQLSTATE` returned, etc. If you are not using the Connection Manager, `PQcmSocket()` returns -1.

3.3.4 Behavior of PQhost() or PQhostaddr() or PQport()

`PQhost()`, `PQhostaddr()` or `PQport()` typically return a host parameter or `hostaddr` parameter or port parameter specified in the connection string by the user application. However, if you specify a connection destination for the `conmgr` process, the destination for the `conmgr` process you specify will be changed to the database connection destination information provided by the `conmgr` process before the connection is completed. This behavior is similar to simply specifying multiple hosts in the connection string without using the Connection Manager.

3.3.5 Behavior of PQstatus()

If you are using an asynchronous connection method, you can monitor the intermediate state of the connection to the database with `PQstatus()`. If you are using the Connection Manager, the enum value returned by `PQstatus()` is appended with the following:

```
CONNECTION_AWAITING_CMRESPONSE
/ * Waiting for a response from the conmgr process * /
```

3.3.6 PQcmSocket()

You can get a socket that leads to the `conmgr` process. It returns a value equal to or more than 0 for a valid socket, or -1 if you are not connected to the `conmgr` process.

```
int PQcmSocket(const PGconn *conn);
```

Appendix A System Views

A.1 pgx_stat_watchdog

A row in this view corresponds to conmgr process, which is connected to watchdog process. Additional columns may be added in future versions versions.

Column	Type	Description
conmgr_addr	inet	IP address of conmgr process.
conmgr_port	integer	The conmgr (ephemeral) port number that conmgr process is using to communicate with watchdog process. This is not the port number to be set in conmgr.conf.
heartbeat_interval	integer	The interval at which heartbeat packets are sent to and from this conmgr process. The unit is seconds.
heartbeat_timeout	integer	The timeout value for the heartbeat to and from this conmgr process. The unit is seconds.

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FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Glossary

Preface

Purpose of this document

This document explains FUJITSU Enterprise Postgres terminology.

Intended readers

This document is aimed at all users of FUJITSU Enterprise Postgres.

Export restrictions

Exportation/release of this document may require necessary procedures in accordance with the regulations of your resident country and/or US export control laws.

Issue date and version

Edition 2.0: February 2021

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Glossary

Arbitration command

A user command called when an abnormality is detected using operating system/server heartbeat monitoring in database multiplexing mode.

Arbitration server

A dedicated server on which the Server Assistant program is installed.

Archive log

Contains the history of updates made to the database, and is used during recovery.

Backup data storage destination

The directory that stores the backup data.

Client command

A command that is executed from the client machine and used. Also known as a client application.

Connection Manager

The replication operation to continue without knowing where the application is connected.

The Connection Manager feature improves the availability.

Data storage destination

The directory that stores the database clusters.

Database cluster

The database storage area on the database storage disk. Database clusters are a collection of databases managed by an instance.

Data masking

A feature that can change the returned data for queries generated by applications, to prevent exposing actual data.

Database multiplexing

Mechanism in which a database is made redundant on multiple servers, by transferring transaction logs (WAL) via the network to enable application jobs to be continued.

Database superuser

A user defined in the database with access privileges for all database objects.

Encoding

Indicates the character set.

Fencing

A process that isolates a database server with an unstable status from the cluster system in database multiplexing mode. This process is implemented as a fencing command.

Fencing command

A user command that implements fencing in database multiplexing mode.

Global Meta Cache

The Global Meta Cache feature cache the informations about system catalogs and table definitions information (meta cache) in shared memory. The meta cache on shared memory is called the Global Meta Cache (GMC).

Instance

A series of server processes for managing database clusters.

Instance administrator

The OS user account that owns the database cluster files and operates the database server processes.

Instance name

Indicates the instance name.

Masking policy

A method of changing data under specific conditions when it is returned for a query from an application. You can configure masking target, masking type, masking condition and masking format.

Mirrored transaction log

The log that mirrors the transaction log at the backup data storage destination.

Mirroring Controller arbitration process

A process that performs arbitration and fencing on the arbitration server.

Mirroring Controller monitoring process

A process that performs heartbeat monitoring of the Mirroring Controller process. If the Mirroring Controller process returns no response or is down, the Mirroring Controller monitoring process is restarted automatically.

Mirroring Controller process

A process that performs operating system/server and process heartbeat monitoring and disk abnormality monitoring between database servers. Additionally, the process issues arbitration requests to the arbitration server and executes arbitration commands.

Pgpool-II connection pooling

The connection pooling feature of Pgpool-II supported by FUJITSU Enterprise Postgres.

This feature maintains the connection established with the database server and reuses that connection each time a new connection with the same properties (user name, database, and protocol version) arrives. By reducing the connection overhead for the database server, throughput of the whole system is improved.

Pgpool-II failover

The automatic failover feature of Pgpool-II supported by FUJITSU Enterprise Postgres.

If any of the database servers crashes or can no longer be reached, this feature disconnects the server and continues operation on the remaining servers. The streaming replication feature of PostgreSQL is combined with Pgpool-II to achieve a high-availability system.

Pgpool-II load balancing

The load balancing feature of Pgpool-II supported by FUJITSU Enterprise Postgres.

This feature distributes reference queries to multiple database servers, improving throughput of the whole system. The database multiplexing feature or PostgreSQL streaming replication feature is combined with Pgpool-II to reduce the load on the database server.

Pgpool-II server

A server for using the failover, connection pooling, and load balancing features of Pgpool-II. It is a dedicated server that has a server program installed for using these features.

Primary server

The server that processes the main database jobs during multiplexed database operation.

Server Assistant

A feature that objectively determines the status of database servers as a third party, and if necessary, isolates affected databases if the database servers are unable to accurately ascertain their mutual statuses in database multiplexing mode, such as due to a network error between database servers, or server instability.

Server Assistant program

A program to be installed on the arbitration server.

Server command

A command used on the database server. Also known as a server application.

Standby server

A server that generates a replicated database synchronized with the primary server, and that can run as an alternative server in case the primary server fails during multiplexed database operation.

State transition command

A user command called when Mirroring Controller performs a state transition of a database server in database multiplexing mode. State transition commands include the post-switch command, pre-detach command, and post-attach command.

Transaction log

Contains the history of updates made to the database by transactions. Also known as the WAL (Write-Ahead Log).

Transaction log storage destination

The directory that stores the transaction log.

VCI (Vertical Clustered Index)

An index with columnar data structure suitable for aggregation.

WAL (Write-Ahead Log)

Has the same meaning as 'transaction log'.

WebAdmin program

A GUI-based program installed on a database server or a dedicated WebAdmin server, used to manage database instances.

WebAdmin server

By using the WebAdmin program on a different server to the database server, instances on multiple database servers can be managed from a dedicated WebAdmin server on which the WebAdmin program is installed.

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Reference Guide

Preface

Purpose of this document

This document is a command reference, and explains FUJITSU Enterprise Postgres commands and options with features expanded on from PostgreSQL.

Intended readers

This document is aimed at people who manage and operate FUJITSU Enterprise Postgres. Readers of this document are also assumed to have general knowledge of:

- PostgreSQL
- SQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Command List and Specification Format](#)

Lists commands and describes their specification format.

[Chapter 2 Client Commands](#)

Explains options not listed in "PostgreSQL Client Applications" in the PostgreSQL Documentation.

[Chapter 3 Server Commands](#)

Explains commands and options not listed in "PostgreSQL Server Applications" in the PostgreSQL Documentation.

[Chapter 4 Mirroring Controller Commands](#)

Explains the Mirroring Controller commands.

[Chapter 5 Connection Manager Commands](#)

Explains the Connection Manager commands.

How to read this document

Examples in this document are predominantly for UNIX/Linux.

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Chapter 1 Command List and Specification Format

This chapter lists commands and describes their specification format.

1.1 Command List

This chapter lists commands and options not explained in "PostgreSQL Client Applications" or in "PostgreSQL Server Applications" in the PostgreSQL Documentation.

1.1.1 Client Commands

The commands below have options not explained in "PostgreSQL Client Applications" in the PostgreSQL Documentation.

Command	Functional overview
pg_dumpall	Extract a PostgreSQL database cluster into a script file

The command below is not explained in "Client Applications" in the PostgreSQL Documentation.

Command	Functional overview
pgx_loader	Loads data from an external file into a PostgreSQL table.

1.1.2 Server Commands

The commands below have options not explained in "PostgreSQL Server Applications" in the PostgreSQL Documentation.

Command	Functional overview
pg_ctl	Initialize, start, stop, or control a PostgreSQL server
postgres	PostgreSQL database server

The commands below are not explained in "PostgreSQL Server Applications" in the PostgreSQL Documentation.

Command	Functional overview
pgx_dmpall	Backs up the data directory, tablespaces, and configuration files.
pgx_fjqssinf	Collects failure investigation data
pgx_keystore	Manages keystore
pgx_rcvall	Recovers the data directory, tablespaces, and configuration files.

1.1.3 Mirroring Controller Commands

Mirroring Controller has the following commands:

Command	Functional overview
mc_arb	Start, stop and display the status of the Mirroring Controller arbitration process.
mc_ctl	Start and stop Mirroring Controller, switch/disconnect the server, or display the server status.

1.1.4 Connection Manager Commands

Connection Manager has the following commands:

Command	Functional overview
cm_ctl	Start, stop or display the status of the conmgr process

1.2 Command Specification Format

The table below shows the command specification format.

Item	Explanation
[]	Indicates optional element.
...	Indicates that the item can be specified repeatedly.

Chapter 2 Client Commands

This chapter explains options not listed in "PostgreSQL Client Applications" in the PostgreSQL Documentation.

2.1 pg_dumpall

Name

`pg_dumpall` -- Extract a PostgreSQL database cluster into a script file

Synopsis

```
pg_dumpall [connectionOption...] [option...]
```

Options

`--no-tablespace-encryption`

Do not output commands to encrypt tablespaces. Running the generated SQL script will restore the originally encrypted data without being encrypted.

See

Refer to "pg_dumpall" in the PostgreSQL Documentation for details.

2.2 pgx_loader

Name

`pgx_loader` --Loads data from a file into a PostgreSQL table.

Overview

```
pgx_loader load -c command [options...]
```

```
pgx_loader recovery -t table
```

Description

The `pgx_loader` command loads data from an external file into PostgreSQL tables, and commits or rolls back transactions prepared during data load.

In load mode, data is loaded at high speed by executing the COPY FROM command specified in *command* at a certain degree of parallelism. If load is completed successfully, the message below is output to the standard output.

```
LOAD count
Note: count is the number of rows loaded.
```

In recovery mode, commit or rollback of transactions prepared during data load is performed.

Options

`-a`

`--echo-sql`

Display the executed command in the standard output.

`-c command`

`--copy-command=command`

Specify the COPY FROM command to be executed. If STDIN is specified for the FROM clause, data will be loaded from the standard input. In this case, SQL superuser privileges (or having one of the roles `pg_read_server_files` or `pg_execute_server_program`) are not

required, because local user access privileges will be used for external files and external programs, instead of database server access privileges.

"binary" cannot be specified for the FORMAT option of the COPY FROM command specified in this option. Therefore, input files in binary format cannot be specified.

The FREEZE option cannot be specified for the COPY FROM command specified in this option.



See

.....
Refer to "COPY" in the PostgreSQL Documentation for information on the COPY FROM command.
.....

-j *number-of-jobs*

--jobs=*number-of-jobs*

Specify the number of background workers (parallel workers) that the COPY COMMAND should use to simultaneously perform data conversion, table creation, and index creation. This option can dramatically reduce the time for loading a large amount of data on instances that runs on multiple processor machines.

The optimal value depends on the server, client, and network configurations. The number of CPU cores and disk configuration also affect the optimal value. The number of CPU cores of the server is recommended as the initial value to try. Naturally, if a value that is too large is used, performance degradation will occur due to thrashing and context switching.

Specify a value from 2 to 128. The default is 2.

-t *table*

--table=*table*

Complete the prepared transactions only for the specified table.

-?

--help

Show how to use `pgx_loader` command line arguments, and exit.

The command line options below control the database connection parameters.

-d *connstr*

--dbname=*connstr*

Specify the database name to connect to.

If this option is not specified, the PGDATABASE environment variable will be used. If the environment variable is not set, your operating-system user name will be used.

-h *host*

--host=*host*

Specify the host name of the machine the database server runs on. If the specified value starts with a slash, it will be used as the directory for a Unix domain socket.

If this option is not specified, the PGHOST environment variable will be used. If the environment variable is not set, it will be considered a Unix domain socket connection.

-p *port*

--port=*port*

Specify the TCP port to be used by the server to monitor the connection, or extension of the local Unix domain socket file.

If this option is not specified, the PGPORT environment variable will be use. If the environment variables is not set, 27500 will be used.

-U *username*

--username=*username*

User name for connection to the database.

`-w`
`--no-password`

Never prompt for the password. If the server requires password authentication but other means (such as a `.pgpass` file) are not available, the connection attempt will fail. This option can be useful in batch jobs, scripts, and so on, where no user is present to enter a password.

`-W`
`--password`

Force `pgx_loader` to prompt for the password before connecting to the database. This option is never essential, since `pgx_loader` will automatically prompt for the password if the server demands password authentication. However, `pgx_loader` will waste a connection attempt finding out if the server requires a password. In some cases it is worth specifying this option to avoid the extra connection attempt.

Diagnostics

load mode

0: Normal exit

Other than 0: Abnormal exit

recovery mode

0: There are no prepared transactions that must be completed

3: A prepared transaction was committed

4: A prepared transaction was rolled back

Other than the above: Abnormal exit



The order of the table rows loaded by `pgx_loader` may not match the order of the file lines. This is because the file lines will have been inserted into the table in parallel, by multiple parallel workers.

Example

The example below loads the file `/path/to/data.csv` (2000 records) into table `tbl` using a degree of parallelism of 3.

```
$ pgx_loader load -j 3 -c "COPY tbl FROM '/path/to/data.csv' WITH CSV"  
LOAD 2000
```

The example below reads the file `/path/to/data.csv` (2000 records) from the standard input and loads into table `tbl` using a degree of parallelism of 3.

```
$ pgx_loader load -j 3 -c "COPY tbl FROM STDIN WITH CSV" < /path/to/data.csv  
LOAD 2000
```

The example below completes the transactions prepared for table `tbl`.

```
$ pgx_loader recovery -t tbl
```

Chapter 3 Server Commands

This chapter explains commands and options not listed in "PostgreSQL Server Applications" in the PostgreSQL Documentation.

3.1 pg_ctl

Name

pg_ctl -- Initialize, start, stop, or control a PostgreSQL server

Synopsis

```
pg_ctl start [-D datadir] [-l filename] [-W] [-t seconds] [-s]
           [-o options] [-p path] [-c] [--user-pin | --keystore-passphrase]
```

```
pg_ctl restart [-D datadir] [-m s[mart] | f[ast] | i[m]mediate ]
              [-W] [-t seconds] [-s] [-o options] [-c]
              [--user-pin | --keystore-passphrase]
```

Options

Hardware-based key store options

--user-pin

Prompts for a user pin to open a keystore.

File-based key store options

--keystore-passphrase

Prompt for the passphrase to open the keystore.

See

Refer to "pg_ctl" in the PostgreSQL Documentation for details.

3.2 pgx_dmpall

Name

pgx_dmpall - Backs up the data directory, tablespaces, and configuration files.

Synopsis

```
pgx_dmpall [option...]
```

Description

The `pgx_dmpall` command backs up the data directory, tablespaces, and configuration files. The backup data is stored in the directory specified by `backup_destination` parameter of `postgresql.conf`. The `pgx_dmpall` command also deletes archived Write Ahead Logs (WAL) that are no longer necessary for recovery when the backup completes successfully.

Options

-c

This option only backs up configuration files. The configuration files are as follows:

- `postgresql.conf` (`postgresql.conf`)
- File for host-based authentication (`pg_hba.conf`)

- Configuration file for ident authentication (pg_ident.conf)

If an external reference, such as 'include' in postgresql.conf, is set, the reference destination files are also backed up.

-C fast|spread

--checkpoint=fast|spread

Sets checkpoint mode to fast or spread (default).

If fast is specified, the checkpoint processing at the start of backup becomes quick, but the impact on performance of running applications gets larger due to intense I/O. In spread mode, the impact on applications is smaller but the backup takes longer, because the checkpoint is performed slowly.

-D *dataDir*

Specify the data directory. If this option is omitted, the value of the environment variable PGDATA is used.

-f *configFile*

Specify the postgresql.conf configuration file. This option is set if the data directory and the configuration file set in the 'data_directory' parameter of the postgresql.conf file are running in separate directories.

-P *tablespacesListFile*

--tablespaces-list-file=*tablespacesListFile*

Specify the full path of the file containing the names of the tablespaces to be backed up using the copy command, using less than 1024 bytes.

The file format is described below:

tablespaceName<newline>

tablespaceName<newline>

...

Tablespaces not listed in the specified file are backed up to the backup storage directory. If this option is not specified, all tablespaces are backed up using the copy command.

This option can be specified if the -Y option has been specified, and it is used to limit the tablespaces backed up using the copy command.

-U *username*

--username=*username*

Specify the user name of the database superuser. This defaults to the name of the effective user running pgx_dmpall.

-Y *copyCommandFile*

--copy-command=*copyCommandFile*

Specify the full path of the file of the copy command for backup, using less than 1024 bytes. This option cannot be specified together with the -c option.

-w

--no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W

--password

Force pgx_dmpall to prompt for a password before connecting to a database.

This option is never essential, since pgx_dmpall will automatically prompt for a password if the server demands password authentication. However, pgx_dmpall will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing -W to avoid the extra connection attempt.

-z

Enables zlib compression of backup files with the default compression level.

This option cannot be specified together with the -c option.

-Z level

--compress=level

Enables compression by zlib for backup files by specifying a compression level. (0 through 9, 0 being no compression and 9 being highest compression)

This option cannot be specified together with the `-c` option.

--maintenance-db=*dbname*

Specifies the name of the database to connect to. If not specified, the postgres database will be used; if that does not exist, template1 will be used.

Any database can be specified as long as it can be connected to.

--exclude-copy-cluster

Excludes a database cluster from backup via the copy command. This option can be specified if the `-Y` option has been specified. If this option is not specified, the database cluster will be backed up using the copy command.

Environment

PGDATA

Specify the data directory. You can overwrite using the `-D` option.

Diagnostics

0: Normal end

Other than 0: Abnormal end

Notes

This command can only be executed when the database server is running.

Execute this command as a PostgreSQL user account.

Do not update or delete files in the backup storage directory. Otherwise, you may not be able to recover the database.

Do not store other files in the backup storage directory.

This command uses one database connection. To establish a connection, this command uses the UNIX domain socket on the operating systems. Therefore, permit these connections in `pg_hba.conf`.

This command cannot be executed on the standby server.

Example

In the following example, the data directory, tablespaces, and configuration files are backed up. At this time, stored WALs are no longer necessary because the backups are destroyed.

```
$ pgx_dmpall
```

Related item

`pgx_rcvall`

3.3 pgx_fjqssinf

Name

`pgx_fjqssinf` - Collects failure investigation data.

Synopsis

```
pgx_fjqssinf [-c 1|2|3] [-w directory]
```

Description

When the cause of a trouble that occurred during the construction or operation of the environment is not identified, information for the initial investigation is collected. The collected investigation information is created in the destination directory as `pgx_fjqssinf_YYYYMMDD_HHMMSS/`.

Options

`-c 1|2|3`

Specifies the incident of the trouble that occurred. 1 is specified for process error, 2 for process result error, and 3 for no response. This option must be specified for the database server to gather information. There is no need to specify this option when collecting information with the arbitration server.

`-w directory`

Specifies the destination directory for the collected data. The default is `/tmp`.

Environment (When the information is collected by a database server)

`PGDATA`

Specifies the data directory.

`PGDATABASE`

Specifies the name of the database to connect to. Any database that can be connected to may be specified.

`PGPORT`

Specifies the port number of the instance. This should not be specified if the default port number (27500) has not been changed.

`PGUSER`

Specifies the user name of the database superuser. The database superuser must be configured to allow client authentication.

`MCCONTROLDIR`

Specifies the Mirroring Controller management directory. This should only be specified when database multiplexing operation is set up.

Environment (When information is collected by an arbitration server)

`ARBCONTROLDIR`

Specifies the management directory for the Mirroring Controller arbitration process.

`ARBUSER`

Specifies the OS user that initialized the Mirroring Controller arbitration process.

Diagnostics

0: Normal end

Other than 0: Abnormal end

Notes

This command must be executed as a superuser (root) account.

Example

Below is an example of collecting information for initial investigation in the event of a process failure.

```
$ /opt/fsepv12server64/bin/pgx_fjqssinf -i 1
```

Below is an example of collecting information for an initial investigation by an arbitration server.

```
$ /opt/fsepv12assistant/bin/pgx_fjqssinf
```

3.4 pgx_keystore

Name

pgx_keystore -- Manages keystore

Synopsis

```
pgx_keystore [option...] keystore_location
```

Description

pgx_keystore enables auto-open of a keystore.

Options

-a

--enable-auto-open

Enables auto-open of a keystore. This allows the keystore to open automatically without entering the passphrase when the database server starts.

When auto-open is enabled, an obfuscated copy keystore.aks is created in the same directory where the keystore file keystore.ks is stored. To disable auto-open, delete keystore.aks.

-P *passphrase*

--passphrase=*passphrase*

Specify the passphrase to open the keystore. If this option is omitted, the prompt to enter the passphrase is displayed.

keystore_location

Specify the absolute or relative path of the keystore file.

Diagnostics

0: Normal exit

Other than 0: Abnormal exit

Notes

This command can be executed whether the database server is running or stopped. It does not connect to the database server.

Example

Enables auto-open of a keystore.

```
$ pgx_keystore -a /key/store/location/keystore.ks
```

3.5 pgx_rcvall

Name

pgx_rcvall - Recovers the data directory, tablespaces, and configuration files.

Synopsis

```
pgx_rcvall [option...]
```

Description

The `pgx_rcvall` command recovers the data directory, tablespaces, and configuration files using the data that was backed up with `pgx_dmpall` command and archived Write-Ahead-Log (WAL). If none of the options that indicate the recovery point is specified, all archived WAL are applied and the data will be recovered to the latest point.

Options

-B *backupdir*

Specify the backup storage directory. If the data directory is damaged, this option cannot be omitted.

-D *datadir*

Specify the data directory. If this option is omitted, the value of the environment variable `PGDATA` is used.

-e *targetTime*

Specify this option to recover the data as of the specified date and time.

targetTime

Specify the time at which the data is recovered. The format is as follows:

```
"YYYY-MM-DD HH:MM:SS"
```

-l

This option displays a list of the backup data information in the backup storage directory that was obtained using the `pgx_dmpall` command. If the `pgx_dmpall` command was executed using the copy command (`-Y` option) for backup, the resources backed up using the copy command will also be listed. This cannot be specified together with `-p`, `-e` or `-n` option.

-n *restorePoint*

Specify this option to recover the data to the specified restore point. Restore points are created with SQL function `pg_create_restore_point`. If multiple restore points with the same names were created, the first one after the backup was taken is used for recovery. If the specified restore point does not exist, all archived WAL are applied. This cannot be specified together with `-e` or `-p` option.

-p

Specify this option to recover the data as of the time when the last backup completed. This cannot be specified together with `-e` or `-n` option.

-s *connectionString*

Construct a standby server from the backup created by `pgx_dmpall`. Specify as an argument a connection string for connecting to the primary server. This is the same as `primary_conninfo` parameter in `recovery.conf`. This option can only be specified together with `-D` and `-B`.

-x

Specify this option if you do not want to include transactions committed at the time specified in the `-e` option as part of the recovery.

-Y *copyCommandFile*

--copy-command=*copyCommandFile*

Specify the full path of the file of the copy command for recovery, using less than 1024 bytes. This option cannot be specified together with the `-l` option.

--user-pin

Prompts for a user pin to open the keystore. This option can only be specified on Hardware-based key store.

--keystore-passphrase

Prompt for the passphrase to open the keystore. This option can only be specified on File-based key store.

--view-results-of-copying

Output the backup information file that was written by the copy command executed via the `pgx_dmpall` command. This option cannot be specified together with the `-l`, `-p`, `-e`, `-n`, or `-Y` option.

Environment

PGDATA

Specify the data directory. You can overwrite using the `-D` option.

PGPORT

Specify the port number for connecting to the database.

PGUSER

Specify the user name of the database superuser. This defaults to the name of the effective user running `pgx_dmpall`.

Diagnosis

0: Normal exit

Other than 0: Abnormal exit

Backup data information

Date

Date the backup data was created using the `pgx_dmpall` command.

Dir

This is the name of the directory in the backup storage directory that is used to store the backup data.

Directory naming format: Time format (YYYY-MM-DD_HH-MM-SS)

Status

This is the status of the `pgx_dmpall` command backup data.

COMPLETE: Complete

INCOMPLETE: Incomplete

Compression

This is the compression status of the `pgx_dmpall` command backup data.

USED: compressed

This information is not displayed if it is not compressed.

Resources backed up by the copy command

List of resources that were backed up by the copy command executed via the `pgx_dmpall` command.

If there are resources that were backed up by the copy command, then database clusters ('pg_data') or tablespace names will be listed, delimited by header and halfwidth comma.

Notes

This command can only be executed when the database server is stopped, except when it is executed with `-l` option.

Execute this command as a PostgreSQL user account.

Use backup data that was taken from the recovery target data directory.

Before executing this command, disconnect all application database connections. Additionally, do not connect to the database during recovery.

The configuration files are restored from those files that were taken by the last `pgx_dmpall` (including `-c` option).

This command connects to the database to determine whether the recovery has completed. So ensure that you set the port number with `PGPORT` environment variable in the environment where multiple instances exist.

Match the OS timezone setting when running `pgx_dmpall/pgx_rcvall` to the timezone specified by `timezone` parameter in `postgresql.conf`.

Otherwise, data might be recovered to an unexpected time when `-e` or `-p` is specified.

If you recover to a past point, a new timeline (history of database updates) begins at that point. That recovery point is the latest point in the new timeline when the recovery is completed. If you subsequently recover to the latest point, the database updates in the new timeline will be replayed.

Valid restore points are the ones that were created in the timeline where the backup had been taken. That means that if you recover to a past point, those restore points created thereafter are unavailable. Therefore, take a backup when you have restored the past data desired.

If the `pgx_dmpall` command was executed using the copy command (`-Y` option) for backup, it is necessary to execute this command using the copy command (`-Y` option) for recovery. However, because the list of resources (database cluster or tablespace) that were backed up using the copy command is recorded in the backup directory, there is no need to specify the target resources when executing this command. The `-I` option can be used to check the target resources for which a backup is retrieved using the copy command.

Example

In the following example, the data directory, tablespaces, and configuration files are recovered.

```
$ pgx_rcvall -B /home/pgsql/Backupdir
```

In the following example, the data directory and tablespaces are recovered at 10:00:00 on 01-05-2017. The configuration files are recovered at the point at which the last of the data is obtained.

```
$ pgx_rcvall -B /home/pgsql/Backupdir -e "2017-05-01 10:00:00"
```

In the following example, the data directory and tablespaces are recovered up to the time of restore point "before_match_20170510_1". The configuration files are restored from the latest backup.

```
$ pgx_rcvall -B /home/pgsql/Backupdir -n before_match_20170510_1
```

In the following example, the obtained backup data information in the backup storage directory is displayed in a list.

```
$ pgx_rcvall -l
```

Related item

`pgx_dmpall`

3.6 postgres

Name

`postgres` -- PostgreSQL database server

Synopsis

```
postgres [option...]
```

Options

`-K`

Prompt for the passphrase to open the keystore. This option works in single-user mode only, so you must also specify the `--single` option, as shown below:

```
postgres --single -K
```

See

Refer to "postgres" in the PostgreSQL Documentation for details.

Chapter 4 Mirroring Controller Commands

This chapter explains the Mirroring Controller commands.

4.1 mc_arb

Name

mc_arb - Start, stop, and display the status of the Mirroring Controller arbitration process

Overview

```
mc_arb start [-M mcdir] [-w| -W]
```

```
mc_arb stop [-M mcdir] [-e]
```

```
mc_arb status [-M mcdir]
```

Description

mc_arb starts, stops, and displays the status of the Mirroring Controller arbitration process.

The start mode starts the Mirroring Controller arbitration process.

The stop mode stops the Mirroring Controller arbitration process.

The status mode displays the connection status of the Mirroring Controller arbitration process with the Mirroring Controller processes of the primary server and standby server.

If the Mirroring Controller arbitration process has not been started on the server executing the command, stop mode and status mode will terminate with an error.

Additionally, if Mirroring Controller is forcibly stopped on the database server, it may take a few moments until the status mode displays the status of the server connection as offline.

This command can be executed by any user.

Options

-e

Specify this option to forcibly stop the Mirroring Controller arbitration process on the active server.

Specify this option to stop the Mirroring Controller arbitration process but keep Mirroring Controller running (to stop both, first stop Mirroring Controller of the database server, and then the Mirroring Controller arbitration process). This option can also be specified to halt the arbitration process (by stopping the Mirroring Controller arbitration process) when the fencing command called by the arbitration process becomes unresponsive.

-M *mcdir*

Specify the Mirroring Controller arbitration process management directory.

ASCII characters can be specified in the directory path.

If this option is omitted, the value of the environment variable ARBCTRLDIR is used.

-w

Waits for operations to finish.

This option is the default of start mode.

-W

Does not wait for operations to finish.

Environment

ARBCONTROLDIR

Specify the Mirroring Controller arbitration process management directory.

ASCII characters can be specified in the directory path.

You can specify the `-M` option to override this value.

Diagnostics

0: Normal end

Other than 0: Abnormal end

Notes

If the Mirroring Controller arbitration process is forcibly stopped or communication between the command and the Mirroring Controller arbitration process is interrupted while the Mirroring Controller arbitration process is being stopped, a message that the command is being executed may be output and stopping may terminate in error, even though no other instances of the `mc_arb` command are being executed. To solve this issue, ensure that other instances of the `mc_arb` command are not being executed before forcibly stopping the Mirroring Controller arbitration process.

Example

Start the Mirroring Controller arbitration process.

```
$ mc_arb start -M /mcarb_dir/arbiter1
```

Display details of `mc_arb` status

server_id	host	status
(1)	(2)	(3)

(1) Server identifier

(2) Host name or IP address

(3) Server connection status

online : Connected

offline : Disconnected

4.2 mc_ctl

Name

`mc_ctl` - Start and stop Mirroring Controller, switch/disconnect the server, or display the server status.

Overview

```
mc_ctl start [-M mcdir] [-w| -W] [-f| -F] [--mc-only] [--async-connect-arbiter] [--local-server server_id]
```

```
mc_ctl stop [-M mcdir] [[-a] [--mc-only]| [-e][--local-server server_id]]
```

```
mc_ctl status [-M mcdir] [--arbiter] [--local-server server_id]
```

```
mc_ctl switch [-M mcdir] [--force [--no-fencing ]] [--local-server server_id]
```

```
mc_ctl detach [-M mcdir] [--no-fencing] [--local-server server_id]
```

```
mc_ctl enable-failover [-M mcdir] [--local-server server_id]
```

```
mc_ctl disable-failover [-M mcdir] [--local-server server_id]
```

Description

`mc_ctl` starts and stops Mirroring Controller, switches/disconnects the server, or displays the server status.

The start mode starts Mirroring Controller. If the `--mc-only` option is omitted, the command starts a database instance.

The stop mode stops Mirroring Controller. If the `--mc-only` option is omitted, the database instance is stopped. If `--mc-only` option is not specified, database instance is also stopped. When executes on standby server without `--mc-only`, standby server will be detached from primary server.

The status mode displays the status of the servers, database instance processes, and disks monitored by Mirroring Controller. Additionally, if the `--arbiter` option is specified, Mirroring Controller arbitration process connection status is displayed.

The switch mode switches the primary server. When the server is switched, the database instance on the primary server stops, and the database instance on the standby server is upgraded to primary server and begins degrading operation. This mode can be executed on the primary server and standby server in an environment where the Mirroring Controller process can communicate with the Mirroring Controller process on the other server.

The detach mode forcibly disconnects the standby server. This mode is used to forcibly disconnect the other server when stopping of Mirroring Controller cannot be performed using stop mode (which requires login to the standby server). It can only be executed on the primary server.

The enable-failover mode enables automatic switching and disconnection.

The disable-failover mode disables automatic switching and disconnection.

If Mirroring Controller has not been started on the server that executes the command, commands for any mode other than the start mode, and status mode.

Execute this command as an instance administrator.

Until you start Mirroring Controller of standby server after starting Mirroring Controller of the primary server, operation can be started with only the primary server. Standby server is incorporated when you start the Mirroring Controller of standby server, and you should be able to operate in the multiplexing configuration.

Options

`-a`

Specify this option to stop Mirroring Controller on all servers.

`-e`

Specify this option to forcibly stop Mirroring Controller on the active server.

`-f`

Specify this option to enable automatic switching and disconnection of Mirroring Controller immediately after startup.

This option is the default of start mode.

`-F`

Specify this option to disable automatic switching and disconnection immediately after startup of Mirroring Controller.

`--async-connect-arbiter`

Specify this option to connect the Mirroring Controller start process asynchronously to the Mirroring Controller arbitration process. This option can be specified to forcibly start Mirroring Controller if the Mirroring Controller arbitration process is not started.

Specify this option if using the Mirroring Controller arbitration server.

`--arbiter`

Specify this option to display the connection status of the Mirroring Controller arbitration process. This option can be specified if using status mode.

Specify this option if using the Mirroring Controller arbitration server.

--local-server *server_id*

If you run a simulation build of the primary and standby servers in a single server (for system testing, for example), specify this option to identify the server to be operated.

For *server_id*, specify the server identifier specified in the network.conf file. ASCII characters other than single-byte space can be specified in the server identifier. The operations will be executed as if the user has logged in to *server_id*.

--mc-only

Specify this option to start and stop only Mirroring Controller processes. At the start mode, this option can be specified only while the database instance is running. If this option is omitted, the database instance is simultaneously started and stopped.

-M *mcdir*

Specify the Mirroring Controller management directory.

ASCII characters can be specified in the directory path.

If this option is omitted, the value of the environment variable MCONTROLDIR is used.

--force

Switching with this option specified can only be specified on the standby server. This option is used to perform switching forcibly after performing fencing on the primary server if communication with the Mirroring Controller process of the other server is not possible (due to a network issue between database servers or unresponsive server, for example), thus preventing normal switching. However, if the --no-fencing option is specified, fencing will not be performed on the primary server.

--no-fencing

When switching or disconnection is executed with the --force option specified, fencing of the server to be degraded is circumvented. Therefore, it is necessary for the user to isolate the server to be degraded from the cluster system in advance.

-w

Waits for operations to finish.

This option is the default of start mode.

-W

Does not wait for operations to finish.

Environment variable

MCONTROLDIR

Specifies the Mirroring Controller management directory.

ASCII characters can be specified in the directory path.

You can specify the -M option to override this value.

Diagnostics

0: Normal end

Other: Abnormal end

Notes

The message under execution might be output though the mc_ctl command is not being executed and, besides, it terminate abnormally when the server is downed while processing execution of this command, an automatic switch, and an automatic separation, and the communication between a primary server and the standby server is cut off. Besides, restart Mirroring Controller to solve this problem after confirming that the mc_ctl command is not in progress. Afterwards, execute a necessary operation.

If a time-out error occurs when the mc_ctl command is in progress, the messages may be different from the processes. Take the actions described in the "Action" section of the message.

Automatic switching and disconnection by the enable-failover mode, the disable-failover mode, and the start mode can be enabled/disabled only while Mirroring Controller is running. Therefore, if you want to enable/disable automatic switching and disconnection on starting, specify the -f option or -F option each time you start Mirroring Controller.

In case of postgresql.conf has any incorrect parameter when this command is executed, this command may be abnormally terminated. If this is the case, re-execute it again after correct the parameter in postgresql.conf.

If the arbitration server of Mirroring Controller is used, connection with the arbitration server will be performed on startup even if startup using start mode is executed with the -F option specified, or if executed with --local-server specified.

For operation using an arbitration server, the amount of time spent attempting to connect with the arbitration server is calculated, so the Mirroring Controller startup time may take longer.

Example

To start Mirroring Controller:

```
$ mc_ctl start -M /mcdir/inst1
```

Display details of mc_ctl status

mirroring status					

(1)					
server_id	host_role	host	host_status	db_proc_status	disk_status
(2)	(3)	(4)	(5)	(6)	(7)

```
(1) Multiplexing status
    switchable      : Switchable
    switching       : Switching
    switched        : Switched (displayed when switching has finished and the degrading operations
status has been enabled)
    not-switchable  : Not switchable (displayed when a server is disconnected and switching is not
possible)
    unknown         : Unknown (*1)
    failover-disabled : Failover is disabled
(2) Server identifier
(3) Server role
    primary : Primary
    standby : Standby
    none(inactivated primary): No role
                                (primary is stopped or being defined as primary)
    none(inactivated standby): No role
                                (standby is stopped or being defined as primary)
(4) Host name or IP address
(5) Live/dead state of the server
    normal : Normal operation
    abnormal : Abnormal
    unknown : Unknown (*1)
(6) DBMS process status
    normal : Normal
    abnormal (abnormal process name (*2)) : Abnormal
    unknown : Unknown (*1)
(7) Disk status
    normal : Normal
    abnormal (abnormal disk type (*3)) : Abnormal
    unknown : Unknown (*1)
```

*1: Displayed when Mirroring Controller is stop state, the management network is abnormal, or Mirroring Controller has failed or is unresponsive.

*2: The names of the DBMS processes in which the abnormality was detected are output. The name has the following meaning: However, if multiple DBMS process issues are detected, only the DBMS for which the first issue was detected is displayed.

-postmaster: Process (postmaster) that accepts application connections
 -wal_sender or wal_receiver: Process (WAL sender or WAL receiver) that sends and receives transaction logs
 *3: The types of disks where the abnormality was detected are output separated by a comma. The type has the following meaning:
 -data: Data storage disk
 -tran_log: Transaction log storage disk
 -tablespace: Tablespace storage disk

Display details of mc_ctl status (with the --arbiter option specified)

arbiter_id	host	status
(1)	(2)	(3)

- (1) Arbitration server identifier
- (2) Host name or IP address
- (3) Mirroring Controller arbitration process connection status
 - online : Connected
 - offline : Disconnected (*1)

*1: When Mirroring Controller is stopped, connections to the Mirroring Controller arbitration process cannot be established, so it will be displayed as "offline".

Chapter 5 Connection Manager Commands

This chapter explains the Connection Manager commands.

5.1 cm_ctl

Name

cm_ctl - Start, stop or display the status of the conmgr process

Synopsis

```
cm_ctl start [-D directory] [-W] [--complete] [-t seconds]
```

```
cm_ctl stop [-D directory] [-W] [-m {smart | fast | immediate}] [-t seconds]
```

```
cm_ctl status [-D directory] [-t seconds] [-i {all | instance | application}]
```

Description

The start mode starts the conmgr process. The command returns at least after the heartbeat monitoring connection is completed with the primary server's instance.

When --complete is specified, wait until all instances configured in conmgr.conf have completed their heartbeat monitoring connections. You can set a timeout for these waits. The default of timeout is 60 seconds. Can be changed using the -t option. If it times out, it simply gives up waiting and the conmgr process remains up.

The stop mode sends a signal to the conmgr process to shut down and wait until the process disappears.

The default of wait time is 60 seconds. Can be changed using the -t option. If it times out, it simply gives up waiting. There are three shutdown methods, "smart", "fast", and "immediate", specify with the -m option. The "smart" waits until all applications using the conmgr process run out of SQL connections before shutting down. The "fast" forces all applications using the conmgr process to disconnect from the conmgr process before shutting it down. As a result, the SQL connection for the application receives an error. The "immediate" terminates the conmgr process immediately. If nothing is specified, it stops in smart mode.

The status mode, if the conmgr process exists, queries the conmgr process for instance and application information known to the conmgr process, and display them to standard output along with the state of conmgr itself.

The -i option allows you to specify what information to query. The "instance" queries information about the instance; The "application" queries information about the application; The "all" queries information about both. conmgr's own information is always displayed. The default time to wait for a query to return is 60 seconds. Can be changed using the -t option.

Options

--complete

Wait until all instances configured in conmgr.conf have completed their heartbeat monitoring connections. If the When used with the -W option, the -W option takes precedence.

-D

-- directory=*directory*

Specify the directory where conmgr.conf is located. If omitted, it refers to the directory specified by the environment variable CMDATA. You cannot omit both.

-i {all | instance | application}

Specify the information to display the status.

-m

--mode={smart | fast | immediate}

Specify the mode of shutdown. The default is smart.

-t *seconds*

--timeout=*seconds*

Specify how long to wait for the operation to complete. The unit is seconds. The default is 60 seconds.

-W

--no-wait

In start mode, cm_ctl command returns immediately after forking conmgr process. In stop mode, the cm_ctl command returns without waiting for the process to disappear.

Diagnostics

start mode or stop mode

0: Normal end

2: Timeout occurred

3: Unable to access the specified directory

Other than the above: None of the above

status mode

0: Normal end

2: Timeout occurred

3: Unable to access the specified directory

4: conmgr process does not exist

Other than the above: None of the above

Privileges

The conmgr process cannot be started by the administrator(e.g. superuser(root) on Linux).

Example

Display details of start mode

The block of information that can be specified with the -i option is used as a unit. There is one blank line between the blocks and no blank lines within the blocks. It includes one or more spaces between columns and between data.

```
$ cm_ctl status -i all
conmgr_status:
status pid
(1)      (2)
ready  3456

instance_information:
addr      port  database_attr
(3)      (4)  (5)
192.0.2.100 27500 standby
192.0.2.110 27500 primary
192.0.2.120 27500 standby
192.0.2.130 27500 unknown

application_infomation:
addr      port  pid  connected_time
(6)      (7)  (8)  (9)
127.0.0.1 12345 5678 2020-01-15 02:03:04
```

- (1) Status of the conmgr process
 - starting : The process is starting its startup sequence but is not ready to accept connections from clients.
 - ready : Ready to accept connections from clients.
 - stopping : It has received an end instruction and is starting the stop sequence.
 - inactive : The conmgr process does not exist.
- (2) PID of the conmgr process
- (3) IP address of the instance
- (4) Port number the postmaster listens on
- (5) Status of the instance (primary | standby | unknown)
- (6) Connection source IP address for conmgr process
- (7) Connection source (ephemeral) port number for conmgr process
- (8) PID of the connection source
- (9) Date and time conmgr process connection
 - The ISO 8601 compliant date is followed by a blank, followed by the ISO 8601 compliant second precision time.
 - This representation is a PostgreSQL string representation of type timestamp.

FUJITSU Enterprise Postgres 12 SP1 on IBM LinuxONE™



Message Guide

Preface

Purpose of this document

This document explains the messages output by FUJITSU Enterprise Postgres.

Intended readers

This document is intended for the following readers:

- Persons using FUJITSU Enterprise Postgres

Prerequisites

Knowledge of the following topics is required to read this document:

- A general understanding of computers
- Jobs
- PostgreSQL
- Linux

Structure of this document

This document is structured as follows:

[Chapter 1 Overview of Messages](#)

This chapter explains the format in which messages are output.

[Chapter 2 FUJITSU Enterprise Postgres Messages](#)

This chapter explains messages output by FUJITSU Enterprise Postgres.

[Chapter 3 Mirroring Controller Messages](#)

This chapter explains messages output by Mirroring Controller.

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Chapter 1 Overview of Messages

This chapter explains the format of messages.

1.1 Message Format

This section explains the format of messages.

- Output format
- Components

1.1.1 Output Format

The message output format is as follows:

Format of messages returned to an application

```
msgType: msgText (msgNumber)
```

Format of messages output to the server message log

```
SQLSTATE: date [processID]: [internalCode-1] user = userName,db = dbName,remote =  
clientIpAddress(portNumber) app = appName msgType: msgText (msgNumber)
```



See

Refer to "PostgreSQL Error Codes" under "Appendixes" in the PostgreSQL Documentation for information on SQLSTATE.



Note

- Notes on monitoring messages output to the server message log

Use SQLSTATE to monitor server messages, noting the following:

- Configuration method

Refer to "Error Log Settings" under "Setup" in the Installation and Setup Guide for Server for details.

- Notes

- The user name, client IP address (port number), and application name may sometimes be blank.
- Multiple message numbers may be output.

- Notes on monitoring messages returned to an application

You can output SQLSTATE to a message to be returned to an application. The following explains how to configure the settings for outputting SQLSTATE and gives cautions to be observed when doing so.

- How to configure the settings:

- In the SET statement, set the log_error_verbosity parameter to VERBOSE.

- For an application that uses the C language library, use the PQsetErrorVerbosity function to set message redundancy to PQERRORS_VERBOSE.

- Cautions

- SQLSTATE is output only to messages to be returned to applications that use the C language library.

- In some cases, *userName*, *clientIpAddress(portNumber)*, and *applicationName* may be blank.
- Multiple message numbers may be output.
- If the email address "pgsql-bugs@postgresql.org" is output to the message and the cause of the error cannot be identified, contact Fujitsu technical support.

 **Example**

Message output to the server message log

```
3D000: 2017-07-10 19:41:05 JST [13899]: [1-1] user = fepuser,db = fep,remote = 127.0.0.1(51902) app = [unknown] FATAL: database "fep" does not exist (10571)
```

1.1.2 Components

This section explains the components of a message.

Message type

The message type indicates the type of error denoted in the message.

The message type will be one of the following:

- Information (INFO, NOTICE, LOG, DEBUG)

This message type denotes a notification from the system, not an error. There is no need to take action.

- Warning (WARNING)

This message type denotes that no error occurred but confirmation or action is required by the user. Take the actions described in the "Action" section of the message.

- Error (ERROR, FATAL, PANIC)

This message type denotes that an error has occurred. Take the actions described in the "Action" section of the message.

- Supplementary information (DETAIL, HINT, QUERY, CONTEXT, LOCATION, STATEMENT)

This message type denotes supplementary information relating to the previous message. If the message was output in English, the message type will also be in English. (Detail, hint, query, context, location, statement)

Message text

The text of the message reports the status of the system or an error in the system.

The notation "@numeric character@" that appears in "[Chapter 2 FUJITSU Enterprise Postgres Messages](#)" indicates an embedded character string. A character string is output to a message that is actually output.

If a message locale other than 'ja' is specified, messages added by FUJITSU Enterprise Postgres will be output in English.

For other message locales, the messages are output in English.

Message number

The message number uniquely identifies each message. It is output as a string of five single-byte numeric characters. Use the message number that is output to find the explanation of the corresponding message in this document. The message numbers may change, so do not use them as keywords for monitoring.

No message number is assigned to messages output by a PL/pgSQL RAISE statement.

The message number is only output if the message locale is 'ja' or 'en'. For other message locales, the message number is not output.

1.2 Mirroring Controller Message Format

This section explains the format of messages output by the Mirroring Controller.

Mirroring Controller messages are output to the following locations:

- System log

Output format

```
programName[processId]: msgType: msgText (msgNumber)
```

For *programName*, use the value of the `syslog_ident` parameter or `event_source` parameter defined in the `serverIdentifier.conf` file.

The message types output by Mirroring Controller, their severity, and their corresponding value in the system log are shown in the table below.

Table 1.1 Message type, severity, and corresponding value in the system log

Message type	Severity	Meaning	System log
INFO	Information	Provides information not categorized as LOG or NOTICE.	INFO
LOG		Provides information recognized as a particularly important event in tracing the operation history. (Example: Automatic switch is complete)	
NOTICE	Notice	Outputs information that takes into account the user instructions within the program in response to an executed or automatically executed process.	NOTICE
WARNING	Warning	Provides a warning, for example it will soon be impossible to maintain multiplexing capabilities.	WARNING
ERROR	Error	Reports that an error other than FATAL or PANIC has occurred.	ERROR
FATAL		Reports that an error has been detected requiring system recovery in one of the multiplexed database systems. It also reports the content and cause of the error.	CRIT
PANIC		Reports that an error has been detected requiring immediate system recovery in all multiplexed database systems. It also reports the content and cause of the error.	ALERT

The message severity has the following meanings:

- Information

Informational status. A message that was reported by the system is displayed. No action is required.

- Notice

Informational status, but a message that should be noted is displayed. If necessary, take the actions described in the "Action" section of the message.

- Warning

No error has occurred, but the user is requested to check, and take action. Take the actions described in the "Action" section of the message.

- Error

An error has occurred. Take the actions described in the "Action" section of the message.

Output destination server

Mirroring Controller messages are output by the database server. When using an arbitration server, Mirroring Controller messages are also output by the arbitration server.

- Messages with a message number that starts with "MCA" are output by the database server.
- Messages with a message number that starts with "MCR" are output by the arbitration server.

Chapter 2 FUJITSU Enterprise Postgres Messages

This chapter explains messages output by FUJITSU Enterprise Postgres.

2.1 Message Numbers Beginning with 10000

2.1.1 10001

no Snowball stemmer available for language "@1@" and encoding "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.2 10002

multiple StopWords parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.3 10003

multiple Language parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.4 10004

unrecognized Snowball parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.5 10005

missing Language parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.6 10006

could not determine which collation to use for index expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.7 10007

old GIN indexes do not support whole-index scans nor searches for nulls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.8 10008

index row size @1@ exceeds maximum @2@ for index "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.9 10009

"@1@" is an index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.10 10010

could not create archive status file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.1.11 10011

could not write archive status file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.1.12 10013

could not write to log file @1@ at offset @2@, length @3@: @4@

[Description]

There are the following cases:

- failed to write transaction log file
- failed to write transaction log file on backup data storage destination

[System Processing]

Processing will be aborted.

[Action]

Lack of storage space or malfunction of storage allocating the file shown in this message is considered.

If it's true, recover the database system according to "Actions when an Error Occurs" of "Operation Guide" or "Cluster Operation Guide (Database Multiplexing)".

If it's not true, identify the cause according to the information in this message such as errno, and work around.

The following major causes are considered.

- the file has no permission or the permission has been changed
- power of the storage allocating the file has been turned off
- unmounted the storage allocating the file
- another process or human operated the file
- the storage allocating the file has crashed

2.1.13 10014

updated min recovery point to @1 @/@2@ on timeline @3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.14 10016

could not create file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.1.15 10017

could not write to file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.1.16 10018

could not fsync file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.17 10026

could not read file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.18 10027

could not remove file "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.1.19 10028

archive file "@1@" has wrong size: @2@ instead of @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.20 10029

restored log file "@1@" from archive

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.21 10030

could not restore file "@1@" from archive: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.22 10032

could not open transaction log directory "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.23 10033

recycled write-ahead log file "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.24 10034

removing write-ahead log file "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.25 10035

could not rename file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.26 10036

could not remove old transaction log file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.27 10037

required WAL directory "@1@" does not exist

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.28 10038

creating missing WAL directory "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.29 10039

could not create missing directory "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.1.30 10040

removing WAL backup history file "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.31 10043

incorrect resource manager data checksum in record at @1@/@2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.32 10044

invalid record offset at @1@/@2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.33 10045

contrecord is requested by @1@/@2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.34 10048

invalid record length at @1@/@2@: wanted @3@, got @4@

[Description]

invalid record length was found on archive log or transaction log data.

[System Processing]

The following causes could be considered.

- if the log level is information(INFO, NOTICE, LOG, DEBUG)

Continue processing.

- if the log level is error(ERROR, FATAL, PANIC)

Processing will be aborted.

[Action]

If the log level is information(INFO, NOTICE, LOG, DEBUG), no action is required.

When the log level is error(ERROR, FATAL, PANIC), take either of the following actions.

- if this message is output during starting instance

Please restore according to "Deal at the time of abnormality" of "Operation Guide" or "Cluster Operation Guide (Database Multiplexing)".

- if this message is output during recovering

Cannot continue to recover with the current backup data because an archive log in the backup has an error.

Recover from the other backup data.

2.1.35 10049

invalid resource manager ID @1@ at @2@/@3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.36 10050

record with incorrect prev-link @1 @/@2@ at @3@/@4@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.37 10051

record length @1 @ at @2@/@3@ too long

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.38 10052

there is no contrecord flag at @1 @/@2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.39 10053

invalid contrecord length @1 @ at @2@/@3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.40 10054

invalid magic number @1@ in log segment @2@, offset @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.41 10055

invalid info bits @1@ in log segment @2@, offset @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.42 10056

WAL file is from different database system: WAL file database system identifier is @1@, pg_control database system identifier is @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.43 10057

unexpected pageaddr @1@/@2@ in log segment @3@, offset @4@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.44 10058

unexpected timeline ID @1@ in log segment @2@, offset @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.45 10059

out-of-sequence timeline ID @1@ (after @2@) in log segment @3@, offset @4@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.46 10060

syntax error in history file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.47 10061

invalid data in history file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.48 10062

invalid data in history file "@1@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.49 10063

new timeline @1@ is not a child of database system timeline @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.50 10064

new target timeline is @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.51 10065

could not rename file "@1@" to "@2@" : @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.52 10066

could not link file "@1@" to "@2@" : @3@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.1.53 10073

database files are incompatible with server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.54 10074

incorrect checksum in control file

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.55 10075

could not write bootstrap write-ahead log file: @1@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.1.56 10076

could not fsync bootstrap write-ahead log file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.57 10077

could not close bootstrap write-ahead log file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.58 10079

parameter "@1@" requires a Boolean value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.59 10085

must specify restore_command when standby mode is not enabled

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.60 10086

recovery target timeline @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.61 10087

archive recovery complete

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.1.62 10088

recovery stopping after commit of transaction @1@, time @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.63 10089

recovery stopping before commit of transaction @1@, time @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.64 10090

recovery stopping after abort of transaction @1@, time @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.65 10091

recovery stopping before abort of transaction @1@, time @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.66 10092

recovery stopping at restore point "@1@", time @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.1.67 10093

recovery has paused

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.1.68 10095

recovery is in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.69 10096

hot standby is not possible because @1@ = @2@ is a lower setting than on the master server (its value was @3@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.70 10097

WAL was generated with wal_level=minimal, data may be missing

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.1.71 10098

hot standby is not possible because wal_level was not set to "replica" or higher on the master server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.1.72 10099

control file contains invalid data

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2 Message Numbers Beginning with 10100

2.2.1 10100

database system was shut down at @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.2 10101

database system was shut down in recovery at @1@

[Description]

Displaying the date and time that the standby server is shut down last time.

[System Processing]

Continues processing.

[Action]

No action is required.

2.2.3 10102

database system shutdown was interrupted; last known up at @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.4 10103

database system was interrupted while in recovery at @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.5 10104

database system was interrupted while in recovery at log time @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.6 10105

database system was interrupted; last known up at @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.7 10106

requested timeline @1@ is not a child of this server's history

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.8 10107

entering standby mode

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.9 10108

starting point-in-time recovery to XID @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.10 10109

starting point-in-time recovery to @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.11 10110

starting point-in-time recovery to "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.12 10111

starting archive recovery

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.13 10112

checkpoint record is at @1@/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.14 10113

could not find redo location referenced by checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.15 10114

could not locate required checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.16 10115

could not locate a valid checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.17 10116

using previous checkpoint record at @1 @/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.18 10121

invalid next transaction ID

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.19 10122

invalid redo in checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.20 10123

invalid redo record in shutdown checkpoint

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.21 10124

database system was not properly shut down; automatic recovery in progress

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.2.22 10125

initializing for hot standby

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.23 10126

redo starts at @1 @/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.24 10127

redo done at @1 @/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.25 10128

last completed transaction was at log time @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.26 10129

redo is not required

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.2.27 10130

requested recovery stop point is before consistent recovery point

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.28 10131

WAL ends before end of online backup

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.29 10132

WAL ends before consistent recovery point

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.30 10133

selected new timeline ID: @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.31 10134

consistent recovery state reached at @1@/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.32 10135

invalid primary checkpoint link in control file

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.33 10136

invalid secondary checkpoint link in control file

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.34 10137

invalid checkpoint link in backup_label file

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.35 10138

invalid primary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.36 10139

invalid secondary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.37 10140

invalid checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.38 10141

invalid resource manager ID in primary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.39 10142

invalid resource manager ID in secondary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.40 10143

invalid resource manager ID in checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.41 10144

invalid xl_info in primary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.42 10145

invalid xl_info in secondary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.43 10146

invalid xl_info in checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.44 10147

invalid length of primary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.45 10148

invalid length of secondary checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.46 10149

invalid length of checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.47 10150

shutting down

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.48 10151

database system is shut down

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.49 10152

concurrent write-ahead log activity while database system is shutting down

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.50 10153

skipping restartpoint, recovery has already ended

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.51 10154

skipping restartpoint, already performed at @1@/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.52 10155

recovery restart point at @1@/@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.53 10156

restore point "@1@" created at @2@/@3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.54 10157

unexpected timeline ID @1@ (after @2@) in checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.55 10158

unexpected timeline ID @1@ (should be @2@) in checkpoint record

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.56 10160

could not fsync write-through log file @1@: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.57 10161

could not fdatsync file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.58 10163

recovery is not in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.59 10164

WAL level not sufficient for making an online backup

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.60 10165

backup label too long (max @1@ bytes)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.61 10166

a backup is already in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.62 10167

could not stat file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.2.63 10168

a backup is not in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.64 10169

invalid data in file "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.65 10170

base backup done, waiting for required WAL segments to be archived

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.66 10171

still waiting for all required WAL segments to be archived (@1@ seconds elapsed)

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.2.67 10172

all required WAL segments have been archived

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.68 10173

WAL archiving is not enabled; you must ensure that all required WAL segments are copied through other means to complete the backup

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.69 10176

WAL level not sufficient for creating a restore point

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.70 10177

value too long for restore point (maximum @1@ characters)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.71 10179

could not read from log segment @1@, offset @2@: @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.2.72 10180

received promote request

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.73 10181

promote trigger file found: @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.74 10182

database is not accepting commands to avoid wraparound data loss in database "@1@"

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.2.75 10183

database is not accepting commands to avoid wraparound data loss in database with OID @1@

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.2.76 10184

database "@1@" must be vacuumed within @2@ transactions**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.2.77 10185

database with OID @1@ must be vacuumed within @2@ transactions**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.2.78 10186

transaction ID wrap limit is @1@, limited by database with OID @2@**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.2.79 10187

transaction identifier "@1@" is too long**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.80 10188

prepared transactions are disabled

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.81 10189

transaction identifier "@1@" is already in use

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.82 10190

maximum number of prepared transactions reached

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.83 10191

prepared transaction with identifier "@1@" is busy

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.84 10192

permission denied to finish prepared transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.85 10193

prepared transaction belongs to another database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.86 10194

prepared transaction with identifier "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.2.87 10195

two-phase state file maximum length exceeded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3 Message Numbers Beginning with 10200

2.3.1 10205

could not recreate file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.2 10209

removing future two-phase state file for transaction @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.3 10210

corrupted two-phase state file for transaction @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.4 10211

removing stale two-phase state file for transaction @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.5 10212

recovering prepared transaction @1@ from shared memory

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.3.6 10213

file "@1@" doesn't exist, reading as zeroes

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.7 10214

could not access status of transaction @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.8 10215

could not truncate directory "@1@": apparent wraparound

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.9 10216

removing file "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.3.10 10217

cannot have more than 2^32-2 commands in a transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.11 10218

maximum number of committed subtransactions (@1@) exceeded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.12 10220

@1@ cannot run inside a transaction block

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.13 10221

@1@ cannot run inside a subtransaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.14 10222

@1@ cannot be executed from a function or multi-command string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.15 10223

@1@ can only be used in transaction blocks

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.16 10224

there is already a transaction in progress

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.17 10225

there is no transaction in progress

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.3.18 10226

no such savepoint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.19 10227

cannot have more than 2³²-1 subtransactions in a transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.20 10228

index "@1@" is not a btree

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.21 10229

version mismatch in index "@1@": file version @2@, code version @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.22 10230

index "@1@" contains unexpected zero page at block @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.23 10231

index "@1@" contains corrupted page at block @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.24 10232

duplicate key value violates unique constraint "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.25 10233

failed to re-find tuple within index "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.3.26 10234

row is too big: size @1@, maximum size @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.27 10235

"@1@" is not an index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.28 10236

"@1@" is a composite type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.29 10237

could not obtain lock on row in relation "@1@"

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.3.30 10238

hash indexes do not support whole-index scans

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.31 10239

index "@1@" is not a hash index

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.32 10240

index "@1@" has wrong hash version

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.33 10241

out of overflow pages in hash index "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.34 10242

index row size @1@ exceeds hash maximum @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.35 10243

column "@1@" cannot be declared SETOF

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.36 10244

number of columns (@1@) exceeds limit (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.37 10245

user-defined relation parameter types limit exceeded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.38 10246

RESET must not include values for parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.39 10247

unrecognized parameter namespace "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.40 10248

unrecognized parameter "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.41 10249

parameter "@1@" specified more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.42 10250

invalid value for boolean option "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.43 10251

invalid value for integer option "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.44 10252

value @1@ out of bounds for option "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.45 10253

invalid value for floating point option "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.46 10254

unsupported format code: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.47 10255

number of index columns (@1@) exceeds limit (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.48 10256

index row requires @1@ bytes, maximum size is @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.49 10257

picksplit method for column @1@ of index "@2@" failed

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.3.50 10259

index "@1@" contains an inner tuple marked as invalid

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.51 10260

aggregate @1@ needs to have compatible input type and transition type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.52 10261

could not create exclusion constraint "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.53 10262

conflicting key value violates exclusion constraint "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.54 10263

RIGHT JOIN is only supported with merge-joinable join conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.55 10264

FULL JOIN is only supported with merge-joinable join conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.56 10265

could not determine actual type of argument declared @1 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.57 10266

@1 @ is not allowed in a SQL function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.58 10267

@1 @ is not allowed in a non-volatile function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.59 10268

could not determine actual result type for function declared to return type @1 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.60 10269

set-valued function called in context that cannot accept a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.61 10270

return type mismatch in function declared to return @1 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.62 10271

return type @1 @ is not supported for SQL functions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.63 10272

cannot change sequence "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.64 10273

cannot change TOAST relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.65 10274

cannot insert into view "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.66 10275

cannot update view "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.67 10276

cannot copy from view "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.68 10278

cannot change relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.69 10279

cannot lock rows in sequence "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.70 10280

cannot lock rows in TOAST relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.71 10281

cannot lock rows in view "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.72 10282

cannot lock rows in foreign table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.73 10283

cannot lock rows in relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.74 10284

null value in column "@1@" violates not-null constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.75 10285

new row for relation "@1@" violates check constraint "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.76 10286

could not serialize access due to concurrent update

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.77 10287

ON COMMIT can only be used on temporary tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.78 10288

cannot create temporary table within security-restricted operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.79 10289

could not rewind hash-join temporary file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.80 10290

could not write to hash-join temporary file: @1@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.3.81 10291

could not read from hash-join temporary file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.3.82 10292

relation "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.83 10293

cursor "@1@" is not a SELECT query

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.84 10294

cursor "@1@" is held from a previous transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.85 10295

cursor "@1@" has multiple FOR UPDATE/SHARE references to table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.86 10296

cursor "@1@" does not have a FOR UPDATE/SHARE reference to table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.87 10297

cursor "@1@" is not positioned on a row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.88 10298

cursor "@1@" is not a simply updatable scan of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.3.89 10299

type of parameter @1@ (@2@) does not match that when preparing the plan (@3@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4 Message Numbers Beginning with 10300

2.4.1 10300

no value found for parameter @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.2 10301

more than one row returned by a subquery used as an expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.3 10302

frame starting offset must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.4 10303

frame starting offset must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.5 10304

frame ending offset must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.6 10305

frame ending offset must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.7 10306

transaction left non-empty SPI stack

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.4.8 10307

subtransaction left non-empty SPI stack

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.4.9 10308

cannot open multi-query plan as cursor

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.10 10309

cannot open @1@ query as cursor

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.11 10310

DECLARE SCROLL CURSOR ... FOR UPDATE/SHARE is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.12 10311

number of array dimensions (@1@) exceeds the maximum allowed (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.13 10312

array subscript in assignment must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.14 10313

attribute @1@ has wrong type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.15 10314

table row type and query-specified row type do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.16 10315

cannot pass more than @1@ argument to a function cannot pass more than @2@ arguments to a function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.17 10317

function returning setof record called in context that cannot accept type record

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.18 10318

function return row and query-specified return row do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.19 10319

table-function protocol for materialize mode was not followed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.20 10320

unrecognized table-function returnMode: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.21 10322

rows returned by function are not all of the same row type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.22 10325

cannot merge incompatible arrays

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.23 10326

multidimensional arrays must have array expressions with matching dimensions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.24 10328

domain @1@ does not allow null values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.25 10329

value for domain @1@ violates check constraint "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.26 10330

aggregate function calls cannot be nested

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.27 10331

window function calls cannot be nested

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.28 10332

target type is not an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.29 10333

ROW() column has type @1@ instead of type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.30 10334

could not identify a comparison function for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.31 10335

OFFSET must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.32 10336

LIMIT must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.33 10337

@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.34 10338

could not find array type for data type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.35 10339

cannot assign to system column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.36 10340

cannot set an array element to DEFAULT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.37 10341

cannot set a subfield to DEFAULT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.38 10342

column "@1@" is of type @2@ but default expression is of type @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.39 10343

row expansion via "*" is not supported here

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.40 10344

cannot assign to field "@1@" of column "@2@" because its type @3@ is not a composite type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.41 10345

cannot assign to field "@1@" of column "@2@" because there is no such column in data type @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.42 10346

array assignment requires type @1@ but expression is of type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.43 10347

column "@1@" is of type @2@ but expression is of type @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.44 10348

cannot cast type @1@ to @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.45 10349

column "@1@" of relation "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.46 10350

column name "@1@" specified more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.47 10351

column reference "@1@" is ambiguous

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.48 10352

cross-database references are not implemented: "@1@.@2@.@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.49 10353

improper qualified name (too many dotted names): @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.50 10354

SELECT * with no tables specified is not valid

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.51 10355

there is no parameter \$@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.52 10356

inconsistent types deduced for parameter \$@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.53 10357

could not determine data type of parameter \$@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.54 10358

identifier "@1@" will be truncated to "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.4.55 10363

aggregate functions are not allowed in DEFAULT expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.56 10365

column name "@1@" appears more than once in USING clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.57 10366

common column name "@1@" appears more than once in left table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.58 10367

column "@1@" specified in USING clause does not exist in left table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.59 10368

common column name "@1@" appears more than once in right table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.60 10369

column "@1@" specified in USING clause does not exist in right table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.61 10370

column alias list for "@1@" has too many entries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.62 10371

argument of @1@ must not contain variables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.63 10372

aggregate functions are not allowed in @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.64 10374

@1@ "@2@" is ambiguous

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.65 10375

non-integer constant in @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.66 10376

@1@ position @2@ is not in select list

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.67 10377

window "@1@" is already defined

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.68 10378

schema "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.69 10379

cannot override PARTITION BY clause of window "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.70 10380

cannot override ORDER BY clause of window "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.71 10382

in an aggregate with DISTINCT, ORDER BY expressions must appear in argument list

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.72 10383

for SELECT DISTINCT, ORDER BY expressions must appear in select list

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.73 10384

SELECT DISTINCT ON expressions must match initial ORDER BY expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.74 10385

"@1@" is not a valid operator name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.75 10386

extension "@1@" already exists, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.4.76 10387

array of serial is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.77 10388

@1@ will create implicit sequence "@2@" for serial column "@3@.@4@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.4.78 10389

conflicting NULL/NOT NULL declarations for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.79 10390

multiple default values specified for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.80 10391

referenced relation "@1@" is not a table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.81 10392

multiple primary keys for table "@1@" are not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.82 10393

cannot use an existing index in CREATE TABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.83 10394

conversion "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.84 10395

index "@1@" is already associated with a constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.85 10396

index "@1@" does not belong to table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.86 10397

index "@1@" is not valid

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.4.87 10399

"@1@" is not a unique index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5 Message Numbers Beginning with 10400

2.5.1 10400

index "@1@" contains expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.2 10401

"@1@" is a partial index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.3 10402

"@1@" is a deferrable index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.4 10403

index "@1@" column number @2@ does not have default sorting behavior

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.5 10404

column "@1@" named in key does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.6 10405

column "@1@" appears twice in primary key constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.7 10406

column "@1@" appears twice in unique constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.8 10408

index expressions and predicates can refer only to the table being indexed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.9 10409

rule WHERE condition cannot contain references to other relations

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.10 10412

rules with WHERE conditions can only have SELECT, INSERT, UPDATE, or DELETE actions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.11 10413

conditional UNION/INTERSECT/EXCEPT statements are not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.12 10414

ON SELECT rule cannot use OLD

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.13 10415

ON SELECT rule cannot use NEW

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.14 10416

ON INSERT rule cannot use OLD

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.15 10417

ON DELETE rule cannot use NEW

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.16 10418

cannot refer to OLD within WITH query

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.17 10419

cannot refer to NEW within WITH query

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.18 10420

misplaced DEFERRABLE clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.19 10421

multiple DEFERRABLE/NOT DEFERRABLE clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.20 10422

misplaced NOT DEFERRABLE clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.21 10423

constraint declared INITIALLY DEFERRED must be DEFERRABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.22 10424

misplaced INITIALLY DEFERRED clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.23 10425

multiple INITIALLY IMMEDIATE/DEFERRED clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.24 10426

misplaced INITIALLY IMMEDIATE clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.25 10427

collations are not supported by type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.26 10428

CREATE specifies a schema (@1@) different from the one being created (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.27 10429

table reference "@1@" is ambiguous

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.28 10430

table reference @1@ is ambiguous

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.29 10431

table name "@1@" specified more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.30 10432

WITH query "@1@" has @2@ columns available but @3@ columns specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.31 10434

relation "@1@.@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.32 10435

type "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.33 10436

a column definition list is only allowed for functions returning "record"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.34 10437

a column definition list is required for functions returning "record"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.35 10438

function "@1@" in FROM has unsupported return type @2@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.36 10439

VALUES lists "@1@" have @2@ columns available but @3@ columns specified**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.37 10440

tables can have at most @1@ columns**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.38 10441

WITH query "@1@" does not have a RETURNING clause**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.39 10442

column @1@ of relation "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.40 10443

invalid reference to FROM-clause entry for table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.41 10444

missing FROM-clause entry for table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.42 10445

unrecognized role option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.43 10446

current database cannot be renamed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.44 10447

time zone interval must be HOUR or HOUR TO MINUTE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.45 10449

MATCH PARTIAL not yet implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.46 10451

CREATE ASSERTION is not yet implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.47 10453

RECHECK is no longer required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.48 10454

missing argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.49 10457

number of columns does not match number of values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.50 10458

LIMIT #,# syntax is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.51 10459

VALUES in FROM must have an alias

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.52 10460

subquery in FROM must have an alias

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.5.53 10461

precision for type float must be at least 1 bit

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.54 10462

precision for type float must be less than 54 bits

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.55 10463

UNIQUE predicate is not yet implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.56 10464

RANGE PRECEDING is only supported with UNBOUNDED

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.57 10465

RANGE FOLLOWING is only supported with UNBOUNDED

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.58 10466

frame start cannot be UNBOUNDED FOLLOWING

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.59 10467

frame starting from following row cannot end with current row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.60 10468

frame end cannot be UNBOUNDED PRECEDING

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.61 10469

frame starting from current row cannot have preceding rows

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.62 10470

frame starting from following row cannot have preceding rows

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.63 10471

type modifier cannot have parameter name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.64 10472

wrong number of parameters on left side of OVERLAPS expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.65 10473

wrong number of parameters on right side of OVERLAPS expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.66 10474

syntax error

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.67 10475

multiple ORDER BY clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.68 10476

multiple OFFSET clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.69 10477

multiple LIMIT clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.70 10478

multiple WITH clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.71 10479

OUT and INOUT arguments aren't allowed in TABLE functions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.72 10480

multiple COLLATE clauses not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.73 10481

operator does not exist: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.74 10482

could not identify an ordering operator for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.75 10483

could not identify an equality operator for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.76 10484

operator requires run-time type coercion: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.77 10485

operator @1@ is not commutative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.78 10486

operator is only a shell: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.79 10487

op ANY/ALL (array) requires array on right side

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.80 10488

op ANY/ALL (array) requires operator to yield boolean

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.81 10489

op ANY/ALL (array) requires operator not to return a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.82 10490

column "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.83 10491

column "@1@" not found in data type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.84 10492

could not identify column "@1@" in record data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.85 10493

column notation .@1@ applied to type @2@, which is not a composite type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.86 10494

function @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.87 10495

NULLIF requires = operator to yield boolean

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.5.88 10498

subquery must return only one column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6 Message Numbers Beginning with 10500

2.6.1 10500

subquery has too many columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.2 10501

subquery has too few columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.3 10502

cannot determine type of empty array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.4 10503

could not find range type for data type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.5 10504

unnamed XML attribute value must be a column reference

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.6 10505

unnamed XML element value must be a column reference

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.7 10506

XML attribute name "@1@" appears more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.8 10507

cannot cast XMLSERIALIZE result to @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.9 10508

unequal number of entries in row expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.10 10509

cannot compare rows of zero length

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.11 10510

row comparison operator must yield type boolean, not type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.12 10511

row comparison operator must not return a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.13 10512

could not determine interpretation of row comparison operator @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.14 10513

IS DISTINCT FROM requires = operator to yield boolean

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.15 10515

VALUES lists must all be the same length

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.16 10520

INSERT has more expressions than target columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.17 10521

INSERT has more target columns than expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.18 10525

invalid UNION/INTERSECT/EXCEPT ORDER BY clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.19 10526

INTO is only allowed on first SELECT of UNION/INTERSECT/EXCEPT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.20 10527

UNION/INTERSECT/EXCEPT member statement cannot refer to other relations of same query level

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.21 10528

each @1@ query must have the same number of columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.22 10535

cannot specify both SCROLL and NO SCROLL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.23 10537

DECLARE CURSOR must not contain data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.24 10538

DECLARE CURSOR WITH HOLD ... @1@ is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.25 10539

DECLARE INSENSITIVE CURSOR ... @1@ is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.26 10552

aggregate function calls cannot contain window function calls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.27 10558

window functions are not allowed in JOIN conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.28 10562

column "@1@.@2@" must appear in the GROUP BY clause or be used in an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.29 10563

subquery uses ungrouped column "@1@.@2@" from outer query

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.30 10564

parameter name "@1@" used more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.31 10565

positional argument cannot follow named argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.32 10566

@1@(*) specified, but @2@ is not an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.33 10567

DISTINCT specified, but @1@ is not an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.34 10568

ORDER BY specified, but @1@ is not an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.35 10569

OVER specified, but @1@ is not a window function nor an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.36 10570

function @1@ is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.37 10571

database "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.38 10572

@1@(*) must be used to call a parameterless aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.39 10573

aggregates cannot return sets

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.40 10574

aggregates cannot use named arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.41 10576

DISTINCT is not implemented for window functions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.42 10577

aggregate ORDER BY is not implemented for window functions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.43 10578

window functions cannot return sets

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.44 10580

extension "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.45 10582

aggregate @1 @(*) does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.46 10583

server "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.47 10584

function "@1@" is an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.48 10585

argument of @1 @ must be a type name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.49 10586

argument of @1 @ must not return a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.50 10587

argument of @1 @ must be type boolean, not type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.51 10588

@1 @ types @2@ and @3@ cannot be matched

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.52 10589

@1@ could not convert type @2@ to @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.53 10590

arguments declared "anyelement" are not all alike

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.54 10591

arguments declared "anyarray" are not all alike

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.55 10592

argument declared @1@ is not an array but type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.56 10593

argument declared @1@ is not consistent with argument declared @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.57 10595

type matched to anyonarray is an array type: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.58 10596

type matched to anyenum is not an enum type: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.59 10597

recursive reference to query "@1@" must not appear within its non-recursive term

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.60 10598

recursive reference to query "@1@" must not appear within a subquery

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.6.61 10599

recursive reference to query "@1@" must not appear within an outer join

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7 Message Numbers Beginning with 10600

2.7.1 10600

recursive reference to query "@1@" must not appear within INTERSECT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.2 10601

recursive reference to query "@1@" must not appear within EXCEPT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.3 10602

WITH query name "@1@" specified more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.4 10604

WITH clause containing a data-modifying statement must be at the top level

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.5 10605

recursive query "@1@" column @2@ has type @3@ in non-recursive term but type @4@ overall

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.6 10606

recursive query "@1@" column @2@ has collation "@3@" in non-recursive term but collation "@4@" overall

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.7 10607

table "@1@" has @2@ columns available but @3@ columns specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.8 10608

mutual recursion between WITH items is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.9 10609

recursive query "@1@" must not contain data-modifying statements

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.10 10610

recursive query "@1@" does not have the form non-recursive-term UNION [ALL] recursive-term

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.11 10611

ORDER BY in a recursive query is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.12 10612

OFFSET in a recursive query is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.13 10613

LIMIT in a recursive query is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.14 10614

FOR UPDATE/SHARE in a recursive query is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.15 10615

recursive reference to query "@1@" must not appear more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.16 10616

unsafe use of string constant with Unicode escapes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.17 10617

invalid Unicode escape

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.18 10618

unsafe use of \\' in a string literal

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.19 10619

@1@ at end of input

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.20 10620

@1@ at or near "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.21 10621

nonstandard use of \ in a string literal

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.22 10622

nonstandard use of \\ in a string literal

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.23 10623

nonstandard use of escape in a string literal

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.24 10624

collation mismatch between implicit collations "@1@" and "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.25 10625

collation mismatch between explicit collations "@1@" and "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.26 10626

target lists can have at most @1@ entries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.27 10627

cannot subscript type @1@ because it is not an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.28 10628

array subscript must have type integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.29 10629

array assignment to "@1@" requires type @2@ but expression is of type @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.30 10630

improper @1@TYPE reference (too few dotted names): @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.31 10631

improper @1@TYPE reference (too many dotted names): @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.32 10632

type reference @1@ converted to @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.33 10633

return type @1@ is only a shell

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.34 10634

type modifier cannot be specified for shell type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.35 10635

type modifier is not allowed for type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.36 10636

type modifiers must be simple constants or identifiers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.37 10637

invalid type name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.38 10638

canceling the wait for synchronous replication and terminating connection due to administrator command

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.39 10639

canceling wait for synchronous replication due to user request

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.40 10640

standby "@1@" now has synchronous standby priority @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.7.41 10642

could not connect to the primary server: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.7.42 10643

could not receive database system identifier and timeline ID from the primary server: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.7.43 10644

invalid response from primary server

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.7.44 10645

database system identifier differs between the primary and standby

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.45 10646

highest timeline @1@ of the primary is behind recovery timeline @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.7.46 10647

could not start WAL streaming: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.7.47 10651

could not receive data from WAL stream: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.7.48 10652

replication terminated by primary server

[Description]

Primary server has stopped.

[System Processing]

Processing will be aborted.

[Action]

No action is required.

2.7.49 10653

could not send data to WAL stream: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.7.50 10655

base backup could not send data, aborting backup

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.7.51 10656

duplicate option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.52 10658

could not stat file or directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.53 10659

could not remove symbolic link "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.54 10660

skipping special file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.7.55 10663

unexpected EOF on standby connection

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.7.56 10664

invalid standby message type "@1@"

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.7.57 10667

terminating walsender process due to replication timeout

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.7.58 10668

standby "@1@" has now caught up with primary

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.7.59 10670

requested WAL segment @1@ has already been removed

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.7.60 10672

materialize mode required, but it is not allowed in this context

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.61 10673

terminating walreceiver process due to administrator command

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.7.62 10674

cannot continue WAL streaming, recovery has already ended

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.7.63 10675

authentication failed for user "@1@": host rejected

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.64 10677

"trust" authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.65 10678

Ident authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.66 10679

Peer authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.67 10680

password authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.68 10681

GSSAPI authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.69 10682

SSPI authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.70 10683

PAM authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.71 10684

LDAP authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.72 10685

certificate authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.73 10686

RADIUS authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.74 10687

authentication failed for user "@1@": invalid authentication method

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.75 10689

connection requires a valid client certificate

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.76 10690

pg_hba.conf rejects replication connection for host "@1@", user "@2@", @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.77 10691

pg_hba.conf rejects replication connection for host "@1@", user "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.78 10692

[pg_hba.conf rejects connection for host "@1@", user "@2@", database "@3@", @4@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.79 10693

[pg_hba.conf rejects connection for host "@1@", user "@2@", database "@3@"](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.80 10694

[no pg_hba.conf entry for replication connection from host "@1@", user "@2@", @3@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.81 10695

[no pg_hba.conf entry for replication connection from host "@1@", user "@2@"](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.82 10696

no pg_hba.conf entry for host "@1@", user "@2@", database "@3@", @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.83 10697

no pg_hba.conf entry for host "@1@", user "@2@", database "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.84 10698

MD5 authentication is not supported when "db_user_namespace" is enabled

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.7.85 10699

expected password response, got message type @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8 Message Numbers Beginning with 10700

2.8.1 10700

invalid password packet size

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.2 10707

GSSAPI is not supported in protocol version 2

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.3 10708

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.8.4 10709

expected GSS response, got message type @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.5 10710

SSPI is not supported in protocol version 2

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.6 10711

expected SSPI response, got message type @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.7 10712

could not create socket for Ident connection: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.

- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.8 10713

could not bind to local address "@1@": @2@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.9 10714

could not connect to Ident server at address "@1@", port @2@: @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.10 10715

could not send query to Ident server at address "@1@", port @2@: @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.11 10716

could not receive response from Ident server at address "@1@", port @2@: @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

a) If the COMMIT process is not executed after update, add the COMMIT process.

b) If the total number of update records in a single transaction is high, split it into short transactions.

c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

a) Confirm that the database server has not stopped.

b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.12 10717

invalidly formatted response from Ident server: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.13 10718

peer authentication is not supported on this platform

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.14 10719

could not get peer credentials: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)

- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

a) If the COMMIT process is not executed after update, add the COMMIT process.

b) If the total number of update records in a single transaction is high, split it into short transactions.

c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

a) Confirm that the database server has not stopped.

b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.15 10720

could not look up local user ID @1@: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.16 10721

empty password returned by client

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.17 10722

error from underlying PAM layer: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.18 10723

could not create PAM authenticator: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.19 10724

pam_set_item(PAM_USER) failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.20 10725

pam_set_item(PAM_CONV) failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.21 10726

pam_authenticate failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.22 10727

pam_acct_mgmt failed: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.23 10728

could not release PAM authenticator: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.24 10729

could not initialize LDAP: error code @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.25 10730

could not set LDAP protocol version: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.26 10731

could not load wldap32.dll

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.27 10732

could not load function _ldap_start_tls_sA in wldap32.dll

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.28 10733

could not start LDAP TLS session: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.29 10734

LDAP server not specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.30 10735

invalid character in user name for LDAP authentication

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.31 10736

could not perform initial LDAP bind for ldapbinddn "@1@" on server "@2@" : @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.32 10737

could not search LDAP for filter "@1@" on server "@2@" : @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.33 10738

LDAP search for filter "@1@" on server "@2@" returned no entries.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.34 10740

could not get dn for the first entry matching "@1@" on server "@2@" : @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.35 10741

could not unbind after searching for user "@1@" on server "@2@" : @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.36 10742

LDAP login failed for user "@1@" on server "@2@" : @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.37 10743

certificate authentication failed for user "@1@" : client certificate contains no user name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.38 10744

RADIUS server not specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.39 10745

RADIUS secret not specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.40 10746

could not translate RADIUS server name "@1@" to address: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.41 10747

RADIUS authentication does not support passwords longer than @1@ characters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.42 10748

could not generate random encryption vector

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.43 10749

could not perform MD5 encryption of password

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.44 10750

could not create RADIUS socket: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.45 10751

could not bind local RADIUS socket: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.46 10752

could not send RADIUS packet: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.47 10753

timeout waiting for RADIUS response

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.48 10754

could not check status on RADIUS socket: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.49 10755

could not read RADIUS response: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.50 10756

RADIUS response from @1@ was sent from incorrect port: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.51 10757

RADIUS response too short: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.52 10759

RADIUS response is to a different request: @1@ (should be @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.53 10760

could not perform MD5 encryption of received packet

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.54 10761

RADIUS response from @1@ has incorrect MD5 signature

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.55 10762

RADIUS response from @1@ has invalid code (@2@) for user "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.56 10763

SSL error: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.57 10764

unrecognized SSL error code: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.58 10767

could not create SSL context: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.59 10768

could not load server certificate file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.60 10769

could not access private key file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.61 10770

private key file "@1@" has group or world access

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.62 10771

could not load private key file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.63 10772

check of private key failed: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.64 10774

could not load root certificate file "@1@": @2@**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.65 10775

SSL certificate revocation list file "@1@" ignored**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.8.66 10776

could not load SSL certificate revocation list file "@1@": @2@**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.8.67 10777

could not initialize SSL connection: @1@**[Description]**

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.68 10778

could not set SSL socket: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.69 10779

could not accept SSL connection: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.70 10780

could not accept SSL connection: EOF detected

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.71 10781

could not accept SSL connection: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.72 10782

SSL certificate's common name contains embedded null

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.73 10783

SSL connection from "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.8.74 10784

could not translate host name "@1@", service "@2@" to address: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.75 10785

could not translate service "@1@" to address: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.76 10786

could not bind to all requested addresses: MAXLISTEN (@1@) exceeded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.77 10787

could not create @1@ socket for address "@2@": @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.78 10788

setsockopt(SO_REUSEADDR) failed for @1@ address "@2@": @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.

- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.79 10789

setsockopt(IPV6_V6ONLY) failed for @1 @ address "@2@": @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.80 10790

could not bind @1 @ address "@2@": @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.81 10791

could not listen on @1@ address "@2@": @3@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.82 10792

type @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.8.83 10793

could not set group of file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.84 10794

could not set permissions of file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.8.85 10795

could not accept new connection: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

- a) Confirm that the database server has not stopped.
- b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.8.86 10796

could not set socket to nonblocking mode: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.87 10798

could not receive data from client: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.8.88 10799

unexpected EOF within message length word

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9 Message Numbers Beginning with 10800

2.9.1 10800

invalid message length

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9.2 10801

incomplete message from client

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9.3 10802

could not send data to client: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9.4 10803

authentication file token too long, skipping: "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.9.5 10804

could not open secondary authentication file "@@1@" as "@2@": @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.6 10806

authentication option "@1@" is only valid for authentication methods @2@**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.7 10807

authentication method "@1@" requires argument "@2@" to be set**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.8 10808

local connections are not supported by this build**[Description]**

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.9.9 10809

hostssl record cannot match because SSL is disabled**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.10 10810

hostssl record cannot match because SSL is not supported by this build

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.9.11 10811

invalid connection type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.12 10812

end-of-line before database specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.13 10813

end-of-line before role specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.14 10814

end-of-line before IP address specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.15 10815

invalid IP address "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.16 10816

specifying both host name and CIDR mask is invalid: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.17 10817

invalid CIDR mask in address "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.18 10818

end-of-line before netmask specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.19 10819

invalid IP mask "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.20 10820

IP address and mask do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.21 10821

end-of-line before authentication method

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.22 10822

invalid authentication method "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.23 10823

invalid authentication method "@1@": not supported by this build

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.9.24 10825

gssapi authentication is not supported on local sockets

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.25 10826

peer authentication is only supported on local sockets

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.26 10827

cert authentication is only supported on hostssl connections

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.27 10828

authentication option not in name=value format: @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.28 10829

clientcert can only be configured for "hostssl" rows**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.29 10830

client certificates can only be checked if a root certificate store is available**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.9.30 10831

clientcert can not be set to "no-verify" when using "cert" authentication**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.31 10832

invalid LDAP port number: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.32 10833

invalid RADIUS port number: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.33 10834

unrecognized authentication option name: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.34 10835

cannot use ldapbasedn, ldapbinddn, ldapbindpasswd, ldapsearchattribute, or ldapurl together with ldapprefix

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.35 10836

authentication method "ldap" requires argument "ldapbasedn", "ldapprefix", or "ldapsuffix" to be set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.36 10837

could not open configuration file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.37 10838

invalid regular expression "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.38 10839

regular expression match for "@1@" failed: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.39 10840

regular expression "@1@" has no subexpressions as requested by backreference in "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.40 10841

missing entry in file "@1@" at end of line @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.41 10842

provided user name (@1@) and authenticated user name (@2@) do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.42 10843

no match in usermap "@1@" for user "@2@" authenticated as "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.43 10844

could not open server file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.44 10845

invalid large-object descriptor: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.45 10846

permission denied for large object @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.46 10847

large object descriptor @1@ was not opened for writing

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.47 10848

must be owner of large object @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.48 10849

must be superuser to use server-side lo_import()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.49 10850

could not read server file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.50 10851

could not create server file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.9.51 10852

must be superuser to use server-side lo_export()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.52 10853

could not write server file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.9.53 10854

could not write file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.9.54 10855

no data left in message

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9.55 10856

insufficient data left in message

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.56 10857

invalid string in message

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9.57 10858

invalid message format

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.9.58 10859

"@1@" is not a sequence

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.59 10861

cannot drop @1@ because it is required by the database system

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.60 10862

role @1@ was concurrently dropped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.61 10863

tablespace @1@ was concurrently dropped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.62 10864

database @1@ was concurrently dropped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.63 10865

cannot drop objects owned by @1@ because they are required by the database system

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.64 10866

permission denied to create "@1@.@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.65 10867

joins can have at most @1@ columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.66 10868

column name "@1@" conflicts with a system column name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.67 10869

column "@1@" specified more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.68 10871

column "@1@" has pseudo-type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.69 10872

composite type @1@ cannot be made a member of itself

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.70 10873

no collation was derived for column "@1@" with collatable type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.71 10874

relation "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.72 10875

type "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.73 10876

check constraint "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.74 10877

constraint "@1@" for relation "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.75 10878

merging constraint "@1@" with inherited definition

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.9.76 10879

generation expression is not immutable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.77 10881

cannot use subquery in DEFAULT expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.78 10882

aggregate functions are not allowed in index expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.79 10883

aggregate functions are not allowed in transform expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.80 10884

subfield "@1@" is of type @2@ but expression is of type @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.81 10885

only table "@1@" can be referenced in check constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.82 10886

cannot use subquery in check constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.83 10887

aggregate functions are not allowed in check constraints

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.84 10888

window functions are not allowed in check constraints

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.85 10889

unsupported ON COMMIT and foreign key combination

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.86 10890

cannot truncate a table referenced in a foreign key constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.87 10891

invalid type internal size @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.88 10892

alignment "@1@" is invalid for passed-by-value type of size @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.89 10893

internal size @1@ is invalid for passed-by-value type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.90 10894

alignment "@1@" is invalid for variable-length type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.91 10895

fixed-size types must have storage PLAIN

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.92 10896

could not form array type name for type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.93 10897

cannot determine transition data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.94 10898

return type of transition function @1@ is not @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.9.95 10899

must not omit initial value when transition function is strict and transition type is not compatible with input type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10 Message Numbers Beginning with 10900

2.10.1 10900

cannot determine result data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.2 10901

unsafe use of pseudo-type "internal"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.3 10902

sort operator can only be specified for single-argument aggregates

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.4 10903

function @1@ returns a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.5 10904

function @1@ requires run-time type coercion

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.6 10905

large object @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.7 10906

primary keys cannot be expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.8 10907

user-defined indexes on system catalog tables are not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.9 10908

concurrent index creation on system catalog tables is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.10 10909

shared indexes cannot be created after initdb

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.11 10910

building index "@1@" on table "@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.10.12 10911

cannot reindex temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.13 10912

invalid enum label "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.14 10913

"@1@" is not an existing enum label

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.15 10914

ALTER TYPE ADD BEFORE/AFTER is incompatible with binary upgrade

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.16 10915

"@1@" is already an attribute of type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.17 10916

function "@1@" already exists with same argument types

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.18 10917

cannot change return type of existing function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.19 10918

cannot change name of input parameter "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.20 10919

cannot remove parameter defaults from existing function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.21 10920

cannot change data type of existing parameter default value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.22 10921

function "@1@" is not an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.23 10922

"@1@" is an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.24 10923

function "@1@" is a window function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.25 10924

function "@1@" is not a window function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.26 10925

there is no built-in function named "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.27 10926

SQL functions cannot return type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.28 10927

SQL functions cannot have arguments of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.29 10928

invalid fork name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.30 10929

cannot drop @1@ because @2@ requires it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.31 10930

drop auto-cascades to @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.10.32 10931

cannot drop @1@ because other objects depend on it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.33 10932

cannot drop desired object(s) because other objects depend on them

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.34 10934

constraint "@1@" for domain @2@ already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.35 10935

table "@1@" has multiple constraints named "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.36 10936

constraint "@1@" for table "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.37 10937

grant options can only be granted to roles

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.38 10938

no privileges were granted for column "@1@" of relation "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.39 10939

no privileges were granted for "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.40 10940

not all privileges were granted for column "@1@" of relation "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.41 10941

not all privileges were granted for "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.42 10942

no privileges could be revoked for column "@1@" of relation "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.43 10943

no privileges could be revoked for "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.44 10944

not all privileges could be revoked for column "@1@" of relation "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.45 10945

not all privileges could be revoked for "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.46 10946

invalid privilege type @1@ for relation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.47 10947

invalid privilege type @1@ for sequence

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.48 10948

invalid privilege type @1@ for database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.49 10949

invalid privilege type @1@ for domain

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.50 10950

invalid privilege type @1@ for function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.51 10951

invalid privilege type @1@ for large object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.52 10952

invalid privilege type @1@ for language

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.53 10953

invalid privilege type @1@ for schema

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.54 10954

invalid privilege type @1@ for foreign-data wrapper

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.55 10955

invalid privilege type @1@ for foreign server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.56 10956

column privileges are only valid for relations

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.57 10957

conflicting or redundant options

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.58 10958

default privileges cannot be set for columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.59 10959

"@1@" is not a domain

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.60 10960

sequence "@1@" only supports USAGE, SELECT, and UPDATE privileges

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.61 10961

invalid privilege type @1@ for table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.62 10962

invalid privilege type @1@ for tablespace

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.63 10963

sequence "@1@" only supports SELECT column privileges

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.10.64 10964

language "@1@" is not trusted

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.65 10965

unrecognized privilege type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.66 10966

permission denied for column @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.67 10967

permission denied for relation @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.68 10968

permission denied for sequence @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.69 10969

permission denied for database @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.70 10970

permission denied for function @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.71 10971

permission denied for operator @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.72 10972

permission denied for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.73 10973

permission denied for language @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.74 10974

permission denied for large object @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.75 10975

permission denied for schema @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.76 10976

permission denied for operator class @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.77 10977

permission denied for operator family @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.78 10978

permission denied for collation @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.79 10979

permission denied for conversion @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.80 10980

permission denied for tablespace @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.81 10981

permission denied for text search dictionary @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.82 10982

permission denied for text search configuration @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.83 10983

permission denied for foreign-data wrapper @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.84 10984

permission denied for foreign server @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.85 10985

permission denied for extension @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.86 10986

must be owner of relation @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.87 10987

must be owner of sequence @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.88 10988

must be owner of database @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.89 10989

must be owner of function @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.90 10990

must be owner of operator @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.91 10991

must be owner of type @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.92 10992

must be owner of language @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.93 10993

must be owner of large object @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.94 10994

must be owner of schema @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.95 10995

must be owner of operator class @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.96 10996

must be owner of operator family @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.97 10997

must be owner of collation @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.98 10998

must be owner of conversion @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.10.99 10999

must be owner of tablespace @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11 Message Numbers Beginning with 11000

2.11.1 11000

must be owner of text search dictionary @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.2 11001

must be owner of text search configuration @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.3 11002

must be owner of foreign-data wrapper @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.4 11003

must be owner of foreign server @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.5 11004

must be owner of extension @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.6 11005

permission denied for column "@1@" of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.7 11007

attribute @1@ of relation with OID @2@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.8 11008

relation with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.9 11009

database with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.10 11010

function with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.11 11011

language with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.12 11012

schema with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.13 11013

tablespace with OID @1 @ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.14 11014

foreign-data wrapper with OID @1 @ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.15 11015

foreign server with OID @1 @ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.16 11016

type with OID @1 @ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.17 11017

operator with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.18 11018

operator class with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.19 11019

operator family with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.20 11020

text search dictionary with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.21 11021

text search configuration with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.22 11022

collation with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.23 11023

conversion with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.24 11024

extension with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.25 11025

conversion "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.26 11026

default conversion for @1@ to @2@ already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.27 11027

cross-database references are not implemented: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.28 11028

temporary tables cannot specify a schema name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.29 11029

no schema has been selected to create in

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.30 11030

text search parser "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.31 11031

text search dictionary "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.32 11032

text search template "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.33 11033

text search configuration "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.34 11035

cannot move objects into or out of temporary schemas

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.35 11036

cannot move objects into or out of TOAST schema

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.36 11037

language "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.37 11038

improper relation name (too many dotted names): @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.38 11039

collation "@1@" for encoding "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.39 11040

cursor "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.40 11041

permission denied to create temporary tables in database "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.41 11042

cannot create temporary tables during recovery

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.11.42 11045

"@1@" is not a table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.43 11046

"@1@" is not a foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.44 11047

must be owner of type @1 @ or type @2 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.45 11048

must be superuser

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.46 11049

must have CREATEROLE privilege

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.47 11050

schema "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.48 11051

@1@ is not a valid encoding name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.49 11052

only binary operators can have commutators

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.50 11053

only binary operators can have join selectivity

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.51 11054

only binary operators can merge join

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.52 11055

only binary operators can hash

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.53 11056

only boolean operators can have negators

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.54 11057

only boolean operators can have restriction selectivity

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.55 11058

only boolean operators can have join selectivity

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.56 11059

only boolean operators can merge join

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.57 11060

only boolean operators can hash

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.58 11061

operator @1@ already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.59 11062

operator cannot be its own negator or sort operator

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.60 11063

cannot remove dependency on @1@ because it is a system object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.61 11064

collation "@1@" for encoding "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.62 11065

collation "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.63 11066

cannot access temporary or unlogged relations during recovery

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.64 11068

could not implement GROUP BY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.65 11069

could not implement DISTINCT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.66 11070

could not implement window PARTITION BY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.67 11071

could not implement window ORDER BY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.68 11072

could not implement recursive UNION

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.69 11073

could not implement @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.70 11074

FULL JOIN is only supported with merge-joinable or hash-joinable join conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.71 11075

unexpected EOF on client connection

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.11.72 11076

invalid frontend message type @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.11.73 11077

statement: @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.74 11078

current transaction is aborted, commands ignored until end of transaction block

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.75 11079

duration: @1@ ms

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.76 11080

duration: @1@ ms statement: @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.77 11081

parse @1@: @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.78 11082

cannot insert multiple commands into a prepared statement

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.79 11083

duration: @1@ ms parse @2@: @3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.80 11084

bind @1@ to @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.81 11085

prepared statement "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.82 11086

bind message has @1@ parameter formats but @2@ parameters

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.11.83 11087

bind message supplies @1@ parameters, but prepared statement "@2@" requires @3@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.11.84 11088

incorrect binary data format in bind parameter @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.85 11089

duration: @1@ ms bind @2@@3@@4@: @5@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.86 11090

table "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.87 11091

@1@ @2@@3@@4@: @5@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.88 11092

duration: @1@ ms @2@ @3@@4@@5@: @6@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.89 11094

floating-point exception

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.11.90 11095

terminating autovacuum process due to administrator command

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.91 11096

terminating connection due to conflict with recovery

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.11.92 11097

terminating connection due to administrator command

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.11.93 11098

canceling authentication due to timeout

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.11.94 11099

canceling statement due to statement timeout

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.12 Message Numbers Beginning with 11100

2.12.1 11100

canceling autovacuum task

[Description]

Processing was canceled.

[System Processing]

Processing will be aborted.

[Action]

Check the message text.

2.12.2 11101

canceling statement due to conflict with recovery

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.12.3 11102

canceling statement due to user request

[Description]

Processing was canceled.

[System Processing]

Processing will be aborted.

[Action]

Check the message text.

2.12.4 11103

stack depth limit exceeded

[Description]

The depth of the execution stack exceeded the allowable value during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

If executing a complex SQL, modify it to a simple SQL.

2.12.5 11104

--@1@ requires a value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.6 11105

-c @1@ requires a value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.7 11107

@1@: invalid command-line arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.8 11108

@1@: no database nor user name specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.9 11109

invalid CLOSE message subtype @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.10 11110

invalid DESCRIBE message subtype @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.11 11111

disconnection: session time: @1@: @2@: @3@. @4@ user=@5@ database=@6@ host=@7@ @8@ @9@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.12 11112

permission denied: "@1@" is a system catalog

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.12.13 11113

cannot execute @1@ in a read-only transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.14 11114

cannot execute @1 @ during recovery

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.15 11115

cannot execute @1 @ within security-restricted operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.16 11116

must be superuser to do CHECKPOINT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.17 11117

invalid argument size @1 @ in function call message

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.18 11118

fastpath function call: "@1@" (OID @2@)

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.12.19 11119

duration: @1@ ms fastpath function call: "@2@" (OID @3@)

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.12.20 11120

function call message contains @1@ arguments but function requires @2@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.21 11121

function call message contains @1@ argument formats but @2@ arguments

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.22 11122

incorrect binary data format in function argument @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.23 11123

bind message has @1@ result formats but query has @2@ columns

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.24 11124

portal "@1@" cannot be run

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.25 11125

cursor can only scan forward

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.26 11126

could not open usermap file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.27 11127

unexpected delimiter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.28 11128

unexpected end of line or lexeme

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.29 11129

unexpected end of line

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.30 11130

thesaurus sample word "@1@" isn't recognized by subdictionary (rule @2@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.31 11131

thesaurus sample word "@1@" is a stop word (rule @2@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.32 11132

thesaurus substitute word "@1@" is a stop word (rule @2@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.33 11133

thesaurus substitute word "@1@" isn't recognized by subdictionary (rule @2@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.34 11134

thesaurus substitute phrase is empty (rule @1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.35 11135

multiple DictFile parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.36 11136

multiple Dictionary parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.37 11137

unrecognized Thesaurus parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.38 11138

missing DictFile parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.39 11139

missing Dictionary parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.40 11140

invalid text search configuration file name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.41 11141

could not open statistics file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.42 11142

unrecognized headline parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.43 11143

MinWords should be less than MaxWords

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.44 11144

MinWords should be positive

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.45 11145

ShortWord should be ≥ 0

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.46 11146

MaxFragments should be ≥ 0

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.47 11147

string is too long for tsvector (@1 @ bytes, max @2@ bytes)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.48 11148

multiple Accept parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.49 11149

unrecognized simple dictionary parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.50 11150

could not open log file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.51 11151

invalid regular expression: @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.52 11153

could not open synonym file "@1@": @2@**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.53 11154

IsPELL dictionary supports only "default", "long", and "num" flag values**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.54 11155

affix file contains both old-style and new-style commands**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.55 11156

unrecognized synonym parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.56 11157

missing Synonyms parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.57 11158

could not open thesaurus file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.58 11159

word is too long to be indexed

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.12.59 11160

conversion from wchar_t to server encoding failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.60 11161

text search parser does not support headline creation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.61 11162

multiple AffFile parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.62 11163

unrecognized lspell parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.63 11164

missing AffFile parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.64 11166

WAL streaming (max_wal_senders > 0) requires wal_level "replica" or "logical"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.65 11167

invalid list syntax in parameter "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.66 11168

could not create listen socket for "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.12.67 11169

could not create any TCP/IP sockets

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.12.68 11170

could not create Unix-domain socket in directory "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.12.69 11171

no socket created for listening

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.12.70 11172

could not create I/O completion port for child queue

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.12.71 11173

could not load pg_hba.conf

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.72 11174

@1@: could not locate matching postgres executable**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.73 11175

could not open directory "@1@": @2@**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.12.74 11176

directory "@1@" does not exist**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.75 11177

could not read permissions of directory "@1@": @2@**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.12.76 11178

specified data directory "@1@" is not a directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.77 11179

data directory "@1@" has wrong ownership

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.78 11180

data directory "@1@" has group or world access

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.79 11181

select() failed in postmaster: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.12.80 11182

incomplete startup packet

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.81 11183

invalid length of startup packet

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.82 11184

failed to send GSSAPI negotiation response: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.83 11185

unsupported frontend protocol @1@.@2@: server supports @3@.0 to @4@.@5@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.84 11187

invalid startup packet layout: expected terminator as last byte

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.12.85 11188

no PostgreSQL user name specified in startup packet

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.86 11189

the database system is starting up

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.12.87 11190

the database system is shutting down

[Description]

The database system is shutting down.

[System Processing]

Processing will be aborted.

[Action]

Retry any necessary applications or commands after restarting the database system.

2.12.88 11191

the database system is in recovery mode

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.12.89 11192

sorry, too many clients already

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.12.90 11193

wrong key in cancel request for process @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.12.91 11194

PID @1@ in cancel request did not match any process

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.12.92 11195

received SIGHUP, reloading configuration files

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.12.93 11196

@1@ was not reloaded

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.12.94 11197

received smart shutdown request

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.12.95 11198

received fast shutdown request

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.12.96 11199

aborting any active transactions

[Description]

Rollback any active transactions because the database system is being requested to shut down.

[System Processing]

Continues processing.

[Action]

Retry any necessary applications or commands after restarting the database system.

2.13 Message Numbers Beginning with 11200

2.13.1 11200

received immediate shutdown request

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.2 11201

aborting startup due to startup process failure

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.3 11202

database system is ready to accept connections

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.4 11203

terminating any other active server processes

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.5 11204

@1@ (PID @2@) exited with exit code @3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.6 11205

@1@ (PID @2@) was terminated by exception 0x@3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.7 11207

@1@ (PID @2@) was terminated by signal @3@: @4@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.8 11208

@1@ (PID @2@) exited with unrecognized status @3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.9 11209

abnormal database system shutdown

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.10 11210

all server processes terminated; reinitializing

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.11 11211

could not fork new process for connection: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.12 11212

connection received: host=@1@ port=@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.13 11213

connection received: host=@1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.14 11214

could not execute server process "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.15 11215

database system is ready to accept read only connections

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.16 11216

could not fork startup process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.17 11217

could not fork background writer process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.18 11218

could not fork WAL writer process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.19 11219

could not fork WAL receiver process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.20 11220

could not fork archiver: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.21 11221

could not duplicate socket @1@ for use in backend: error code @2@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.22 11224

checkpoint request failed

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.23 11225

compacted fsync request queue from @1@ entries to @2@ entries

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.24 11226

could not resolve "localhost": @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.13.25 11227

trying another address for the statistics collector

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.26 11228

could not create socket for statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

a) Confirm that the database server has not stopped.

b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.27 11229

could not bind socket for statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)

- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

a) If the COMMIT process is not executed after update, add the COMMIT process.

b) If the total number of update records in a single transaction is high, split it into short transactions.

c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

a) Confirm that the database server has not stopped.

b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.28 11230

could not get address of socket for statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)

- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

a) If the COMMIT process is not executed after update, add the COMMIT process.

- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.29 11231

could not connect socket for statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.30 11232

could not send test message on socket for statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.31 11233

select() failed in statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.32 11234

test message did not get through on socket for statistics collector

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.13.33 11235

could not receive test message on socket for statistics collector: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.34 11236

incorrect test message transmission on socket for statistics collector

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.35 11237

could not set statistics collector socket to nonblocking mode: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- If the COMMIT process is not executed after update, add the COMMIT process.
 - If the total number of update records in a single transaction is high, split it into short transactions.
 - If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - Confirm that the database server has not stopped.
 - If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.36 11238

disabling statistics collector for lack of working socket

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.37 11239

could not fork statistics collector: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.38 11241

unrecognized reset target: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.13.39 11243

could not read statistics message: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.13.40 11244

could not open temporary statistics file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.41 11245

could not write temporary statistics file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.13.42 11246

could not close temporary statistics file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.43 11247

could not rename temporary statistics file "@1@" to "@2@" : @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.44 11248

could not open dictionary file "@1@" : @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.45 11249

corrupted statistics file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.46 11250

database hash table corrupted during cleanup --- abort

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.47 11252

could not read from logger pipe: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.13.48 11253

logger shutting down

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.49 11254

could not create pipe for syslog: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.13.50 11255

could not fork system logger: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.51 11256

could not redirect stdout: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.52 11257

could not redirect stderr: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.53 11258

could not open affix file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.54 11259

disabling automatic rotation (use SIGHUP to re-enable)

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.55 11260

could not fork process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.56 11261

archive_mode enabled, yet archive_command is not set

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.57 11262

archiving write-ahead log file "@1@" failed too many times, will try again later

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.58 11263

archive command failed with exit code @1@

[Description]

An error occurred during executing the command specified by archive_command parameter at postgresql.conf.

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the messages shown before this message and the return code shown in this message. And then work around if necessary.

2.13.59 11264

archive command was terminated by exception 0x@1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.60 11266

archive command was terminated by signal @1@: @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.61 11267

archive command exited with unrecognized status @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.13.62 11268

archived write-ahead log file "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.63 11269

could not open archive status directory "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.64 11270

could not fork autovacuum launcher process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.65 11271

autovacuum launcher started

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.66 11272

autovacuum launcher shutting down

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.67 11273

could not fork autovacuum worker process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.68 11274

autovacuum: processing database "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.69 11275

autovacuum: dropping orphan temp table "@1@.@2@.@3@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.70 11276

autovacuum: found orphan temp table "@1@"."@2@" in database "@3@"

[Description]

Uncollected garbage of the temporary table was found during automatic vacuuming

[System Processing]

Continues processing.

[Action]

No action required. The garbage of the temporary table will be collected automatically later.

If you want to collect it and obtain the storage space immediately,

drop the schema derived from @1 with the database user having superuser permission.

2.13.71 11277

autovacuum not started because of misconfiguration

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.72 11278

no empty local buffer available

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.13.73 11279

cannot cluster temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.13.74 11280

unexpected data beyond EOF in block @1@ of relation @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.75 11281

Continues processing past damaged page headers.

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.76 11283

could not write block @1@ of @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.77 11284

could not truncate file "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.13.78 11285

cannot extend file "@1@" beyond @2@ blocks

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.13.79 11287

could not extend file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.13.80 11288

could not extend file "@1@": wrote only @2@ of @3@ bytes at block @4@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.13.81 11289

could not read block @1@ in file "@2@": @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.82 11290

could not read block @1@ in file "@2@": read only @3@ of @4@ bytes

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.83 11291

could not write block @1@ in file "@2@": @3@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.13.84 11292

could not write block @1@ in file "@2@": wrote only @3@ of @4@ bytes

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.13.85 11293

could not truncate file "@1@" to @2@ blocks: it's only @3@ blocks now

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.86 11294

could not truncate file "@1@" to @2@ blocks: @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.87 11296

could not forward fsync request because request queue is full

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.13.88 11297

could not open file "@1@" (target block @2@): @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.89 11298

could not seek to end of file "@1@" : @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.13.90 11299

memory for serializable conflict tracking is nearly exhausted

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14 Message Numbers Beginning with 11300

2.14.1 11300

not enough shared memory for data structure "@1@" (@2@ bytes requested)

[Description]

There was insufficient free space in the database server's shared memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.14.2 11301

deferrable snapshot was unsafe; trying a new one

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.3 11302

out of shared memory

[Description]

There was insufficient free space in the database server's shared memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.14.4 11303

could not serialize access due to read/write dependencies among transactions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.5 11304

deadlock detected

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.14.6 11305

cannot acquire lock mode @1@ on database objects while recovery is in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.7 11307

process @1@ avoided deadlock for @2@ on @3@ by rearranging queue order after @4@.@5@ ms

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.8 11308

process @1@ detected deadlock while waiting for @2@ on @3@ after @4@.@5@ ms

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.9 11309

process @1@ still waiting for @2@ on @3@ after @4@.@5@ ms

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.10 11310

process @1@ acquired @2@ on @3@ after @4@.@5@ ms

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.14.11 11311

process @1@ failed to acquire @2@ on @3@ after @4@.@5@ ms

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.12 11314

getrlimit failed: @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.13 11315

insufficient file descriptors available to start server process

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.14.14 11316

out of file descriptors: @1@; release and retry

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.14.15 11317

temporary file: path "@1@", size @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.14.16 11318

could not read directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.17 11320

could not create directory "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.14.18 11322

could not create ShmemIndex entry for data structure "@1@"

[Description]

There was insufficient free space in the database server's shared memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.14.19 11323

ShmemIndex entry size is wrong for data structure "@1@" : expected @2@, actual @3@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.14.20 11324

requested shared memory size overflows size_t

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.21 11325

corrupted page pointers: lower = @1@, upper = @2@, special = @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.22 11326

corrupted line pointer: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.23 11327

corrupted item lengths: total @1@, available space @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.24 11328

corrupted line pointer: offset = @1@, size = @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.25 11329

could not write block @1@ of temporary file: @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.14.26 11330

could not read block @1@ of temporary file: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.27 11331

could not create unique index "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.28 11332

could not find function "@1@" in file "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.29 11333

could not access file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.30 11334

could not load library "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.31 11335

incompatible library "@1@": missing magic block

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.32 11336

incompatible library "@1@": version mismatch

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.33 11337

incompatible library "@1@": magic block mismatch

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.34 11338

access to library "@1@" is not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.35 11339

invalid macro name in dynamic library path: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.36 11340

zero-length component in parameter "dynamic_library_path"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.37 11341

component in parameter "dynamic_library_path" is not an absolute path

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.38 11342

could not determine actual result type for function "@1@" declared to return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.39 11343

number of aliases does not match number of columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.40 11344

no column alias was provided

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.41 11345

could not determine row description for function returning record

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.42 11346

internal function "@1@" is not in internal lookup table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.43 11347

unrecognized API version @1@ reported by info function "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.44 11349

cached plan must not change result type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.45 11350

"@1@" is not a type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.46 11351

record type has not been registered

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.47 11352

@1@ is not an enum

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.48 11353

could not create relation-cache initialization file "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.49 11354

cannot PREPARE a transaction that modified relation mapping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.50 11355

could not open file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.51 11357

relation mapping file "@1@" contains invalid data

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.52 11358

relation mapping file "@1@" contains incorrect checksum

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.53 11359

could not write file "@1@"

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.14.54 11360

could not fsync file "@1@" : @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.55 11361

could not close file "@1@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.56 11362

argument type @1@ is only a shell

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.57 11363

no binary input function available for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.58 11364

no binary output function available for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.59 11365

no input function available for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.60 11366

no output function available for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.61 11367

could not reopen file "@1@" as stderr: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.62 11368

could not reopen file "@1@" as stdout: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.14.63 11369

cursor "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.64 11370

closing existing cursor "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.65 11371

cannot drop active portal "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.66 11372

cannot PREPARE a transaction that has created a cursor WITH HOLD

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.67 11373

word is too long (@1@ bytes, max @2@ bytes)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.68 11374

string is too long for tsvector (@1 @ bytes, max @2@ bytes)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.69 11375

argument of ntile must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.70 11376

argument of nth_value must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.71 11379

integer out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.72 11380

argument must be empty or one-dimensional array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.73 11381

cannot concatenate incompatible arrays

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.74 11382

invalid number of dimensions: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.75 11383

could not determine input data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.76 11385

division by zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.77 11387

timestamp out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.78 11391

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.14.79 11398

global tablespace never has databases

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.14.80 11399

@1@ is not a tablespace OID

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.15 Message Numbers Beginning with 11400

2.15.1 11400

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.2 11401

syntax error in tsquery: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.3 11402

syntax error in tsvector: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.4 11403

there is no escaped character: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.5 11404

wrong position info in tsvector: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.6 11405

sequence "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.7 11406

more than one function named "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.8 11407

more than one operator named @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.9 11408

too many arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.10 11409

invalid name syntax

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.11 11410

expected a left parenthesis

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.12 11411

expected a right parenthesis

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.13 11412

expected a type name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.14 11413

improper type name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.15 11414

invalid type modifier

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.16 11415

TIME(@1@)@2@ precision must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.17 11416

TIME(@1@)@2@ precision reduced to maximum allowed, @3@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.15.18 11417

date out of range: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.19 11419

timestamp cannot be NaN

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.20 11420

timestamp(@1@) precision must be between @2@ and @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.21 11421

interval out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.22 11422

invalid INTERVAL type modifier

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.23 11423

TIMESTAMP(@1 @)@2@ precision must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.24 11424

TIMESTAMP(@1 @)@2@ precision reduced to maximum allowed, @3@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.15.25 11425

interval(@1 @) precision must be between @2@ and @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.26 11426

cannot subtract infinite timestamps

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.27 11427

timestamp units "@1@" not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.28 11428

"time" units "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.29 11429

timestamp with time zone units "@1@" not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.30 11430

"time with time zone" units "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.31 11431

interval units "@1@" not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.32 11432

timestamp units "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.33 11434

time zone "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.34 11435

interval time zone "@1@" must not include months or days

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.35 11436

step size cannot equal zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.36 11437

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.37 11438

value "@1@" is out of range for type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.38 11439

bigint out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.39 11440

smallint out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.40 11441

OID out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.41 11442

input of anonymous composite types is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.42 11443

malformed record literal: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.43 11444

wrong number of columns: @1@, expected @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.44 11445

wrong data type: @1@, expected @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.45 11446

improper binary format in record column @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.46 11447

cannot compare dissimilar column types @1@ and @2@ at record column @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.47 11448

cannot compare record types with different numbers of columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.48 11449

int2vector has too many elements

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.49 11450

invalid int2vector data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.50 11451

oidvector has too many elements

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.51 11452

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.52 11453

invalid cidr value: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.53 11454

could not format inet value: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.54 11455

invalid address family in external "@1@" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.55 11456

invalid bits in external "@1@" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.56 11457

invalid length in external "@1@" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.57 11458

invalid external "cidr" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.58 11459

invalid mask length: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.59 11460

could not format cidr value: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.60 11461

cannot AND inet values of different sizes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.61 11462

cannot OR inet values of different sizes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.62 11463

input is out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.63 11464

cannot subtract inet values of different sizes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.64 11465

invalid Datum pointer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.65 11466

dimension values cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.66 11467

"[" must introduce explicitly-specified array dimensions.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.67 11468

upper bound cannot be less than lower bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.68 11469

Array value must start with "{" or dimension information.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.69 11471

Specified array dimensions do not match array contents.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.70 11472

malformed array literal: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.71 11473

array size exceeds the maximum allowed (@1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.72 11474

invalid array flags

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.73 11475

wrong element type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.74 11476

improper binary format in array element @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.75 11477

slices of fixed-length arrays not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.76 11478

wrong number of array subscripts

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.77 11479

array subscript out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.78 11480

cannot assign null value to an element of a fixed-length array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.79 11481

updates on slices of fixed-length arrays not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.80 11482

source array too small

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.81 11483

null array element not allowed in this context

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.82 11484

cannot compare arrays of different element types

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.83 11485

could not identify a hash function for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.84 11486

dimension array or low bound array cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.85 11487

wrong range of array subscripts

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.86 11491

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.87 11492

"@1@" is out of range for type real

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.88 11493

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.89 11494

"@1@" is out of range for type double precision

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.90 11495

cannot take square root of a negative number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.91 11496

zero raised to a negative power is undefined

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.92 11497

a negative number raised to a non-integer power yields a complex result

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.93 11498

cannot take logarithm of zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.15.94 11499

cannot take logarithm of a negative number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16 Message Numbers Beginning with 11500

2.16.1 11500

result is out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.2 11501

count must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.3 11502

operand, lower bound, and upper bound cannot be NaN

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.4 11503

lower and upper bounds must be finite

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.5 11504

lower bound cannot equal upper bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.6 11505

requested length too large

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.7 11506

requested character too large

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.8 11507

requested character too large for encoding: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.9 11508

null character not permitted

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.10 11509

typmod array must be typecstring[]

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.11 11510

typmod array must be one-dimensional

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.12 11511

typmod array must not contain nulls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.13 11512

suppress_redundant_updates_trigger: must be called as trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.14 11513

suppress_redundant_updates_trigger: must be called on update

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.15 11514

suppress_redundant_updates_trigger: must be called before update

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.16 11515

suppress_redundant_updates_trigger: must be called for each row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.17 11517

value "@1@" is out of range for type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.18 11518

invalid oidvector data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.19 11519

invalid line specification: must be two distinct points

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.20 11521

date/time field value out of range: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.21 11522

interval field value out of range: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.22 11523

time zone displacement out of range: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.23 11524

unrecognized encoding: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.24 11525

invalid hexadecimal digit: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.25 11526

invalid hexadecimal data: odd number of digits

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.26 11527

unexpected "=" while decoding base64 sequence

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.27 11528

invalid symbol "@1@" while decoding base64 sequence

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.28 11529

invalid base64 end sequence

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.29 11530

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.30 11531

ts_stat query must return one tsvector column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.31 11532

tsvector column "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.32 11533

column "@1@" is not of tsvector type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.33 11534

configuration column "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.34 11535

column "@1@" is not of regconfig type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.35 11536

configuration column "@1@" must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.36 11537

text search configuration name "@1@" must be schema-qualified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.37 11538

column "@1@" is not of a character type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.38 11539

ts_rewrite query must return two tsquery columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.39 11540

encoding conversion from @1@ to ASCII not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.40 11541

"@1@" is not a valid encoding name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.41 11542

@1@ is not a valid encoding code

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.42 11543

insert or update on table "@1@" violates foreign key constraint "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.43 11544

function "@1@" was not called by trigger manager

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.44 11545

function "@1@" must be fired AFTER ROW

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.45 11546

function "@1@" must be fired for INSERT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.46 11547

function "@1@" must be fired for UPDATE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.47 11548

function "@1@" must be fired for INSERT or UPDATE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.48 11549

function "@1@" must be fired for DELETE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.49 11550

no pg_constraint entry for trigger "@1@" on table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.50 11551

referential integrity query on "@1@" from constraint "@2@" on "@3@" gave unexpected result

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.16.51 11552

update or delete on table "@1@" violates foreign key constraint "@2@" on table "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.52 11553

invalid input value for enum @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.53 11554

invalid internal value for enum: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.54 11555

could not determine actual enum type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.55 11556

enum @1@ contains no values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.56 11557

invalid format specification for an interval value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.57 11558

"EEEE" must be the last pattern used

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.58 11559

"9" must be ahead of "PR"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.59 11560

"0" must be ahead of "PR"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.60 11561

multiple decimal points

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.61 11562

cannot use "V" and decimal point together

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.62 11563

cannot use "S" twice

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.63 11564

cannot use "S" and "PL"/"MI"/"SG"/"PR" together

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.64 11565

cannot use "S" and "MI" together

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.65 11566

cannot use "S" and "PL" together

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.66 11567

cannot use "S" and "SG" together

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.67 11568

cannot use "PR" and "S"/"PL"/"MI"/"SG" together

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.68 11569

cannot use "EEEE" twice

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.69 11570

"EEEE" is incompatible with other formats

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.70 11571

"@1@" is not a view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.71 11572

could not determine which collation to use for regular expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.72 11573

could not determine which collation to use for @1@ function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.73 11574

could not determine which collation to use for @1@ function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.74 11575

invalid combination of date conventions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.75 11576

conflicting values for "@1@" field in formatting string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.76 11577

source string too short for "@1@" formatting field

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.77 11578

invalid argument for @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.78 11579

value for "@1@" in source string is out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.79 11581

invalid input string for "Y,YYY"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.80 11582

hour "@1@" is invalid for the 12-hour clock

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.81 11584

cannot calculate day of year without year information

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.82 11585

"EEEE" not supported for input

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.83 11586

"RN" not supported for input

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.84 11587

could not open directory "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.85 11588

array of weight must be one-dimensional

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.86 11589

array of weight is too short

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.87 11590

array of weight must not contain nulls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.88 11591

weight out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.89 11592

regular expression failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.90 11593

invalid regular expression option: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.91 11594

invalid escape string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.92 11595

@1@ does not support the "global" option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.93 11596

unsupported XML feature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.94 11597

invalid encoding name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.95 11598

invalid XML comment

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.16.96 11599

not an XML document

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17 Message Numbers Beginning with 11600

2.17.1 11600

invalid XML processing instruction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.2 11601

xmlvalidate is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.3 11602

could not initialize XML library

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.17.4 11603

date out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.5 11604

invalid query

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.6 11605

invalid array for XML namespace mapping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.7 11606

empty XPath expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.8 11607

neither namespace name nor URI may be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.9 11608

could not register XML namespace with name "@1@" and URI "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.10 11609

value "@1@" is out of range for type smallint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.11 11610

value "@1@" is out of range for type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.12 11611

value "@1@" is out of range for 8-bit integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.13 11612

gtsvector_in not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.14 11613

identifier too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.15 11615

no operand in tsquery: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.16 11616

value is too big in tsquery: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.17 11617

operand is too long in tsquery: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.18 11618

word is too long in tsquery: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.19 11619

text-search query doesn't contain lexemes: "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.17.20 11620

length for type @1@ must be at least 1**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.21 11621

length for type @1@ cannot exceed @2@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.22 11622

value too long for type character(@1@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.23 11623

value too long for type character varying(@1@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.24 11624

reference to parent directory ("..") not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.25 11625

absolute path not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.26 11626

path must be in or below the current directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.27 11627

could not open file "@1@" for writing: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.17.28 11628

could not seek in file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.17.29 11629

must be superuser to read files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.30 11630

requested length cannot be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.31 11631

must be superuser to get file information

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.32 11632

must be superuser to get directory listings

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.33 11633

too many points requested

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.34 11639

invalid number of points in external "path" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.35 11641

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.36 11642

function "dist_lb" not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.37 11643

function "close_lb" not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.38 11645

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.39 11646

invalid number of points in external "polygon" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.40 11647

function "poly_distance" not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.41 11648

function "path_center" not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.42 11649

open path cannot be converted to polygon

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.43 11650

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.44 11652

invalid radius in external "circle" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.45 11653

cannot convert circle with radius zero to polygon

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.46 11654

must request at least 2 points

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.47 11656

bit string length @1@ does not match type bit(@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.48 11657

"@1@" is not a valid binary digit

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.49 11658

"@1@" is not a valid hexadecimal digit

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.50 11659

invalid length in external bit string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.51 11660

bit string too long for type bit varying(@1 @)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.52 11661

negative substring length not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.53 11662

cannot AND bit strings of different sizes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.54 11663

cannot OR bit strings of different sizes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.55 11664

cannot XOR bit strings of different sizes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.56 11665

bit index @1@ out of valid range (0..@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.57 11666

new bit must be 0 or 1

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.58 11667

unrecognized key word: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.59 11668

missing name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.60 11669

missing "=" sign

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.61 11670

invalid mode character: must be one of "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.62 11671

a name must follow the "/" sign

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.63 11672

defaulting grantor to user ID @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.17.64 11673

ACL array contains wrong data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.65 11674

ACL arrays must be one-dimensional

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.66 11675

ACL arrays must not contain null values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.67 11676

extra garbage at the end of the ACL specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.68 11677

grant options cannot be granted back to your own grantor

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.69 11678

dependent privileges exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.70 11679

aclinsert is no longer supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.71 11680

acremove is no longer supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.72 11681

unrecognized privilege type: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.73 11682

must be member of role "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.74 11683

view "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.75 11684

INTERVAL(@1@) precision must not be negative

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.76 11685

INTERVAL(@1@) precision reduced to maximum allowed, @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.17.77 11686

timestamp out of range: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.78 11687

cannot subtract infinite dates

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.79 11688

date out of range for timestamp

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.80 11690

time out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.81 11691

interval units "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.82 11692

time zone displacement out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.83 11693

timestamp with time zone units "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.84 11695

"@1@" is not a composite type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.85 11696

invalid input syntax for type @1@: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.86 11697

invalid octet value in "macaddr" value: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.87 11698

could not determine which collation to use for @1@ function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.17.88 11699

could not convert string to UTF-16: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18 Message Numbers Beginning with 11700

2.18.1 11700

could not compare Unicode strings: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.2 11701

index @1@ out of valid range, 0..@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.3 11702

field position must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.4 11703

unrecognized format() type specifier "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.5 11705

format specifies argument 0, but arguments are numbered from 1

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.6 11706

could not create locale "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.7 11707

collations with different collate and ctype values are not supported on this platform

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.8 11708

ICU is not supported in this build

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.9 11709

invalid multibyte character for locale

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.10 11710

could not determine which collation to use for ILIKE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.11 11711

text-search query contains only stop words or doesn't contain lexemes, ignored

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.18.12 11714

invalid sign in external "numeric" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.13 11715

invalid digit in external "numeric" value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.14 11716

NUMERIC precision @1@ must be between 1 and @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.15 11717

NUMERIC scale @1@ must be between 0 and precision @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.16 11718

invalid NUMERIC type modifier

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.17 11719

value overflows numeric format

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.18 11720

cannot convert NaN to integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.19 11721

cannot convert NaN to bigint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.20 11722

cannot convert NaN to smallint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.21 11723

numeric field overflow

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.22 11725

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.23 11727

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.24 11728

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.25 11729

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.26 11730

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.27 11731

cannot accept a value of type language_handler

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.28 11732

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.29 11733

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.30 11734

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.31 11735

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.32 11736

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.33 11737

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.34 11738

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.35 11739

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.36 11740

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.37 11741

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.38 11742

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.39 11743

cannot accept a value of a shell type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.40 11744

cannot display a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.41 11745

cannot accept a value of type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.42 11746

"char" out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.43 11747

LIKE pattern must not end with escape character

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.44 11750

function @1@ is not an aggregate

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.45 11751

rule "@1@" has unsupported event type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.46 11752

replication connection authorized: user=@1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.18.47 11753

connection authorized: user=@1@ database=@2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.18.48 11754

database "@1@" has disappeared from pg_database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.49 11755

database "@1@" is not currently accepting connections

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.50 11756

permission denied for database "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.51 11757

too many connections for role "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.52 11758

database locale is incompatible with operating system

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.53 11759

no roles are defined in this database system

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.18.54 11760

new replication connections are not allowed during database shutdown

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.55 11761

must be superuser to connect during database shutdown

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.56 11762

must be superuser to connect in binary upgrade mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.57 11763

remaining connection slots are reserved for non-replication superuser connections

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.58 11765

template database "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.59 11766

database @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.60 11767

could not stat directory "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.61 11768

could not change directory to "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.62 11769

cannot set parameter "@1@" within security-restricted operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.63 11770

role "@1@" is not permitted to log in

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.64 11771

too many connections for database "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.65 11772

permission denied to set session authorization

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.66 11773

invalid role OID: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.67 11774

could not create lock file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.18.68 11775

could not open stop-word file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.69 11776

could not open lock file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.70 11777

lock file "@1@" already exists

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.71 11778

pre-existing shared memory block (key @1@, ID @2@) is still in use

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.18.72 11779

could not remove old lock file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.73 11780

could not read lock file "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.18.74 11781

could not read from file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.18.75 11782

"@1@" is not a valid data directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.76 11784

loaded library "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.18.77 11785

unexpected encoding ID @1@ for WIN character sets

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.18.78 11786

unexpected encoding ID @1@ for ISO 8859 character sets

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.18.79 11787

conversion between @1@ and @2@ is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.80 11788

default conversion function for encoding "@1@" to "@2@" does not exist

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.18.81 11789

invalid source encoding name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.82 11790

invalid destination encoding name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.83 11791

invalid byte value for encoding "@1@": 0x@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.84 11792

encoding name too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.85 11793

invalid byte sequence for encoding "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.86 11795

invalid encoding number: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.87 11796

unrecognized configuration parameter "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.88 11797

parameter "@1@" cannot be changed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.89 11798

parameter "@1@" cannot be changed without restarting the server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.18.90 11799

parameter "@1@" cannot be changed now

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19 Message Numbers Beginning with 11800

2.19.1 11800

parameter "@1@" cannot be set after connection start

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.2 11801

permission denied to set role "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.3 11802

cannot set parameter "@1@" within security-definer function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.4 11803

invalid value for parameter "@1@": "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.5 11804

@1@@2@@3@ is outside the valid range for parameter "@4@" (@5@ .. @6@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.6 11805

@1@ requires a numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.7 11806

@1@@2@@3@ is outside the valid range for parameter "@4@" (@5@ .. @6@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.8 11807

must be superuser or a member of pg_read_all_settings to examine "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.9 11808

SET @1@ takes only one argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.10 11809

SET requires parameter name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.11 11810

attempt to redefine parameter "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.19.12 11811

could not parse setting for parameter "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.13 11812

invalid value for parameter "@1@" : @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.14 11813

invalid value for parameter "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.15 11814

parameter "@1@" removed from configuration file, reset to default

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.16 11815

parameter "@1@" changed to "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.17 11816

could not open configuration file "@1@": maximum nesting depth exceeded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.18 11817

syntax error in file "@1@" line @2@, near end of line

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.19 11818

syntax error in file "@1@" line @2@, near token "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.20 11819

user mapping not found for "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.21 11820

foreign-data wrapper "@1@" has no handler

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.22 11821

invalid option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.23 11822

foreign-data wrapper "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.24 11823

index "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.25 11824

could not create shared memory segment: @1@

[Description]

There was insufficient free space in the database server's shared memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.19.26 11825

could not stat data directory "@1@" : @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.19.27 11826

could not create semaphore: error code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.19.28 11827

could not lock semaphore: error code @1@

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.19.29 11828

could not unlock semaphore: error code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.19.30 11829

could not try-lock semaphore: error code @1@

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.19.31 11830

could not create semaphores: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.19.32 11832

pre-existing shared memory block is still in use

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.19.33 11833

oldest xmin is far in the past

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.34 11834

some databases have not been vacuumed in over 2 billion transactions

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.35 11835

skipping analyze of "@1@" --- lock not available

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.36 11836

skipping "@1@" --- only superuser can analyze it

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.37 11837

skipping "@1@" --- only superuser or database owner can analyze it

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.38 11838

skipping "@1@" --- only table or database owner can analyze it

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.39 11839

skipping "@1@" --- cannot analyze non-tables or special system tables

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.40 11840

operator class "@1@" does not exist for access method "@2@", skipping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.41 11841

operator family "@1@" does not exist for access method "@2@", skipping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.42 11842

operator family "@1@" for access method "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.43 11843

access method "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.44 11844

must be superuser to create an operator class

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.45 11845

invalid operator number @1@, must be between 1 and @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.46 11846

invalid procedure number @1@, must be between 1 and @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.47 11847

storage type specified more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.48 11848

storage type cannot be different from data type for access method "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.49 11849

operator class "@1@" for access method "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.50 11850

could not make operator class "@1@" be default for type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.51 11851

must be superuser to create an operator family

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.52 11852

must be superuser to alter an operator family

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.53 11853

operator argument types must be specified in ALTER OPERATOR FAMILY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.54 11854

STORAGE cannot be specified in ALTER OPERATOR FAMILY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.55 11855

one or two argument types must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.56 11856

index operators must be binary

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.57 11857

access method "@1@" does not support ordering operators

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.58 11858

index search operators must return boolean

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.59 11859

btree comparison procedures must have two arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.60 11860

btrees comparison procedures must return integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.61 11861

hash procedures must have one argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.62 11862

hash procedures must return integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.63 11863

associated data types must be specified for index support procedure

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.64 11864

procedure number @1@ for (@2@, @3@) appears more than once**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.65 11865

operator number @1@ for (@2@, @3@) appears more than once**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.66 11866

operator @1@(@2@, @3@) already exists in operator family "@4@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.67 11867

function @1@(@2@, @3@) already exists in operator family "@4@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.68 11868

operator @1@(@2@, @3@) does not exist in operator family "@4@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.69 11869

function @1@(@2@,@3@) does not exist in operator family "@4@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.70 11870

operator class "@1@" for access method "@2@" already exists in schema "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.71 11871

operator family "@1@" for access method "@2@" already exists in schema "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.72 11872

no security label providers have been loaded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.73 11873

must specify provider when multiple security label providers have been loaded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.74 11874

security label provider "@1@" is not loaded

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.75 11875

"@1@" is not a table, view, materialized view, composite type, or foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.76 11876

aggregate attribute "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.77 11877

parameter "lc_collate" must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.78 11878

database "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.79 11879

collation "@1@" for encoding "@2@" already exists in schema "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.80 11880

function @1@ already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.81 11881

unrecognized value for EXPLAIN option "@1@": "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.82 11882

unrecognized EXPLAIN option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.83 11883

EXPLAIN option BUFFERS requires ANALYZE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.84 11884

type "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.85 11885

collation attribute "@1@" not recognized

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.86 11886

aggregate stype must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.87 11887

aggregate sfunc must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.88 11888

aggregate input type must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.89 11889

basetype is redundant with aggregate input type specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.90 11890

aggregate transition data type cannot be @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.91 11891

function @1@(@2@) does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.92 11892

collation "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.19.93 11894

vacuuming "@1@.@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.19.94 11896

"@1@": removed @2@ row versions in @3@ pages

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.19.95 11897

"@1@": found @2@ removable, @3@ nonremovable row versions in @4@ pages

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.19.96 11898

"@1@": removed @2@ row versions in @3@ pages

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.19.97 11899

scanned index "@1@" to remove @2@ row versions

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20 Message Numbers Beginning with 11900

2.20.1 11900

index "@1@" now contains @2@ row versions in @3@ pages

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.2 11901

"@1@": truncated @2@ to @3@ pages

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.3 11902

option "@1@" not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.4 11903

option "@1@" provided more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.5 11904

permission denied to change owner of foreign-data wrapper "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.6 11905

function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.7 11906

permission denied to create foreign-data wrapper "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.8 11907

foreign-data wrapper "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.9 11908

permission denied to alter foreign-data wrapper "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.10 11909

changing the foreign-data wrapper handler can change behavior of existing foreign tables

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.11 11910

changing the foreign-data wrapper validator can cause the options for dependent objects to become invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.12 11912

foreign-data wrapper "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.13 11913

server "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.14 11914

type "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.15 11916

user mapping for "@1@" does not exist for server "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.16 11917

server "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.17 11918

user mapping for "@1@" does not exist for server "@2@", skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.18 11919

foreign table "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.19 11920

collation "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.20 11921

tablespace "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.21 11922

conversion "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.22 11923

constraint "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.23 11924

schema "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.24 11925

extension "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.25 11926

operator @1@ does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.26 11927

@1@ is not a domain

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.27 11929

table "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.28 11931

only shared relations can be placed in pg_global tablespace

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.29 11933

truncate cascades to table "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.30 11934

cannot vacuum temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.31 11935

cannot inherit from temporary relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.32 11936

relation "@1@" would be inherited from more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.33 11937

merging multiple inherited definitions of column "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.34 11938

inherited column "@1@" has a type conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.35 11939

inherited column "@1@" has a collation conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.36 11940

inherited column "@1@" has a storage parameter conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.37 11941

merging column "@1@" with inherited definition

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.38 11942

column "@1@" has a type conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.39 11943

column "@1@" has a collation conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.40 11944

column "@1@" has a storage parameter conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.41 11945

column "@1@" inherits conflicting default values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.42 11946

check constraint name "@1@" appears multiple times but with different expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.43 11947

cannot rename column of typed table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.44 11948

"@1@" is not a table, view, materialized view, composite type, index, or foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.45 11949

inherited column "@1@" must be renamed in child tables too

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.46 11950

cannot rename system column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.47 11951

cannot rename inherited column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.48 11952

column "@1@" of relation "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.49 11953

cannot @1@ "@2@" because it is being used by active queries in this session

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.20.50 11954

cannot @1@ "@2@" because it has pending trigger events

[Description]

An error occurred because execution is temporarily impossible.

[System Processing]

Processing will be aborted.

[Action]

Restart the application. If the same error occurs when you restart the application, to check if there are any problems in the database server.

2.20.51 11955

type @1@ is not a composite type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.52 11956

cannot rewrite system relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.53 11957

cannot truncate temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.54 11958

rewriting table "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.55 11959

verifying table "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.56 11960

column "@1@" contains null values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.57 11961

check constraint "@1@" is violated by some row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.58 11962

"@1@" is not a table, materialized view, or index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.59 11963

"@1@" is not a table or view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.60 11964

"@1@" is not a table or foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.61 11965

"@1@" is not a table, composite type, or foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.62 11966

"@1@" is of the wrong type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.63 11967

cannot alter type "@1@" because it is the type of a typed table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.64 11968

type @1@ is not a domain

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.65 11969

cannot add column to typed table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.66 11970

child table "@1@" has different type for column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.67 11971

child table "@1@" has different collation for column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.68 11973

merging definition of column "@1@" for child "@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.69 11974

column must be added to child tables too

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.70 11975

cannot alter system column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.71 11976

column "@1@" is in a primary key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.72 11977

statistics target @1@ is too low

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.73 11978

lowering statistics target to @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.74 11979

invalid storage type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.75 11980

column data type @1@ can only have storage PLAIN

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.76 11981

cannot drop column from typed table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.77 11982

column "@1@" of relation "@2@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.20.78 11983

cannot drop system column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.79 11984

cannot drop inherited column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.80 11985

ALTER TABLE / ADD CONSTRAINT USING INDEX will rename index "@1@" to "@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.20.81 11986

constraint must be added to child tables too

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.82 11987

inherited relation "@1@" is not a table or foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.83 11988

constraints on permanent tables may reference only permanent tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.84 11989

constraints on unlogged tables may reference only permanent or unlogged tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.85 11990

constraints on temporary tables may reference only temporary tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.86 11991

number of referencing and referenced columns for foreign key disagree

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.87 11992

foreign key constraint "@1@" cannot be implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.88 11993

constraint "@1@" of relation "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.89 11994

column "@1@" referenced in foreign key constraint does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.90 11995

cannot have more than @1@ keys in a foreign key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.91 11996

cannot use a deferrable primary key for referenced table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.92 11997

there is no primary key for referenced table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.93 11998

cannot use a deferrable unique constraint for referenced table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.20.94 11999

there is no unique constraint matching given keys for referenced table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21 Message Numbers Beginning with 12000

2.21.1 12000

validating foreign key constraint "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.2 12001

cannot drop inherited constraint "@1@" of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.3 12002

constraint "@1@" of domain "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.4 12003

constraint "@1@" of relation "@2@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.5 12004

cannot alter column type of typed table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.6 12005

cannot alter inherited column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.7 12007

cannot use subquery in index expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.8 12010

column "@1@" cannot be cast automatically to type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.9 12011

type of inherited column "@1@" must be changed in child tables too

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.10 12012

cannot alter type of column "@1@" twice

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.11 12013

default for column "@1@" cannot be cast automatically to type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.12 12014

cannot alter type of a column used by a view or rule

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.13 12015

cannot alter type of a column used in a trigger definition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.14 12016

cannot change owner of index "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.15 12017

cannot change owner of sequence "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.16 12018

"@1@" is not a table, materialized view, index, or foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.17 12019

index "@1@" for table "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.18 12020

cannot have multiple SET TABLESPACE subcommands

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.19 12021

"@1@" is not a table, view, materialized view, index, or TOAST table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.20 12022

cannot move system relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.21 12023

cannot rewrite temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.22 12024

cannot change inheritance of typed table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.23 12025

circular inheritance not allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.24 12027

column "@1@" in child table must be marked NOT NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.25 12028

child table is missing column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.26 12029

child table "@1@" has different definition for check constraint "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.27 12030

child table is missing constraint "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.28 12031

relation "@1@" is not a parent of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.29 12032

typed tables cannot inherit

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.30 12033

table is missing column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.31 12034

table has column "@1@" where type requires "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.32 12035

table "@1@" has different type for column "@2@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.33 12036

table has extra column "@1@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.34 12037

"@1@" is not a typed table**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.35 12038

cannot move an owned sequence into another schema**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.36 12039

conversion "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.37 12040

unlogged sequences are not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.38 12041

nextval: reached maximum value of sequence "@1@" (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.39 12042

nextval: reached minimum value of sequence "@1@" (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.40 12043

currval of sequence "@1@" is not yet defined in this session

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.41 12044

lastval is not yet defined in this session

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.42 12045

setval: value @1 @ is out of bounds for sequence "@2@" (@3@..@4@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.43 12046

INCREMENT must not be zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.44 12047

MINVALUE (@1 @) must be less than MAXVALUE (@2 @)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.45 12048

START value (@1 @) cannot be less than MINVALUE (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.46 12049

START value (@1 @) cannot be greater than MAXVALUE (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.47 12050

RESTART value (@1 @) cannot be less than MINVALUE (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.48 12051

RESTART value (@1 @) cannot be greater than MAXVALUE (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.49 12052

CACHE (@1@) must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.50 12053

invalid OWNED BY option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.51 12054

sequence must have same owner as table it is linked to

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.52 12055

sequence must be in same schema as table it is linked to

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.53 12056

invalid cursor name: must not be empty

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.54 12057

utility statements cannot be prepared

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.55 12058

prepared statement is not a SELECT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.56 12059

wrong number of parameters for prepared statement "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.57 12060

cannot use subquery in EXECUTE parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.58 12061

aggregate functions are not allowed in EXECUTE parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.59 12062

window functions are not allowed in EXECUTE parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.60 12063

parameter \$@1@ of type @2@ cannot be coerced to the expected type @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.61 12064

prepared statement "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.62 12065

unnamed prepared statement does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.63 12066

skipping vacuum of "@1@" --- lock not available

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.64 12067

skipping "@1@" --- only superuser can vacuum it

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.65 12068

skipping "@1@" --- only superuser or database owner can vacuum it

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.66 12069

skipping "@1@" --- only table or database owner can vacuum it

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.67 12070

skipping "@1@" --- cannot vacuum non-tables or special system tables

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.68 12071

analyzing "@1@.@2@" inheritance tree

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.69 12072

analyzing "@1@.@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.70 12073

automatic analyze of table "@1@.@2@.@3@" system usage: @4@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.71 12074

"@1@": scanned @2@ of @3@ pages, containing @4@ live rows and @5@ dead rows; @6@ rows in sample, @7@ estimated total rows

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.72 12075

cannot move temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.73 12076

there is no previously clustered index for table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.74 12077

cannot cluster a shared catalog

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.75 12078

cannot access temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.76 12079

"@1@" is not an index for table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.77 12080

cannot cluster on index "@1@" because access method does not support clustering

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.78 12081

cannot cluster on partial index "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.79 12082

cannot cluster on invalid index "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.80 12083

clustering "@1@.@2@" using index scan on "@3@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.81 12084

clustering "@1@.@2@" using sequential scan and sort

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.21.82 12086

invalid statement name: must not be empty

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.83 12088

SQL function cannot return shell type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.84 12089

type "@1@" is only a shell

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.85 12090

type "@1@" is not yet defined

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.86 12091

SQL function cannot accept shell type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.87 12092

type @1@ is only a shell

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.21.88 12093

token type "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.89 12094

functions cannot accept set arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.90 12095

VARIADIC parameter must be the last input parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.91 12096

VARIADIC parameter must be an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.92 12097

argument name "@1@" used more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.93 12098

only input parameters can have default values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.21.94 12099

cannot use table references in parameter default value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22 Message Numbers Beginning with 12100

2.22.1 12103

input parameters after one with a default value must also have defaults

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.2 12104

no function body specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.3 12105

no language specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.4 12106

COST must be positive

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.5 12107

ROWS must be positive

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.6 12108

unrecognized function attribute "@1@" ignored

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.7 12109

only one AS item needed for language "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.8 12110

role "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.9 12111

function result type must be @1@ because of OUT parameters**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.10 12112

function result type must be specified**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.11 12113

ROWS is not applicable when function does not return a set**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.12 12114

aggregate @1@(@2@) does not exist, skipping**[Description]**

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.13 12116

source data type @1@ is a pseudo-type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.14 12117

target data type @1@ is a pseudo-type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.15 12118

cast function must take one to three arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.16 12119

argument of cast function must match or be binary-coercible from source data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.17 12120

second argument of cast function must be type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.18 12122

return data type of cast function must match or be binary-coercible to target data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.19 12123

cast function must not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.20 12124

cast function must not be an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.21 12125

cast function must not be a window function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.22 12126

cast function must not return a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.23 12127

must be superuser to create a cast WITHOUT FUNCTION

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.24 12128

source and target data types are not physically compatible

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.25 12129

composite data types are not binary-compatible

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.26 12130

enum data types are not binary-compatible

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.27 12131

array data types are not binary-compatible

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.28 12132

domain data types must not be marked binary-compatible

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.29 12133

source data type and target data type are the same

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.30 12134

cast from type @1@ to type @2@ already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.31 12135

cast from type @1@ to type @2@ does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.32 12136

cast from type @1@ to type @2@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.33 12138

no inline code specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.34 12139

language "@1@" does not support inline code execution

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.35 12140

channel name cannot be empty

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.36 12141

channel name too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.37 12142

payload string too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.38 12143

cannot PREPARE a transaction that has executed LISTEN, UNLISTEN, or NOTIFY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.39 12144

too many notifications in the NOTIFY queue

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.40 12145

NOTIFY queue is @1@@2@ full

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.41 12147

must be superuser to create text search parsers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.42 12148

text search parser parameter "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.43 12149

text search parser start method is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.44 12150

text search parser gettoken method is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.45 12151

text search parser end method is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.46 12152

text search parser lextypes method is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.47 12153

must be superuser to rename @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.48 12154

text search parser "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.49 12156

text search parser "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.50 12157

text search template "@1@" does not accept options

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.51 12158

text search template is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.52 12159

text search dictionary "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.53 12160

text search dictionary "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.54 12161

must be superuser to create text search templates

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.55 12162

text search template parameter "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.56 12163

text search template lexize method is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.57 12165

text search template "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.58 12167

text search template "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.59 12168

text search configuration parameter "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.60 12169

cannot specify both PARSER and COPY options

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.61 12170

text search parser is required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.62 12171

text search configuration "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.63 12172

text search configuration "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.64 12174

mapping for token type "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.65 12175

mapping for token type "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.66 12176

invalid parameter list format: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.67 12177

group "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.68 12178

invalid extension name: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.69 12179

invalid extension version name: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.70 12180

could not open extension control file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.22.71 12181

parameter "@1@" cannot be set in a secondary extension control file

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.72 12183

parameter "@1@" must be a list of extension names**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.73 12184

unrecognized parameter "@1@" in file "@2@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.74 12185

parameter "schema" cannot be specified when "relocatable" is true**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.75 12186

transaction control statements are not allowed within an extension script**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.76 12187

permission denied to create extension "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.77 12188

permission denied to update extension "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.78 12189

extension "@1@" has no update path from version "@2@" to version "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.79 12190

relation "@1@" already exists, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.80 12191

extension "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.81 12192

nested CREATE EXTENSION is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.82 12193

version to install must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.83 12194

FROM version must be different from installation target version "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.84 12195

extension "@1@" must be installed in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.85 12196

required extension "@1@" is not installed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.86 12197

language "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.22.87 12198

OID @1@ does not refer to a table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.22.88 12199

table "@1@" is not a member of the extension being created

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23 Message Numbers Beginning with 12200

2.23.1 12200

extension "@1@" does not support SET SCHEMA

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.2 12201

nested ALTER EXTENSION is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.3 12202

version "@1@" of extension "@2@" is already installed

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.23.4 12203

@1@ is already a member of extension "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.5 12204

@1@ is not a member of extension "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.6 12205

using pg_pltemplate information instead of CREATE LANGUAGE parameters

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.23.7 12206

must be superuser to create procedural language "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.8 12208

unsupported language "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.9 12209

must be superuser to create custom procedural language

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.10 12210

changing return type of function @1@ from @2@ to @3@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.11 12211

language "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.12 12212

relation "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.13 12213

unacceptable schema name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.14 12214

sequence "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.15 12215

source encoding "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.16 12216

destination encoding "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.17 12217

encoding conversion function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.18 12218

view "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.19 12219

relation "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.20 12220

could not remove directory "@1@" : @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.23.21 12221

"@1@" exists but is not a directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.22 12222

permission denied to create tablespace "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.23 12223

tablespace location cannot contain single quotes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.24 12224

tablespace location must be an absolute path

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.25 12225

tablespace location "@1@" is too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.26 12226

unacceptable tablespace name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.27 12227

tablespace "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.28 12228

tablespaces are not supported on this platform

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.29 12229

window "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.30 12230

index "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.31 12231

tablespace "@1@" is not empty

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.32 12232

aggregate @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.33 12233

could not set permissions on directory "@1@" : @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.23.34 12234

some useless files may be left behind in old database directory "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.35 12235

directory "@1@" already in use as a tablespace

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.36 12236

could not create symbolic link "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.23.37 12237

could not read symbolic link "@1@": @2@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.23.38 12238

could not read directory "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.23.39 12239

"@1@" is a foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.40 12240

"@1@" is a view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.41 12241

TRUNCATE FOR EACH ROW triggers are not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.42 12242

INSTEAD OF triggers must be FOR EACH ROW

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.43 12243

INSTEAD OF triggers cannot have WHEN conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.44 12244

INSTEAD OF triggers cannot have column lists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.45 12245

cannot use subquery in trigger WHEN condition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.46 12246

aggregate functions are not allowed in trigger WHEN conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.47 12247

window functions are not allowed in trigger WHEN conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.48 12248

statement trigger's WHEN condition cannot reference column values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.49 12249

INSERT trigger's WHEN condition cannot reference OLD values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.50 12250

DELETE trigger's WHEN condition cannot reference NEW values

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.51 12251

BEFORE trigger's WHEN condition cannot reference NEW system columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.52 12252

changing return type of function @1@ from @2@ to @3@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.53 12254

trigger "@1@" for relation "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.54 12255

ignoring incomplete trigger group for constraint "@1@" @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.55 12256

converting trigger group into constraint "@1@" @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.23.56 12257

trigger "@1@" for relation "@2@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.57 12258

trigger "@1@" for table "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.58 12259

permission denied: "@1@" is a system trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.59 12260

trigger function @1@ returned null value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.60 12261

BEFORE STATEMENT trigger cannot return a value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.61 12262

constraint "@1@" is not deferrable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.62 12264

SYSID can no longer be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.63 12265

invalid connection limit: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.64 12266

must be superuser to create superusers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.65 12267

must be superuser to create replication users

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.66 12268

permission denied to create database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.67 12269

role name "@1@" is reserved

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.68 12270

role "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.69 12271

must be superuser to alter superusers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.70 12272

must be superuser to alter replication users

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.71 12273

permission denied

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.72 12274

permission denied to create role

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.73 12275

tablespace "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.74 12276

current user cannot be dropped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.75 12277

session user cannot be dropped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.76 12278

must be superuser to drop superusers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.77 12279

role "@1@" cannot be dropped because some objects depend on it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.78 12280

session user cannot be renamed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.79 12281

current user cannot be renamed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.80 12282

must be superuser to rename superusers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.81 12283

permission denied to rename database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.82 12284

MD5 password cleared because of role rename

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.83 12285

column names cannot be included in GRANT/REVOKE ROLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.84 12286

permission denied to drop role

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.85 12287

permission denied to drop objects

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.86 12288

must have admin option on role "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.87 12289

must be superuser to set grantor

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.88 12290

role "@1@" is a member of role "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.89 12291

role "@1@" is already a member of role "@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.23.90 12292

role "@1@" is not a member of role "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.23.91 12293

COPY BINARY is not supported to stdout or from stdin

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.23.92 12294

could not write to COPY file: @1@

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.23.93 12295

connection lost during COPY to stdout

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.23.94 12296

could not read from COPY file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.23.95 12297

COPY from stdin failed: @1@

[Description]

Processing was canceled.

[System Processing]

Processing will be aborted.

[Action]

Check the message text.

2.23.96 12298

unexpected message type 0x@1@ during COPY from stdin

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.23.97 12299

must be superuser to COPY to or from a file

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24 Message Numbers Beginning with 12300

2.24.1 12300

COPY format "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.2 12301

argument to option "@1@" must be a list of column names

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.3 12302

argument to option "@1@" must be a valid encoding name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.4 12303

option "@1@" not recognized

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.24.5 12304

cannot specify DELIMITER in BINARY mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.6 12305

cannot specify NULL in BINARY mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.7 12306

COPY delimiter must be a single one-byte character

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.8 12307

COPY delimiter cannot be newline or carriage return

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.9 12308

COPY null representation cannot use newline or carriage return

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.10 12309

COPY delimiter cannot be "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.11 12310

COPY HEADER available only in CSV mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.12 12311

COPY quote available only in CSV mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.13 12312

COPY quote must be a single one-byte character

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.14 12313

COPY delimiter and quote must be different

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.15 12314

COPY escape available only in CSV mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.16 12315

COPY escape must be a single one-byte character

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.17 12316

COPY force quote available only in CSV mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.18 12317

COPY force quote only available using COPY TO

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.19 12318

COPY force not null available only in CSV mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.20 12319

COPY force not null only available using COPY FROM

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.21 12320

COPY delimiter must not appear in the NULL specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.22 12321

CSV quote character must not appear in the NULL specification

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.23 12324

COPY (SELECT INTO) is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.24 12325

FORCE_QUOTE column "@1@" not referenced by COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.25 12326

FORCE_NOT_NULL column "@1@" not referenced by COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.26 12327

cannot copy from sequence "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.27 12328

cannot copy from foreign table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.28 12329

cannot copy to sequence "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.29 12330

cannot copy from non-table relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.30 12331

relative path not allowed for COPY to file

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.31 12332

could not open file "@1@" for reading: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.24.32 12333

"@1@" is a directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.33 12334

cannot copy to view "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.34 12335

cannot copy to foreign table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.35 12337

cannot copy to non-table relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.36 12338

COPY file signature not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.37 12339

invalid COPY file header (missing flags)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.38 12340

unrecognized critical flags in COPY file header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.39 12341

invalid COPY file header (missing length)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.40 12342

invalid COPY file header (wrong length)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.41 12343

extra data after last expected column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.42 12347

missing data for column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.43 12348

received copy data after EOF marker

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.44 12349

row field count is @1@, expected @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.45 12350

literal carriage return found in data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.46 12351

unquoted carriage return found in data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.47 12352

literal newline found in data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.48 12353

unquoted newline found in data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.49 12354

end-of-copy marker does not match previous newline style

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.50 12355

end-of-copy marker corrupt

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.51 12356

unterminated CSV quoted field

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.52 12357

unexpected EOF in COPY data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.53 12358

invalid field size

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.54 12359

incorrect binary data format

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.55 12360

must specify at least one column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.56 12361

cannot use more than @1@ columns in an index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.57 12362

cannot create index on foreign table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.58 12363

cannot create indexes on temporary tables of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.59 12364

substituting access method "gist" for obsolete method "rtree"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.24.60 12365

access method "@1@" does not support unique indexes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.61 12366

access method "@1@" does not support multicolumn indexes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.62 12367

access method "@1@" does not support exclusion constraints

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.63 12368

@1@ @2@ will create implicit index "@3@" for table "@4@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.24.64 12369

cannot use subquery in index predicate

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.65 12370

aggregate functions are not allowed in index predicates

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.66 12371

functions in index predicate must be marked IMMUTABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.67 12372

cannot use subquery in transform expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.68 12374

functions in index expression must be marked IMMUTABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.69 12375

could not determine which collation to use for string comparison

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.70 12376

operator is not unique: @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.71 12377

operator @1@ is not a member of operator family "@2@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.72 12378

access method "@1@" does not support ASC/DESC options**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.73 12379

access method "@1@" does not support NULLS FIRST/LAST options**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.74 12380

data type @1@ has no default operator class for access method "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.75 12381

operator class "@1@" does not accept data type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.76 12382

there are multiple default operator classes for data type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.77 12384

can only reindex the currently open database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.78 12385

table "@1@.@2@" was reindexed

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.24.79 12386

@1@ requires a parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.80 12387

@1@ requires a Boolean value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.81 12389

argument of @1@ must be a name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.82 12391

@1@ requires an integer value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.83 12393

LOCATION is not supported anymore

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.24.84 12396

permission denied to copy database "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.85 12397

invalid server encoding @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.24.86 12399

new encoding (@1@) is incompatible with the encoding of the template database (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25 Message Numbers Beginning with 12400

2.25.1 12400

new collation (@1@) is incompatible with the collation of the template database (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.2 12401

new LC_CTYPE (@1@) is incompatible with the LC_CTYPE of the template database (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.3 12402

pg_global cannot be used as default tablespace

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.4 12403

cannot assign new default tablespace "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.5 12404

database "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.6 12405

source database "@1@" is being accessed by other users

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.7 12406

encoding "@1@" does not match locale "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.8 12407

role "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.9 12408

cannot drop a template database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.10 12409

cannot drop the currently open database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.11 12410

database "@1@" is being accessed by other users

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.12 12411

permission denied to rename role

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.13 12412

current database cannot be changed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.14 12413

cannot change the tablespace of the currently open database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.15 12414

some relations of database "@1@" are already in tablespace "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.16 12415

permission denied to change owner of database

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.17 12417

SETOF type not allowed for operator argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.18 12418

operator attribute "@1@" not recognized

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.19 12419

operator procedure must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.20 12420

at least one of leftarg or rightarg must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.21 12421

restriction estimator function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.22 12422

join estimator function @1 @ must return type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.23 12424

must be superuser to create a base type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.24 12425

type attribute "@1@" not recognized

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.25 12426

invalid type category "@1@": must be simple ASCII

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.26 12427

array element type cannot be @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.27 12428

alignment "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.28 12429

storage "@1@" not recognized

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.29 12430

type input function must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.30 12431

type output function must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.31 12432

type modifier output function is useless without a type modifier input function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.32 12433

changing return type of function @1@ from @2@ to @3@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.33 12434

type input function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.34 12436

type output function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.35 12437

type receive function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.36 12438

type send function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.37 12439

"@1@" is not a number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.38 12440

"@1@" is not a valid base type for a domain

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.39 12441

multiple default expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.40 12442

conflicting NULL/NOT NULL constraints

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.41 12443

unique constraints not possible for domains

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.42 12444

primary key constraints not possible for domains

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.43 12445

exclusion constraints not possible for domains

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.44 12446

foreign key constraints not possible for domains

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.45 12447

specifying constraint deferrability not supported for domains

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.46 12448

changing argument type of function @1@ from "opaque" to "cstring"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.47 12449

changing argument type of function @1@ from "opaque" to @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.48 12450

typmod_in function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.49 12451

typmod_out function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.50 12452

type analyze function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.51 12453

column "@1@" of table "@2@" contains null values**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.52 12454

column "@1@" of table "@2@" contains values that violate the new constraint**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.53 12456

cannot use table references in domain check constraint**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.54 12457

@1@ is a table's row type**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.55 12458

cannot alter array type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.56 12460

could not obtain lock on relation "@1@.@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.57 12462

could not determine which collation to use for view column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.58 12464

cannot drop columns from view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.59 12465

cannot change name of view column "@1@" to "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.60 12466

cannot change data type of view column "@1@" from @2@ to @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.61 12467

views must not contain SELECT INTO

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.62 12468

views must not contain data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.63 12469

CREATE VIEW specifies more column names than columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.64 12470

view "@1@" will be a temporary view

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.25.65 12471

views cannot be unlogged because they do not have storage

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.66 12472

rule "@1@" for relation "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.67 12473

portal "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.68 12475

rule "@1@" for relation "@2@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.25.69 12476

WITH query name "@1@" appears in both a rule action and the query being rewritten

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.70 12477

cannot have RETURNING lists in multiple rules

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.71 12478

multiple assignments to same column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.72 12479

infinite recursion detected in rules for relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.73 12480

DO INSTEAD NOTHING rules are not supported for data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.74 12481

conditional DO INSTEAD rules are not supported for data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.75 12482

DO ALSO rules are not supported for data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.76 12483

multi-statement DO INSTEAD rules are not supported for data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.77 12484

cannot perform INSERT RETURNING on relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.78 12485

cannot perform UPDATE RETURNING on relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.79 12486

cannot perform DELETE RETURNING on relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.80 12487

WITH cannot be used in a query that is rewritten by rules into multiple queries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.81 12488

conditional utility statements are not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.82 12489

WHERE CURRENT OF on a view is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.83 12490

rule "@1@" for relation "@2@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.84 12491

rule actions on OLD are not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.85 12492

rule actions on NEW are not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.86 12493

INSTEAD NOTHING rules on SELECT are not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.87 12494

multiple actions for rules on SELECT are not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.88 12495

rules on SELECT must have action INSTEAD SELECT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.89 12496

rules on SELECT must not contain data-modifying statements in WITH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.90 12497

event qualifications are not implemented for rules on SELECT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.91 12498

"@1@" is already a view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.25.92 12499

view rule for "@1@" must be named "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26 Message Numbers Beginning with 12500

2.26.1 12500

could not convert table "@1@" to a view because it is not empty

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.2 12501

could not convert table "@1@" to a view because it has triggers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.3 12502

could not convert table "@1@" to a view because it has indexes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.4 12503

could not convert table "@1@" to a view because it has child tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.5 12504

cannot have multiple RETURNING lists in a rule

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.6 12505

RETURNING lists are not supported in conditional rules

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.7 12506

RETURNING lists are not supported in non-INSTEAD rules

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.8 12507

SELECT rule's target list has too many entries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.9 12508

RETURNING list has too many entries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.10 12509

cannot convert relation containing dropped columns to view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.11 12510

SELECT rule's target entry @1@ has different column name from column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.12 12511

SELECT rule's target entry @1@ has different type from column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.13 12512

RETURNING list's entry @1@ has different type from column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.14 12513

SELECT rule's target entry @1@ has different size from column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.15 12514

RETURNING list's entry @1@ has different size from column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.16 12515

SELECT rule's target list has too few entries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.17 12516

RETURNING list has too few entries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.18 12517

[@1@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.19 12518

[Perl hash contains nonexistent column "@1@"](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.20 12519

[number of array dimensions \(@1@\) exceeds the maximum allowed \(@2@\)](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.21 12520

[multidimensional arrays must have array expressions with matching dimensions](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.22 12521

PL/Perl function must return reference to hash or array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.23 12522

\$_TD->{new} does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.24 12523

\$_TD->{new} is not a hash reference

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.25 12524

PL/Perl functions cannot return type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.26 12525

PL/Perl functions cannot accept type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.27 12526

didn't get a CODE reference from compiling function "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.26.28 12527

set-valued function called in context that cannot accept a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.29 12528

set-returning PL/Perl function must return reference to array or use return_next

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.30 12529

function returning record called in context that cannot accept type record

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.31 12530

ignoring modified row in DELETE trigger

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.26.32 12531

result of PL/Perl trigger function must be undef, "SKIP", or "MODIFY"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.33 12533

trigger functions can only be called as triggers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.34 12534

cannot use return_next in a non-SETOF function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.35 12535

SETOF-composite-returning PL/Perl function must call return_next with reference to hash

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.36 12536

PL/pgSQL functions cannot accept type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.37 12537

could not determine actual return type for polymorphic function "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.38 12538

trigger functions can only be called as triggers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.39 12539

PL/pgSQL functions cannot return type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.40 12540

trigger functions cannot have declared arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.41 12541

parameter name "@1@" used more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.42 12542

column reference "@1@" is ambiguous

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.43 12543

record "@1@" has no field "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.44 12544

variable "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.45 12545

relation "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.46 12546

variable "@1@" has pseudo-type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.47 12547

relation "@1@" is not a table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.48 12548

type "@1@" is only a shell

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.49 12549

unrecognized exception condition "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.50 12550

could not determine actual argument type for polymorphic function "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.51 12551

CONTINUE cannot be used outside a loop

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.52 12552

control reached end of function without RETURN

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.53 12553

set-valued function called in context that cannot accept a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.54 12554

control reached end of trigger procedure without RETURN

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.55 12555

trigger procedure cannot return a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.56 12556

variable "@1@" declared NOT NULL cannot default to NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.57 12557

case not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.58 12558

lower bound of FOR loop cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.59 12559

upper bound of FOR loop cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.60 12560

BY value of FOR loop cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.61 12561

BY value of FOR loop must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.62 12562

cursor "@1@" already in use

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.63 12563

arguments given for cursor without arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.64 12564

arguments required for cursor

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.65 12565

FOREACH expression must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.66 12566

FOREACH expression must yield an array, not type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.67 12567

slice dimension (@1@) is out of the valid range 0..@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.68 12568

FOREACH ... SLICE loop variable must be of an array type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.69 12569

FOREACH loop variable must not be of an array type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.70 12570

cannot use RETURN NEXT in a non-SETOF function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.71 12571

wrong result type supplied in RETURN NEXT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.72 12572

record "@1@" is not assigned yet

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.73 12573

wrong record type supplied in RETURN NEXT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.74 12574

RETURN NEXT must have a parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.75 12575

cannot use RETURN QUERY in a non-SETOF function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.76 12576

RAISE without parameters cannot be used outside an exception handler

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.77 12577

too few parameters specified for RAISE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.78 12578

too many parameters specified for RAISE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.79 12579

RAISE statement option cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.80 12580

RAISE option already specified: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.81 12581

cannot COPY to/from client in PL/pgSQL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.82 12582

cannot begin/end transactions in PL/pgSQL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.83 12583

INTO used with a command that cannot return data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.84 12584

query returned no rows

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.85 12585

query returned more than one row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.86 12586

query has no destination for result data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.87 12587

query string argument of EXECUTE is null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.88 12588

EXECUTE of SELECT ... INTO is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.89 12589

cursor variable "@1@" is null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.90 12590

cursor "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.91 12591

relative or absolute cursor position is null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.92 12592

null value cannot be assigned to variable "@1@" declared NOT NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.93 12593

cannot assign non-composite value to a row variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.94 12594

cannot assign non-composite value to a record variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.95 12595

number of array dimensions (@1@) exceeds the maximum allowed (@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.96 12596

subscripted object is not an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.97 12597

array subscript in assignment must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.26.98 12598

query "@1@" did not return data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27 Message Numbers Beginning with 12600

2.27.1 12600

row or record variable cannot be NOT NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.2 12601

default value for row or record variable is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.3 12603

"@1@" is not a scalar variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.4 12604

loop variable of loop over rows must be a record or row variable or list of scalar variables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.5 12605

cursor FOR loop must have only one target variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.6 12606

cursor FOR loop must use a bound cursor variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.7 12607

integer FOR loop must have only one target variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.8 12608

cannot specify REVERSE in query FOR loop

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.9 12609

loop variable of FOREACH must be a known variable or list of variables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.10 12610

FETCH statement cannot return multiple rows

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.11 12611

cursor variable must be a simple variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.12 12612

variable "@1@" must be of type cursor or refcursor

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.13 12613

"@1@" is not a known variable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.14 12614

missing "@1@" at end of SQL expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.15 12615

missing "@1@" at end of SQL statement

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.16 12616

RETURN cannot have a parameter in function returning set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.17 12617

RETURN cannot have a parameter in function with OUT parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.18 12618

RETURN cannot have a parameter in function returning void

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.19 12620

RETURN NEXT cannot have a parameter in function with OUT parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.20 12622

"@1@" is declared CONSTANT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.21 12623

record or row variable cannot be part of multiple-item INTO list

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.22 12624

too many INTO variables specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.23 12625

end label "@1@" specified for unlabelled block

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.24 12626

end label "@1@" differs from block's label "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.25 12627

cursor "@1@" has no arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.26 12628

cursor "@1@" has arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.27 12629

@1@ at end of input

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.28 12630

unexpected return value from trigger procedure

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.29 12631

PL/Python trigger function returned "MODIFY" in a DELETE trigger -- ignored

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.27.30 12632

TD["new"] deleted, cannot modify row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.31 12633

TD["new"] is not a dictionary

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.32 12634

TD["new"] dictionary key at ordinal position @1@ is not a string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.33 12635

key "@1@" found in TD["new"] does not exist as a column in the triggering row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.34 12636

unsupported set function return mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.35 12637

returned object cannot be iterated

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.36 12638

PL/Python function with return type "void" did not return None

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.37 12639

forcibly aborting a subtransaction that has not been exited

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.27.38 12640

function returning record called in context that cannot accept type record

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.39 12641

trigger functions can only be called as triggers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.40 12642

PL/Python functions cannot return type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.41 12643

PL/Python functions cannot accept type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.42 12645

could not convert Python object into cstring: Python string representation appears to contain null bytes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.43 12646

key "@1@" not found in mapping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.44 12647

length of returned sequence did not match number of columns in row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.45 12648

attribute "@1@" does not exist in Python object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.46 12649

plpy.prepare: type name at ordinal position @1@ is not a string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.47 12652

@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.48 12653

@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.49 12655

trigger functions can only be called as triggers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.27.50 12656

PL/Tcl functions cannot return type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.28 Message Numbers Beginning with 12700

2.28.1 12704

function "@1@" does not exist

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.28.2 12725

operator @1@ is not a valid ordering operator

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.29 Message Numbers Beginning with 12900

2.29.1 12908

could not remove cache file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.29.2 12909

could not open tablespace directory "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.30 Message Numbers Beginning with 13000

2.30.1 13092

too few arguments for format()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.30.2 13094

null values cannot be formatted as an SQL identifier

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.31 Message Numbers Beginning with 13300

2.31.1 13359

online backup was canceled, recovery cannot continue

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.31.2 13362

online backup mode canceled

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.31.3 13363

online backup mode was not canceled

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.32 Message Numbers Beginning with 13400

2.32.1 13449

cannot convert whole-row table reference

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.32.2 13452

cannot alter type "@1@" because column "@2@.@3@" uses it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.32.3 13453

cannot alter foreign table "@1@" because column "@2@.@3@" uses its row type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.32.4 13454

cannot alter table "@1@" because column "@2@.@3@" uses its row type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.32.5 13478

parameter "lc_ctype" must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.32.6 13481

operator family "@1@" does not exist for access method "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.32.7 13490

directories for tablespace @1@ could not be removed

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.32.8 13497

cannot drop extension "@1@" because it is being modified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.32.9 13499

@1@ can only be called from an SQL script executed by CREATE EXTENSION

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.33 Message Numbers Beginning with 13500

2.33.1 13508

must be superuser to set schema of @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.33.2 13580

cannot PREPARE while holding both session-level and transaction-level locks on the same object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.33.3 13589

sending cancel to blocking autovacuum PID @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.33.4 13597

not enough elements in RWConflictPool to record a read/write conflict

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.33.5 13598

not enough elements in RWConflictPool to record a potential read/write conflict

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.34 Message Numbers Beginning with 13700

2.34.1 13761

cannot move extension "@1@" into schema "@2@" because the extension contains the schema

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.35 Message Numbers Beginning with 13800

2.35.1 13833

column @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.35.2 13860

symbolic link "@1@" target is too long

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.35.3 13864

unexpected message type "@1@"

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.35.4 13884

could not create signal listener pipe for PID @1@: error code @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.36 Message Numbers Beginning with 13900

2.36.1 13922

could not close handle to backend parameter variables: error code @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.36.2 13941

conflicting constraint properties

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.36.3 13943

@1@ constraints cannot be marked DEFERRABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.36.4 13944

@1@ constraints cannot be marked NOT VALID

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.37 Message Numbers Beginning with 14000

2.37.1 14024

column name must be qualified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.37.2 14028

cannot create relations in temporary schemas of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.37.3 14029

cannot create temporary relation in non-temporary schema

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.37.4 14030

only temporary relations may be created in temporary schemas

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.37.5 14042

cannot reassign ownership of objects owned by @1@ because they are required by the database system

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.38 Message Numbers Beginning with 14100

2.38.1 14104

cannot convert Perl array to non-array type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.38.2 14105

cannot convert Perl hash to non-composite type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.39 Message Numbers Beginning with 14200

2.39.1 14211

PL/Tcl functions cannot accept type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.39.2 14218

"@1@" is a table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.39.3 14282

cannot add schema "@1@" to extension "@2@" because the schema contains the extension

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.39.4 14284

could not identify current directory: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.5 14285

invalid binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.6 14286

could not read binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.7 14287

could not find a "@1@" to execute

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.8 14289

could not read symbolic link "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.9 14290

child process exited with exit code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.10 14291

child process was terminated by exception 0x@1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.11 14292

child process was terminated by signal @1@: @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.12 14294

child process exited with unrecognized status @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.13 14295

could not identify current directory: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.14 14296

invalid binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.15 14297

could not read binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.16 14298

could not find a "@1@" to execute

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.39.17 14299

could not change directory to "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40 Message Numbers Beginning with 14300

2.40.1 14300

could not read symbolic link "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.2 14301

child process exited with exit code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.3 14302

child process was terminated by exception 0x@1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.4 14303

child process was terminated by signal @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.5 14304

child process was terminated by signal @1@: @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.6 14305

child process exited with unrecognized status @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.7 14306

could not identify current directory: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.8 14307

invalid binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.9 14308

could not read binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.10 14309

could not find a "@1@" to execute

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.11 14310

could not change directory to "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.12 14311

could not read symbolic link "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.13 14318

could not identify current directory: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.14 14319

invalid binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.15 14320

could not read binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.16 14321

could not find a "@1@" to execute

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.17 14322

could not change directory to "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.18 14323

could not read symbolic link "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.19 14324

child process exited with exit code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.20 14325

child process was terminated by exception 0x@1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.21 14326

child process was terminated by signal @1@: @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.22 14328

auto-open of the keystore has been enabled

[Description]

Enabled automatic opening of the keystore.

[System Processing]

Continues processing.

[Action]

No action required.

2.40.23 14329

could not identify current directory: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.24 14330

invalid binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.25 14331

could not read binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.26 14332

could not find a "@1@" to execute

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.27 14333

could not change directory to "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.28 14334

could not read symbolic link "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.29 14335

child process exited with exit code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.30 14336

child process was terminated by exception 0x@1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.31 14337

child process was terminated by signal @1@: @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.32 14339

@1@: no database directory specified and environment variable PGDATA unset

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.33 14340

could not identify current directory: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.34 14341

invalid binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.35 14342

could not read binary "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.36 14343

could not find a "@1@" to execute

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.37 14344

could not change directory to "@1@": @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.38 14345

could not read symbolic link "@1@"

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.39 14346

child process exited with exit code @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.40 14347

child process was terminated by exception 0x@1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.41 14348

child process was terminated by signal @1@: @2@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.40.42 14351

could not access directory for core file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.43 14352

path specified by configuration parameter "@1@" is invalid: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.44 14353

WAL archiving is not active

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.45 14354

could not set permissions on path specified by configuration parameter "@1@": "@2@": @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.46 14366

a failure has occurred while multiplexing transaction log files

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.47 14367

multiplexing of transaction log files has been stopped

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.40.48 14368

must be superuser to control WAL multiplexing

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.49 14369

WAL multiplexing is not configured

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.50 14370

WAL multiplexing is already paused

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.51 14371

WAL multiplexing is not paused

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.52 14372

could not fork XLog multiplexer process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.53 14373

could not set junction for "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.54 14374

could not set junction for "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.55 14375

could not remove file or directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.40.56 14376

could not remove file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.57 14377

could not set junction for "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.58 14378

could not get junction for "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.40.59 14379

could not open directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.40.60 14380

could not read directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.40.61 14381

could not stat file or directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.40.62 14384

could not determine encoding for locale "@1@": codeset is "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.40.63 14385

could not remove file or directory "@1@": @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.40.64 14388

@1@ at or near "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.65 14390

query "@1@" returned more than one row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.66 14391

query "@1@" is not a SELECT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.67 14392

block label must be placed before DECLARE, not after

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.68 14393

collations are not supported by type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.69 14394

row or record variable cannot be CONSTANT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.40.70 14395

cannot use serializable mode in a hot standby

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.41 Message Numbers Beginning with 14400

2.41.1 14419

could not write lock file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.41.2 14421

Expected 1 tuple with 2 fields, got @1@ tuples with @2@ fields.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.41.3 14422

The primary's identifier is @1@, the standby's identifier is @2@.

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.41.4 14423

The transaction has already committed locally, but might not have been replicated to the standby.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.5 14424

You can choose the collation by applying the COLLATE clause to one or both expressions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.6 14425

Query has too few columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.7 14426

Cannot cast type @1@ to @2@ in column @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.8 14427

Query has too many columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.9 14430

No aggregate function matches the given name and argument types. Perhaps you misplaced ORDER BY; ORDER BY must appear after all regular arguments of the aggregate.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.10 14431

No function matches the given name and argument types. You might need to add explicit type casts.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.11 14432

There is a WITH item named "@1@", but it cannot be referenced from this part of the query.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.12 14433

Use WITH RECURSIVE, or re-order the WITH items to remove forward references.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.13 14434

Perhaps you meant to reference the table alias "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.14 14435

There is an entry for table "@1@", but it cannot be referenced from this part of the query.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.15 14436

String constants with Unicode escapes cannot be used when standard_conforming_strings is off.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.16 14437

Unicode escapes must be \uXXXX or \UXXXXXXXX.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.17 14438

Use " to write quotes in strings. \ is insecure in client-only encodings.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.18 14439

Use " to write quotes in strings, or use the escape string syntax (E'...').

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.19 14440

Use the escape string syntax for backslashes, e.g., E'\\'.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.20 14441

Use the escape string syntax for escapes, e.g., E'\r\n'.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.21 14442

Cast the output of the non-recursive term to the correct type.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.22 14443

Use the COLLATE clause to set the collation of the non-recursive term.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.23 14444

Explicitly cast to the desired type, for example ARRAY[]::integer[].

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.24 14445

Row comparison operators must be associated with btree operator families.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.25 14446

There are multiple equally-plausible candidates.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.26 14447

You will need to rewrite or cast the expression.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.27 14448

Use an explicit ordering operator or modify the query.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.28 14449

Could not choose a best candidate operator. You might need to add explicit type casts.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.29 14450

No operator matches the given name and argument type(s). You might need to add explicit type casts.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.30 14451

Aggregates with DISTINCT must be able to sort their inputs.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.31 14452

Constraint "@1@" contains a whole-row reference to table "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.32 14453

Index "@1@" contains a whole-row table reference.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.33 14454

Cannot create a primary key or unique constraint using such an index.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.34 14455

Cannot create a non-deferrable constraint using a deferrable index.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.35 14456

Ordering operators must be "<" or ">" members of btree operator families.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.36 14457

Update your data type.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.37 14458

Use NONE to denote the missing argument of a unary operator.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.38 14459

Use separate LIMIT and OFFSET clauses.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.39 14460

For example, FROM (VALUES ...) [AS] foo.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.40 14461

For example, FROM (SELECT ...) [AS] foo.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.41 14463

The insertion source is a row expression containing the same number of columns expected by the INSERT. Did you accidentally use extra parentheses?

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.42 14464

Only result column names can be used, not expressions or functions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.43 14465

Add the expression/function to every SELECT, or move the UNION into a FROM clause.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.44 14466

Scrollable cursors must be READ ONLY.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.45 14467

Holdable cursors must be READ ONLY.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.46 14468

Insensitive cursors must be READ ONLY.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.47 14469

Valid options in this context are: @1 @

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.48 14470

Specify OWNED BY table.column or OWNED BY NONE.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.49 14471

Extension names must not be empty.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.50 14472

Extension names must not contain "--".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.51 14473

Extension names must not begin or end with "-".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.52 14474

Extension names must not contain directory separator characters.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.53 14475

Version names must not be empty.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.54 14476

Version names must not contain "--".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.55 14477

Version names must not begin or end with "-".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.56 14478

Version names must not contain directory separator characters.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.57 14479

Must be superuser to create this extension.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.58 14480

Must be superuser to update this extension.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.59 14481

@1@ is not in the extension's schema "@2@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.60 14482

Consider using tablespaces instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.61 14483

Use the same encoding as in the template database, or use template0 as template.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.62 14484

Use the same collation as in the template database, or use template0 as template.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.63 14485

Use the same LC_CTYPE as in the template database, or use template0 as template.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.64 14486

There is a conflict because database "@1@" already has some tables in this tablespace.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.65 14487

The chosen LC_CTYPE setting requires encoding "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.66 14488

The chosen LC_COLLATE setting requires encoding "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.67 14489

You must move them back to the database's default tablespace before using this command.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.68 14490

There are @1@ other session(s) and @2@ prepared transaction(s) using the database.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.69 14493

@1@ dead row versions cannot be removed yet. @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.70 14494

The prefix "pg_" is reserved for system schemas.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.71 14496

The server process with PID @1@ is among those with the oldest transactions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.72 14497

The NOTIFY queue cannot be emptied until that process ends its current transaction.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.73 14498

Use the COLLATE clause to set the collation explicitly.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.41.74 14499

The supported languages are listed in the pg_pltemplate system catalog.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42 Message Numbers Beginning with 14500

2.42.1 14500

Anyone can COPY to stdout or from stdin. psql's \copy command also works for anyone.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.2 14501

Try the COPY (SELECT ...) TO variant.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.3 14502

COPY @1@, line @2@, column @3@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.4 14503

COPY @1@, line @2@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.5 14504

COPY @1@, line @2@, column @3@: "@4@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.6 14505

COPY @1@, line @2@, column @3@: null input

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.7 14506

COPY @1@, line @2@: "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.8 14507

Use "\r" to represent carriage return.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.9 14508

Use quoted CSV field to represent carriage return.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.10 14509

Use "\n" to represent newline.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.11 14510

Use quoted CSV field to represent newline.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.12 14512

@1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.13 14513

@1@ index row versions were removed. @2@ index pages have been deleted, @3@ are currently reusable. @4@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.14 14514

Operator class "@1@" already is the default.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.15 14515

Must be superuser to change owner of a foreign-data wrapper.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.16 14516

The owner of a foreign-data wrapper must be a superuser.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.17 14517

Must be superuser to create a foreign-data wrapper.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.18 14518

Must be superuser to alter a foreign-data wrapper.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.19 14520

Expected @1@ parameters but got @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.20 14521

Close open transactions soon to avoid wraparound problems.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.21 14522

You might have already suffered transaction-wraparound data loss.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.22 14523

Must be superuser to create a tablespace.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.23 14524

The prefix "pg_" is reserved for system tablespaces.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.24 14525

Create this directory for the tablespace before restarting the server.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.25 14526

You can remove the directories manually if necessary.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.26 14528

You can alter type @1@, which will alter the array type as well.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.27 14529

Tables cannot have INSTEAD OF triggers.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.28 14530

Views cannot have row-level BEFORE or AFTER triggers.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.29 14531

Views cannot have TRUNCATE triggers.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.30 14532

"@1@" versus "@2@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.31 14533

To resolve the conflict, specify a default explicitly.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.32 14534

Use ALTER TYPE instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.33 14535

Use ALTER ... CASCADE to alter the typed tables too.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.34 14536

Key columns "@1@" and "@2@" are of incompatible types: @3@ and @4@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.35 14537

@1@ depends on @2@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.36 14538

Change the ownership of the index's table, instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.37 14539

Sequence "@1@" is linked to table "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.38 14540

"@1@" is already a child of "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.39 14541

Only commutative operators can be used in exclusion constraints.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.40 14542

The exclusion operator must be related to the index operator class for the constraint.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.41 14543

You must specify an operator class for the index or define a default operator class for the data type.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.42 14544

Creating a shell type definition.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.43 14545

Use CREATE LANGUAGE to load the language into the database.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.44 14546

Use DROP AGGREGATE to drop aggregate functions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.45 14549

Key @1@ is duplicated.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.46 14551

Perhaps you need a different "datestyle" setting.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.47 14552

The operating system could not find any locale data for the locale name "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.48 14553

The server's LC_CTYPE locale is probably incompatible with the database encoding.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.49 14554

Provide two argument types for operator.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.50 14555

Missing left parenthesis.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.51 14556

Too few columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.52 14557

Unexpected end of input.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.53 14558

Too many columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.54 14559

Junk after right parenthesis.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.55 14560

Intervals are not tied to specific calendar dates.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.56 14561

"EEEE" may only be used together with digit and decimal point patterns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.57 14562

Do not mix Gregorian and ISO week date conventions in a formatting template.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.58 14563

This value contradicts a previous setting for the same field type.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.59 14564

Field requires @1@ characters, but only @2@ remain.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.60 14565

If your source string is not fixed-width, try using the "FM" modifier.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.61 14566

Field requires @1@ characters, but only @2@ could be parsed.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.62 14567

Value must be an integer.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.63 14568

Value must be in the range @1@ to @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.64 14569

The given value did not match any of the allowed values for this field.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.65 14570

Use the 24-hour clock, or give an hour between 1 and 12.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.66 14571

Escape string must be empty or one character.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.67 14572

Value has bits set to right of mask.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.68 14573

Target must be "archiver" or "bgwriter".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.69 14574

Identifier must be less than @1@ characters.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.70 14575

This functionality requires the server to be built with libxml support.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.71 14576

You need to rebuild PostgreSQL using --with-libxml.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.72 14577

XML processing instruction target name cannot be "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.73 14578

XML processing instruction cannot contain "?>".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.74 14579

libxml2 has incompatible char type: sizeof(char)=@1 @, sizeof(xmlChar)=@2 @.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.75 14580

XML does not support infinite date values.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.76 14581

XML does not support infinite timestamp values.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.77 14582

The array must be two-dimensional with length of the second axis equal to 2.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.78 14583

ACL key word must be "group" or "user".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.79 14584

A name must follow the "group" or "user" key word.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.80 14585

Use CASCADE to revoke them too.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.81 14586

Dimension array must be one dimensional.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.82 14587

Lower bound of dimension array must be one.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.83 14588

Low bound array has different size than dimensions array.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.84 14589

MATCH FULL does not allow mixing of null and nonnull key values.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.85 14590

Remove this referential integrity trigger and its mates, then do ALTER TABLE ADD CONSTRAINT.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.86 14591

This is most likely due to a rule having rewritten the query.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.87 14593

Key (@1@)=(@2@) is not present in table "@3@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.88 14594

Key (@1@)=(@2@) is still referenced from table "@3@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.89 14595

A field with precision @1@, scale @2@ must round to an absolute value less than @3@@4@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.90 14596

Arrays with element types @1@ and @2@ are not compatible for concatenation.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.91 14597

Arrays of @1@ and @2@ dimensions are not compatible for concatenation.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.92 14598

Arrays with differing element dimensions are not compatible for concatenation.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.42.93 14599

Arrays with differing dimensions are not compatible for concatenation.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43 Message Numbers Beginning with 14600

2.43.1 14600

Is another postgres (PID @1@) running in data directory "@2@"?

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.2 14601

Is another postmaster (PID @1@) running in data directory "@2@"?

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.3 14602

Is another postgres (PID @1@) using socket file "@2@"?

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.4 14603

Is another postmaster (PID @1 @) using socket file "@2@"?

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.5 14605

The file seems accidentally left over, but it could not be removed. Please remove the file by hand and try again.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.6 14606

File "@1@" is missing.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.7 14607

File "@1@" does not contain valid data.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.8 14608

You might need to initdb.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.9 14609

he data directory was initialized by PostgreSQL version @1@, which is not compatible with this version @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.10 14610

Specify an absolute path.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.11 14611

Set up WAL archiving when you configure "@1@" parameter.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.12 14612

Database OID @1 @ now seems to belong to "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.13 14613

User does not have CONNECT privilege.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.14 14614

The database was initialized with LC_COLLATE "@1@", which is not recognized by setlocale().

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.15 14615

Recreate the database with another locale or install the missing locale.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.16 14616

The database was initialized with LC_CTYPE "@1@", which is not recognized by setlocale().

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.17 14617

You should immediately run CREATE USER "@1@" SUPERUSER;.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.18 14618

It seems to have just been dropped or renamed.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.19 14619

The database subdirectory "@1@" is missing.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.20 14620

String of @1@ bytes is too long for encoding conversion.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.21 14621

Continuing anyway, but there's something wrong.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.22 14622

Failed while creating memory context "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.23 14623

Failed on request of size @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.24 14624

Extension libraries are required to use the PG_MODULE_MAGIC macro.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.25 14625

Server is version @1@, library is version @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.26 14627

You need an unconditional ON INSERT DO INSTEAD rule with a RETURNING clause.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.27 14628

You need an unconditional ON UPDATE DO INSTEAD rule with a RETURNING clause.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.28 14629

You need an unconditional ON DELETE DO INSTEAD rule with a RETURNING clause.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.29 14630

Use views or triggers instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.30 14631

Use triggers instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.31 14632

Use views instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.32 14633

In particular, the table cannot be involved in any foreign key relationships.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.33 14634

Failed system call was shmget(key=@1 @, size=@2 @, 0@3 @).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.34 14638

Failed system call was CreateFileMapping(size=@1 @, name=@2 @).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.35 14639

Check if there are any old server processes still running, and terminate them.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.36 14640

Failed system call was DuplicateHandle.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.37 14641

Failed system call was MapViewOfFileEx.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.38 14642

Failed system call was semget(@1@, @2@, 0@3@).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.39 14643

This error does *not* mean that you have run out of disk space. It occurs when either the system limit for the maximum number of semaphore sets (SEMMNI), or the system wide maximum number of semaphores (SEMMNS), would be exceeded. You need to raise the respective kernel parameter. Alternatively, reduce PostgreSQL's consumption of semaphores by reducing its max_connections parameter. The PostgreSQL documentation contains more information about configuring your system for PostgreSQL.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.40 14644

You possibly need to raise your kernel's SEMVMX value to be at least @1@. Look into the PostgreSQL documentation for details.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.41 14645

Some of the datatypes only support hashing, while others only support sorting.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.42 14646

Window partitioning columns must be of sortable datatypes.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.43 14647

Window ordering columns must be of sortable datatypes.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.44 14648

SQL function "@1@" during startup

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.45 14649

All column datatypes must be hashable.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.46 14650

See server log for query details.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.47 14651

Client IP address resolved to "@1@", forward lookup matches.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.48 14652

Client IP address resolved to "@1@", forward lookup not checked.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.49 14653

Client IP address resolved to "@1@", forward lookup does not match.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.50 14654

LDAP over SSL is not supported on this platform.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.51 14655

Is another postmaster already running on port @1@? If not, remove socket file "@2@" and retry.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.52 14656

Is another postmaster already running on port @1@? If not, wait a few seconds and retry.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.53 14657

Anyone can use the client-side lo_import() provided by libpq.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.54 14658

Anyone can use the client-side `lo_export()` provided by `libpq`.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.55 14659

File must have permissions `u=rw (0600)` or less if owned by the database user, or permissions `u=rw,g=r (0640)` or less if owned by root.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.56 14660

SSL library does not support certificate revocation lists.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.57 14662

line `@1@` of configuration file "`@2@`"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.58 14663

Set ssl = on in postgresql.conf.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.59 14664

Compile with --with-openssl to use SSL connections.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.60 14666

Cannot enlarge string buffer containing @1@ bytes by @2@ more bytes.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.61 14667

Please REINDEX it.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.62 14668

Values larger than 1/3 of a buffer page cannot be indexed. Consider a function index of an MD5 hash of the value, or use full text indexing.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.63 14669

Key @1@ already exists.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.64 14670

This may be because of a non-immutable index expression.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.65 14671

To fix this, do REINDEX INDEX "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.66 14672

This is caused by an incomplete page split at crash recovery before upgrading to PostgreSQL 9.1.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.67 14673

The index is not optimal. To optimize it, contact a developer, or try to use the column as the second one in the CREATE INDEX command.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.68 14674

Could not open file "@1@": @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.69 14675

Could not seek in file "@1@" to offset @2@: @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.70 14676

Could not read from file "@1@" at offset @2@: @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.71 14677

Could not write to file "@1@" at offset @2@: @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.72 14678

Could not fsync file "@1@": @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.73 14679

Could not close file "@1@": @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.74 14680

Set max_prepared_transactions to a nonzero value.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.75 14681

Increase max_prepared_transactions (currently @1@).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.76 14682

Must be superuser or the user that prepared the transaction.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.77 14683

Connect to the database where the transaction was prepared to finish it.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.78 14687

Expected a numeric timeline ID.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.79 14688

Timeline IDs must be in increasing sequence.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.80 14689

Timeline IDs must be less than child timeline's ID.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.81 14690

The database cluster was initialized with PG_CONTROL_VERSION @1@ (0x@2@), but the server was compiled with PG_CONTROL_VERSION @3@ (0x@4@).**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.82 14691

This could be a problem of mismatched byte ordering. It looks like you need to initdb.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.83 14692

The database cluster was initialized with PG_CONTROL_VERSION @1@, but the server was compiled with PG_CONTROL_VERSION @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.84 14693

It looks like you need to initdb.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.85 14694

The database cluster was initialized with CATALOG_VERSION_NO @1@, but the server was compiled with CATALOG_VERSION_NO @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.86 14695

The database cluster was initialized with MAXALIGN @1@, but the server was compiled with MAXALIGN @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.87 14696

The database cluster appears to use a different floating-point number format than the server executable.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.88 14697

The database cluster was initialized with BLCKSZ @1@, but the server was compiled with BLCKSZ @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.89 14698

It looks like you need to recompile or initdb.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.43.90 14699

The database cluster was initialized with RELSEG_SIZE @1@, but the server was compiled with RELSEG_SIZE @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44 Message Numbers Beginning with 14700

2.44.1 14700

The database cluster was initialized with XLOG_BLCKSZ @1@, but the server was compiled with XLOG_BLCKSZ @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.2 14701

The database cluster was initialized with XLOG_SEG_SIZE @1@, but the server was compiled with XLOG_SEG_SIZE @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.3 14702

The database cluster was initialized with NAMEDATALEN @1@, but the server was compiled with NAMEDATALEN @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.4 14703

The database cluster was initialized with INDEX_MAX_KEYS @1@, but the server was compiled with INDEX_MAX_KEYS @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.5 14704

The database cluster was initialized with TOAST_MAX_CHUNK_SIZE @1@, but the server was compiled with TOAST_MAX_CHUNK_SIZE @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.6 14707

The database cluster was initialized without USE_FLOAT4_BYVAL but the server was compiled with USE_FLOAT4_BYVAL.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.7 14708

The database cluster was initialized with USE_FLOAT4_BYVAL but the server was compiled without USE_FLOAT4_BYVAL.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.8 14709

The database cluster was initialized without USE_FLOAT8_BYVAL but the server was compiled with USE_FLOAT8_BYVAL.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.9 14710

The database cluster was initialized with USE_FLOAT8_BYVAL but the server was compiled without USE_FLOAT8_BYVAL.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.10 14711

The database server will regularly poll the pg_wal subdirectory to check for files placed there.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.11 14712

Execute pg_wal_replay_resume() to continue.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.12 14713

Recovery control functions can only be executed during recovery.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.13 14714

This happens if you temporarily set wal_level=minimal without taking a new base backup.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.14 14715

Either set wal_level to "replica" on the master, or turn off hot_standby here.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.15 14716

This probably means that some data is corrupted and you will have to use the last backup for recovery.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.16 14717

If this has occurred more than once some data might be corrupted and you might need to choose an earlier recovery target.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.17 14718

If you are restoring from a backup, touch "@1@/recovery.signal" and add required recovery options.If you are not restoring from a backup, try removing the file "@2@/backup_label".Be careful: removing "@3@/backup_label" will result in a corrupt cluster if restoring from a backup.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.18 14719

Online backup started with pg_start_backup() must be ended with pg_stop_backup(), and all WAL up to that point must be available at recovery.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.19 14720

WAL control functions cannot be executed during recovery.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.20 14721

wal_level must be set to "replica" or "logical" at server start.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.21 14722

Run pg_stop_backup() and try again.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.22 14723

If you're sure there is no backup in progress, remove file "@1@" and try again.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.23 14724

Check that your archive_command is executing properly. pg_stop_backup can be canceled safely, but the database backup will not be usable without all the WAL segments.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.24 14727

WAL redo at @1 @/@2@ for @3@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.25 14731

To avoid a database shutdown, execute a database-wide VACUUM in that database. You might also need to commit or roll back old prepared transactions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.26 14732

Values larger than a buffer page cannot be indexed.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.27 14733

Valid values are between "@1@" and "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.28 14734

Valid values are between "@1@" and "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.29 14735

Returned type @1@ does not match expected type @2@ in column @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.30 14736

Number of returned columns (@1@) does not match expected column count (@2@).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.31 14737

Attribute "@1@" of type @2@ does not match corresponding attribute of type @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.32 14738

Attribute "@1@" of type @2@ does not exist in type @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.33 14739

To enable inserting into the view, provide an INSTEAD OF INSERT trigger or an unconditional ON INSERT DO INSTEAD rule.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.34 14740

To enable updating the view, provide an INSTEAD OF UPDATE trigger or an unconditional ON UPDATE DO INSTEAD rule.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.35 14741

To enable deleting from the view, provide an INSTEAD OF DELETE trigger or an unconditional ON DELETE DO INSTEAD rule.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.36 14742

SQL function "@1@" statement @2@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.37 14743

SQL function "@1@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.38 14744

SQL function "@1@" during inlining

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.39 14745

Function's final statement must be SELECT or INSERT/UPDATE/DELETE RETURNING.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.40 14746

Final statement must return exactly one column.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.41 14747

Actual return type is @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.42 14748

Final statement returns too many columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.43 14749

Final statement returns @1@ instead of @2@ at column @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.44 14750

Final statement returns too few columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.45 14751

Input has too many columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.46 14752

Table has type @1@ at ordinal position @2@, but query expects @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.47 14753

Query provides a value for a dropped column at ordinal position @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.48 14754

Input has too few columns.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.49 14755

Check for missing "SPI_finish" calls.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.50 14756

SQL statement "@1@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.51 14757

Table has type @1@, but query expects @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.52 14758

Table row contains @1@ attribute, but query expects @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.53 14759

Physical storage mismatch on dropped attribute at ordinal position @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.54 14760

Returned row contains @1@ attribute, but query expects @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.55 14761

Returned type @1@ at ordinal position @2@, but query expects @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.56 14762

Array with element type @1@ cannot be included in ARRAY construct with element type @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.57 14763

Key @1@ conflicts with key @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.58 14764

Key @1@ conflicts with existing key @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.59 14765

This has been seen to occur with buggy kernels; consider updating your system.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.60 14766

Multiple failures --- write error might be permanent.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.61 14767

writing block @1@ of relation @2@**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.62 14768

Only RowExclusiveLock or less can be acquired on database objects during recovery.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.63 14769

You might need to increase max_locks_per_transaction.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.64 14771

You might need to run fewer transactions at a time or increase max_connections.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.65 14772

There might be an idle transaction or a forgotten prepared transaction causing this.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.66 14773

"default_transaction_isolation" is set to "serializable".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.67 14774

You can use "SET default_transaction_isolation = 'repeatable read'" to change the default.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.68 14775

You might need to increase max_pred_locks_per_transaction.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.69 14776

The transaction might succeed if retried.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.70 14778

User transaction caused buffer deadlock with recovery.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.71 14779

System allows @1@, we need at least @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.72 14782

Check free disk space.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.73 14783

Consider increasing the configuration parameter "max_wal_size".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.74 14784

Consult recent messages in the server log for details.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.75 14785

This may indicate an incomplete PostgreSQL installation, or that the file "@1@" has been moved away from its proper location.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.76 14786

The server must be started by the user that owns the data directory.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.77 14787

Permissions should be u=rwx (0700).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.78 14788

[See C include file "ntstatus.h" for a description of the hexadecimal value.](#)

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.79 14789

[automatic vacuum of table "@1@.@2@.@3@"](#)

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.80 14790

[automatic analyze of table "@1@.@2@.@3@"](#)

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.81 14791

[Enable the "track_counts" option.](#)

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.82 14792

The failed archive command was: @1@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.83 14793

Some of the transaction logs were lost that are necessary to recover the database completely.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.84 14794

Fix the problem by referring to the messages prior to this one. Then take a full backup of the database.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.85 14795

line @1@ of configuration file "@2@": "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.86 14796

Words longer than @1@ characters are ignored.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.87 14797

Use "?" to represent a stop word within a sample phrase.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.88 14798

Declare it with SCROLL option to enable backward scan.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.44.89 14799

prepare: @1@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45 Message Numbers Beginning with 14800

2.45.1 14800

parameters: @1@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.2 14801

abort reason: recovery conflict

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.3 14802

User was holding shared buffer pin for too long.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.4 14803

User was holding a relation lock for too long.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.5 14804

User was or might have been using tablespace that must be dropped.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.6 14805

User query might have needed to see row versions that must be removed.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.7 14806

User was connected to a database that must be dropped.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.8 14808

In a moment you should be able to reconnect to the database and repeat your command.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.9 14809

An invalid floating-point operation was signaled. This probably means an out-of-range result or an invalid operation, such as division by zero.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.10 14810

Increase the configuration parameter "max_stack_depth" (currently @1@kB), after ensuring the platform's stack depth limit is adequate.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.11 14811

Try "@1@ --help" for more information.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.12 14812

An aggregate returning a polymorphic type must have at least one polymorphic argument.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.13 14813

A function returning "internal" must have at least one "internal" argument.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.14 14814

Use DROP FUNCTION @1@ first.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.15 14815

Row type defined by OUT parameters is different.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.16 14816

System catalog modifications are currently disallowed.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.17 14818

A relation has an associated type of the same name, so you must use a name that doesn't conflict with any existing type.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.18 14819

Table "@1@" references "@2@", but they do not have the same ON COMMIT setting.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.19 14820

Table "@1@" references "@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.20 14821

Truncate table "@1@" at the same time, or use TRUNCATE ... CASCADE.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.21 14822

GRANT and REVOKE are not allowed on untrusted languages, because only superusers can use untrusted languages.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.22 14823

You can drop @1@ instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.23 14824

Use DROP ... CASCADE to drop the dependent objects too.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.24 14825

An aggregate using a polymorphic transition type must have at least one polymorphic argument.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.25 14826

A function returning a polymorphic type must have at least one polymorphic argument.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.26 14827

Labels must be @1@ characters or less.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.27 14828

Valid fork names are "main", "fsm", "vm", and "init".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.28 14830

Continuing to retry for 30 seconds.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.29 14831

You might have antivirus, backup, or similar software interfering with the database system.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.30 14832

while executing PostgreSQL::InServer::SPI::bootstrap

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.31 14833

while parsing Perl initialization

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.32 14834

while running Perl initialization

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.33 14835

while executing PLC_TRUSTED

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.34 14836

while executing utf8fix

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.35 14837

while executing plperl.on_plperl_init

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.36 14838

while executing plperl.on_plperlu_init

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.37 14839

PL/Perl function "@1@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.38 14840

compilation of PL/Perl function "@1@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.39 14841

PL/Perl anonymous code block

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.40 14842

PL/Python function "@1@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.41 14843

PL/Python anonymous code block

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.42 14844

while modifying trigger row

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.43 14845

while creating return value

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.44 14846

Expected None or a string.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.45 14847

Expected None, "OK", "SKIP", or "MODIFY".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.46 14848

PL/Python set-returning functions only support returning one value per call.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.47 14849

PL/Python set-returning functions must return an iterable object.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.48 14852

To return null in a column, add the value None to the mapping with the key named after the column.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.49 14853

To return null in a column, let the returned object have an attribute named after column with value None.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.50 14856

The arguments of the trigger can be accessed through TG_NARGS and TG_ARGV instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.51 14857

compilation of PL/pgSQL function "@1@" near line @2@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.52 14858

It could refer to either a PL/pgSQL variable or a table column.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.53 14859

PL/pgSQL function @1@ line @2@ @3@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.54 14860

PL/pgSQL function @1@ @2@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.55 14861

PL/pgSQL function @1@ line @2@ at @3@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.56 14862

PL/pgSQL function @1@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.57 14863

CASE statement is missing ELSE part.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.58 14864

The tuple structure of a not-yet-assigned record is indeterminate.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.59 14865

@1@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.60 14866

Use a BEGIN block with an EXCEPTION clause instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.61 14867

If you want to discard the results of a SELECT, use PERFORM instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.62 14868

You might want to use EXECUTE ... INTO or EXECUTE CREATE TABLE ... AS instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.63 14869

Use RETURN NEXT or RETURN QUERY.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.64 14870

@1@in PL/Tcl function "@2@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.45.65 14871

could not translate host name "@1@" to address: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.66 14873

out of memory

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.45.67 14877

host name must be specified

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.45.68 14881

GSSAPI continuation error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.45.69 14882

duplicate GSS authentication request

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.45.70 14883

GSSAPI name import error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.45.71 14884

SSPI continuation error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.45.72 14885

could not acquire SSPI credentials

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.73 14886

SCM_CRED authentication method not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.74 14887

Kerberos 4 authentication not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.75 14888

Kerberos 5 authentication not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.76 14889

GSSAPI authentication not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.77 14890

SSPI authentication not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.78 14891

Crypt authentication not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.79 14892

authentication method @1@ not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.80 14893

invalid sslmode value: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.81 14894

sslmode value "@1@" invalid when SSL support is not compiled in

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.82 14895

could not set socket to TCP no delay mode: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.83 14896

could not connect to server: @1@ Is the server running locally and accepting connections on Unix domain socket "@2@"?

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.84 14897

could not connect to server: @1@ Is the server running on host "@2@" (@3@) and accepting TCP/IP connections on port @4@?

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.45.85 14898

could not connect to server: @1@ Is the server running on host "@2@" and accepting TCP/IP connections on port @3@?

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46 Message Numbers Beginning with 14900

2.46.1 14902

setsockopt(@1@) failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.2 14903

WSAIoctl(SIO_KEEPA_LIVE_VALS) failed: @1@i

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.3 14904

invalid port number: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.4 14906

could not translate Unix-domain socket path "@1@" to address: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.5 14907

invalid connection state, probably indicative of memory corruption

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.46.6 14908

could not create socket: @1@

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.46.7 14909

could not set socket to nonblocking mode: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.8 14910

could not set socket to close-on-exec mode: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.9 14911

keepalives parameter must be an integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.10 14913

could not get socket error status: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.11 14914

could not get client address from socket: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.12 14915

requirepeer parameter is not supported on this platform

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.13 14916

could not get peer credentials: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.14 14918

requirepeer specifies "@1@", but actual peer user name is "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.15 14919

could not send startup packet: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.16 14921

unexpected message from server during startup

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.17 14922

could not send SSL negotiation packet: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.18 14923

server does not support SSL, but SSL was required

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.19 14924

received invalid response to SSL negotiation: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.20 14925

expected authentication request from server, but received @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.21 14926

out of memory allocating GSSAPI buffer (@1@)

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.46.22 14927

invalid connection state @1@, probably indicative of memory corruption

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.46.23 14928

PGEventProc "@1@" failed during PGEVT_CONNRESET event

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.24 14929

invalid LDAP URL "@1@": scheme must be ldap://

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.25 14930

invalid LDAP URL "@1@": missing distinguished name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.26 14931

invalid LDAP URL "@1@": must have exactly one attribute

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.27 14932

invalid LDAP URL "@1@": must have search scope (base/one/sub)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.28 14933

invalid LDAP URL "@1@": no filter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.29 14934

invalid LDAP URL "@1@": invalid port number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.30 14935

could not create LDAP structure

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.31 14936

lookup on LDAP server failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.32 14937

more than one entry found on LDAP lookup

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.33 14938

no entry found on LDAP lookup

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.34 14939

attribute has no values on LDAP lookup

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.35 14940

missing "=" after "@1@" in connection info string

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.46.36 14941

invalid connection option "@1@"

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.46.37 14942

unterminated quoted string in connection info string

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.46.38 14944

definition of service "@1@" not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.39 14945

service file "@1@" not found

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.46.40 14946

line @1@ too long in service file "@2@"

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.46.41 14947

syntax error in service file "@1@", line @2@

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.46.42 14948

connection pointer is NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.43 14951

password retrieved from file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.46.44 14952

command string is a null pointer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.45 14953

statement name is a null pointer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.46 14954

function requires at least protocol version 3.0

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.47 14955

no connection to the server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.48 14956

another command is already in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.49 14957

length must be given for binary parameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.50 14958

unexpected asyncStatus: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.46.51 14959

PGEventProc "@1@" failed during PGEVT_RESULTCREATE event

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.52 14960

COPY terminated by new PQexec

[Description]

Processing was canceled.

[System Processing]

Processing will be aborted.

[Action]

Check the message text.

2.46.53 14961

COPY IN state must be terminated first

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.54 14962

COPY OUT state must be terminated first

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.55 14963

PQexec not allowed during COPY BOTH

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.56 14964

no COPY in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.57 14965

connection in wrong state

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.58 14966

invalid ExecStatusType code

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.59 14967

column number @1@ is out of range 0..@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.60 14968

row number @1@ is out of range 0..@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.61 14969

parameter number @1@ is out of range 0..@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.62 14970

could not interpret result from server: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.63 14971

incomplete multibyte character

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.64 14972

cannot determine OID of function lo_truncate

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.65 14973

cannot determine OID of function lo_create

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.66 14974

could not open file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.67 14975

could not read from file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.68 14976

could not write to file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.69 14977

query to initialize large object functions did not return data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.70 14978

cannot determine OID of function lo_open

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.71 14979

cannot determine OID of function lo_close

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.72 14980

cannot determine OID of function lo_creat

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.73 14981

cannot determine OID of function lo_unlink

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.74 14982

cannot determine OID of function lo_lseek

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.75 14983

cannot determine OID of function lo_tell

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.76 14984

cannot determine OID of function loread

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.77 14985

cannot determine OID of function lowrite

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.78 14986

integer of size @1@ not supported by pqGetInt

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.79 14987

integer of size @1@ not supported by pqPutInt

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.80 14988

connection not open

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.46.81 14989

server closed the connection unexpectedly This probably means the server terminated abnormally before or while processing the request.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.82 14990

timeout expired

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.46.83 14991

invalid socket

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.84 14992

select() failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.46.85 14993

invalid setenv state @1 @, probably indicative of memory corruption

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.46.86 14994

invalid state @1 @, probably indicative of memory corruption

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.46.87 14995

message type 0x@1 @ arrived from server while idle

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.46.88 14996

unexpected character @1 @ following empty query response ("I" message)

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.89 14997

server sent data ("D" message) without prior row description ("T" message)

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.90 14998

server sent binary data ("B" message) without prior row description ("T" message)

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.46.91 14999

unexpected response from server; first received character was "@1@"

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.47 Message Numbers Beginning with 15000

2.47.1 15000

out of memory for query result

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.47.2 15001

lost synchronization with server, resetting connection

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- If the COMMIT process is not executed after update, add the COMMIT process.
 - If the total number of update records in a single transaction is high, split it into short transactions.
 - If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - Confirm that the database server has not stopped.
 - If the database server is starting or stopping, re-execute the command after the database server starts.

2.47.3 15002

protocol error: id=0x@1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.47.4 15003

server sent data ("D" message) without prior row description ("T" message)

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.47.5 15004

message contents do not agree with length in message type "@1@"

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.47.6 15005

lost synchronization with server: got message type "@1@", length @2@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.47.7 15006

unexpected field count in "D" message

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.47.8 15007

PQgetline: not doing text COPY OUT

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.47.9 15008

could not establish SSL connection: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.47.10 15009

SSL SYSCALL error: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.11 15010

SSL SYSCALL error: EOF detected

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.12 15011

SSL error: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.13 15012

SSL connection has been closed unexpectedly

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
- b) If the total number of update records in a single transaction is high, split it into short transactions.
- c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

a) Confirm that the database server has not stopped.

b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.47.14 15013

unrecognized SSL error code: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.15 15014

could not receive data from server: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)

- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

a) If the COMMIT process is not executed after update, add the COMMIT process.

b) If the total number of update records in a single transaction is high, split it into short transactions.

c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.

- If none of the above situations applies, perform the following:

a) Confirm that the database server has not stopped.

b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.47.16 15015

could not send data to server: @1@

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.47.17 15016

could not get server's host name from server certificate

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.18 15017

SSL certificate's name contains embedded null

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.19 15018

host name must be specified for a verified SSL connection

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.20 15019

server certificate for "@1@" does not match host name "@2@"

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.21 15020

could not create SSL context: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.22 15021

could not open certificate file "@1@": @2@

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.23 15022

could not read certificate file "@1@": @2@

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.24 15023

could not load SSL engine "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.25 15024

could not initialize SSL engine "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.26 15025

could not read private SSL key "@1@" from engine "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.27 15026

could not load private SSL key "@1@" from engine "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.28 15027

certificate present, but not private key file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.29 15028

private key file "@1@" has group or world access; permissions should be u=rw (0600) or less

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.30 15029

could not load private key file "@1@" : @2@

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.31 15030

certificate does not match private key file "@1@" : @2@

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.32 15031

could not read root certificate file "@1@": @2@

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.33 15032

SSL library does not support CRL certificates (file "@1@")

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.47.34 15033

could not get home directory to locate root certificate fileEither provide the file or change sslmode to disable server certificate verification.

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.35 15034

root certificate file "@1@" does not existEither provide the file or change sslmode to disable server certificate verification.

[Description]

The operating environment such as the status of the connection definition file and the connection method specification is abnormal.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the operating environment such as the status of the connection definition file and the connection method specification is normal.

2.47.36 15035

certificate could not be obtained: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.37 15036

no SSL error reported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.38 15037

SSL error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.39 15038

@1@: vacuuming database "@2@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.47.40 15042

skipped creating .ready file for multiplexed transaction log file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.47.41 15043

skipped recycling multiplexed transaction log file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.47.42 15044

skipped removing multiplexed transaction log file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.47.43 15045

no data found on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.44 15046

out of memory on line @1@

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.47.45 15047

unsupported type "@1@" on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.46 15048

too many arguments on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.47 15049

too few arguments on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.48 15050

invalid input syntax for type int: "@1@", on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.49 15051

invalid input syntax for type unsigned int: "@1@", on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.50 15052

invalid input syntax for floating-point type: "@1@", on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.51 15053

invalid syntax for type boolean: "@1@", on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.52 15054

could not convert boolean value: size mismatch, on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.53 15055

empty query on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.54 15056

null value without indicator on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.55 15057

variable does not have an array type on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.56 15058

data read from server is not an array on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.57 15059

inserting an array of variables is not supported on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.58 15060

connection "@1@" does not exist on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.59 15061

not connected to connection "@1@" on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.60 15062

invalid statement name "@1@" on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.61 15063

descriptor "@1@" not found on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.62 15064

descriptor index out of range on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.63 15065

unrecognized descriptor item "@1@" on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.64 15066

variable does not have a numeric type on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.65 15067

variable does not have a character type on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.66 15068

error in transaction processing on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.67 15069

could not connect to database "@1@" on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.68 15070

SQL error @1@ on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.69 15071

the connection to the server was lost

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.70 15072

empty message text

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.71 15074

SP-GiST inner tuple size @1@ exceeds maximum @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.72 15075

backup_label contains data inconsistent with control file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.73 15076

WAL generated with full_page_writes=off was replayed since last restartpoint

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.74 15077

the standby was promoted during online backup

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.75 15078

WAL generated with full_page_writes=off was replayed during online backup

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.76 15080

cannot set privileges of array types

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.77 15081

**drop cascades to @1@ other object
drop cascades to @2@ other objects**

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.47.78 15082

constraint "@1@" conflicts with non-inherited constraint on relation "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.79 15083

DROP INDEX CONCURRENTLY must be first action in transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.80 15085

domain @1@ has multiple constraints named "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.81 15086

functions cannot have more than @1@ argument
functions cannot have more than @2@ arguments

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.82 15087

skipping "@1@" --- cannot analyze this foreign table

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.47.83 15088

could not convert row type

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.47.84 15089

unexpected EOF on client connection with an open transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.85 15090

EXPLAIN option TIMING requires ANALYZE

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.86 15091

only superuser can define a leakproof function

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.87 15092

cast will be ignored because the source data type is a domain

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.88 15093

cast will be ignored because the target data type is a domain

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.89 15094

btree sort support procedures must accept type "internal"**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.90 15095

btree sort support procedures must return void**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.91 15096

Use DROP TABLE to remove a table.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.92 15097

Use DROP SEQUENCE to remove a sequence.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.93 15098

Use DROP VIEW to remove a view.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.47.94 15099

Use DROP INDEX to remove an index.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48 Message Numbers Beginning with 15100

2.48.1 15100

Use DROP TYPE to remove a type.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.2 15101

Use DROP FOREIGN TABLE to remove a foreign table.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.3 15102

DROP INDEX CONCURRENTLY does not support dropping multiple objects

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.4 15103

DROP INDEX CONCURRENTLY does not support CASCADE

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.5 15104

cannot inherit from temporary relation of another session

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.6 15105

constraints on temporary tables must involve temporary tables of this session

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.7 15106

constraint must be validated on child tables too

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.8 15107

cannot inherit to temporary relation of another session

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.9 15108

constraint "@1@" conflicts with non-inherited constraint on child table "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.10 15109

Found referenced table's UPDATE trigger.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.11 15110

Found referenced table's DELETE trigger.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.12 15111

Found referencing table's trigger.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.13 15112

@1 @ constraints cannot be marked NO INHERIT

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.14 15113

type attribute "subtype" is required

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.15 15114

range collation specified but subtype does not support collation

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.16 15115

range canonical function @1@ must be immutable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.17 15116

range subtype diff function @1@ must return type @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.18 15117

range subtype diff function @1@ must be immutable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.19 15118

constraint "@1@" of domain "@2@" does not exist, skipping

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.20 15119

"@1@": suspending truncate due to conflicting lock request

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.21 15120

cannot set transaction read-write mode inside a read-only transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.22 15121

transaction read-write mode must be set before any query

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.23 15122

cannot set transaction read-write mode during recovery

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.24 15123

SET TRANSACTION ISOLATION LEVEL must be called before any query

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.25 15124

SET TRANSACTION ISOLATION LEVEL must not be called in a subtransaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.26 15125

SET TRANSACTION [NOT] DEFERRABLE cannot be called within a subtransaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.27 15126

SET TRANSACTION [NOT] DEFERRABLE must be called before any query

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.28 15127

cannot delete from view "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.29 15128

GLOBAL is deprecated in temporary table creation

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.30 15129

duplicate trigger events specified

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.48.31 15130

unrecognized configuration parameter "@1@" in file "@2@" line @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.32 15131

configuration file "@1@" contains errors

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.33 15132

configuration file "@1@" contains errors; unaffected changes were applied

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.34 15133

configuration file "@1@" contains errors; no changes were applied

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.35 15134

too many syntax errors found, abandoning file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.36 15135

accepting GSS security context failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.37 15136

retrieving GSS user name failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.38 15137

could not acquire SSPI credentials

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.39 15138

could not accept SSPI security context

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.40 15139

could not get token from SSPI security context

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.41 15140

multiple values in ident field

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.42 15141

multiple values specified for connection type

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.43 15142

multiple values specified for host address

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.44 15143

multiple values specified for netmask

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.45 15144

multiple values specified for authentication type

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.46 15145

ident, peer, gssapi, sspi, and cert

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.47 15146

gssapi and sspi

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.48.48 15147

configuration file "@1@" contains no entries

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.49 15148

Unix-domain socket path "@1@" is too long (maximum @2@ bytes)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.50 15149

@1@: WSAStartup failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.51 15150

@1@: real and effective user IDs must match

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.52 15151

could not look up effective user ID @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.53 15153

too many range table entries

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.54 15154

SELECT ... INTO is not allowed here

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.55 15155

arguments declared "anyrange" are not all alike

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.56 15156

argument declared @1@ is not consistent with argument declared @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.57 15157

could not load dbghelp.dll, cannot write crash dump

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.58 15158

could not load required functions in dbghelp.dll, cannot write crash dump

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.59 15159

could not open crash dump file "@1@" for writing: error code @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.60 15160

could not write crash dump to file "@1@": error code @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.61 15161

could not check access token membership: error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.62 15162

could not get SID for Administrators group: error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.63 15163

could not get SID for PowerUsers group: error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.64 15164

could not create signal listener pipe: error code @1@; retrying

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.65 15165

could not create signal dispatch thread: error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.66 15166

@1@: superuser_reserved_connections must be less than max_connections

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.67 15167

[@1@: max_wal_senders must be less than max_connections](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.68 15168

[@1@: invalid datetoken tables, please fix](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.69 15169

[@1@: could not change permissions of external PID file "@2@": @3@](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.70 15170

[@1@: could not write external PID file "@2@": @3@](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.71 15171

could not fork new process for connection:

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.72 15172

could not read exit code for process

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.73 15173

could not post child completion status

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.74 15174

could not write to log file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.75 15175

invalid streaming start location

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.76 15176

unterminated quoted string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.77 15177

unexpected WAL file size "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.78 15178

unterminated bit string literal

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.79 15179

unterminated hexadecimal string literal

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.80 15180

invalid Unicode surrogate pair

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.81 15181

unterminated dollar-quoted string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.82 15182

zero-length delimited identifier

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.83 15183

unterminated quoted identifier

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.84 15184

Unicode escape values cannot be used for code point values above 007F when the server encoding is not UTF8

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.85 15185

invalid Unicode escape value

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.86 15186

invalid Unicode escape character

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.87 15187

temporary file size exceeds temp_file_limit (@1@kB)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.88 15188

a snapshot-importing transaction must not be READ ONLY DEFERRABLE

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.89 15189

could not import the requested snapshot

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.90 15190

connection to client lost

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.48.91 15191

invalid command-line argument for server process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.92 15194

range constructor flags argument must not be null

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.93 15195

result of range difference would not be contiguous

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.94 15196

result of range union would not be contiguous

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.95 15197

range lower bound must be less than or equal to range upper bound

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.96 15198

invalid range bound flags

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.48.97 15199

could not set up XML error handler

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49 Message Numbers Beginning with 15200

2.49.1 15200

keystore_location is not supported by this build

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.2 15201

keystore location is not configured

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.3 15202

could not encrypt or decrypt data because the keystore is not open

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.4 15203

keystore is already open

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.5 15204

passphrase is too short or too long

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.6 15205

passphrase-based key derivation failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.7 15206

a new master encryption key has been set

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.8 15207

passphrase of the keystore has been changed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.9 15208

encryption or decryption of data in tablespace @1@ failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.10 15209

encryption or decryption of data failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.11 15210

could not open keystore "@1@": necessary master encryption key does not exist in the keystore

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.12 15211

decryption of the auto-open keystore "@1@" failed: error code = @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.13 15212

encryption of the auto-open keystore "@1@" failed: error code = @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.14 15213

keystore "@1@" is corrupted: size = @2@ bytes, expected size = @3@ bytes

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.15 15214

could not open keystore "@1@" : passphrase is wrong, or the auto-open keystore was created by another computer or user

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.16 15215

keystore "@1@" is corrupted: invalid CRC

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.17 15216

encryption or decryption of the keystore "@1@" failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.18 15217

character with byte sequence @1@ in encoding "@2@" has no equivalent in encoding "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.19 15218

Enables the planner's use of sequential-scan plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.20 15219

Enables the planner's use of index-scan plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.21 15220

Enables the planner's use of index-only-scan plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.22 15221

Enables the planner's use of bitmap-scan plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.23 15222

Enables the planner's use of TID scan plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.24 15223

Enables the planner's use of explicit sort steps.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.25 15224

Enables the planner's use of hashed aggregation plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.26 15225

Enables the planner's use of materialization.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.27 15226

Enables the planner's use of nested-loop join plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.28 15227

Enables the planner's use of merge join plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.29 15228

Enables the planner's use of hash join plans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.30 15229

Enables genetic query optimization.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.31 15230

Shows whether the current user is a superuser.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.32 15231

Enables advertising the server via Bonjour.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.33 15232

Enables SSL connections.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.34 15233

Forces synchronization of updates to disk.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.35 15235

Writes full pages to WAL when first modified after a checkpoint.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.36 15236

Logs each checkpoint.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.37 15237

Logs each successful connection.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.38 15238

Logs end of a session, including duration.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.39 15239

Shows whether the running server has assertion checks enabled.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.40 15240

Terminate session on any error.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.41 15241

Restarts all server processes on WAL multiplexing errors.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.42 15242

Enables fast WAL multiplexing.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.43 15243

Enables encryption of temporary files used in large queries.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.44 15244

Reinitialize server after backend crash.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.45 15245

Logs the duration of each completed SQL statement.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.46 15246

Logs each query's parse tree.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.47 15247

Logs each query's rewritten parse tree.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.48 15248

Logs each query's execution plan.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.49 15249

Indents parse and plan tree displays.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.50 15250

Writes parser performance statistics to the server log.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.51 15251

Writes planner performance statistics to the server log.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.52 15252

Writes executor performance statistics to the server log.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.53 15253

Writes cumulative performance statistics to the server log.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.54 15255

Collects information about executing commands.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.55 15256

Collects statistics on database activity.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.56 15257

Collects timing statistics for database I/O activity.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.57 15258

Updates the process title to show the active SQL command.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.58 15259

Starts the autovacuum subprocess.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.59 15260

Generates debugging output for LISTEN and NOTIFY.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.60 15261

Logs long lock waits.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.61 15262

Logs the host name in the connection logs.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.62 15264

Encrypt passwords.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.63 15265

Treats "expr=NULL" as "expr IS NULL".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.64 15266

Enables per-database user names.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.65 15268

Sets the default read-only status of new transactions.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.66 15269

Sets the current transaction's read-only status.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.67 15270

Sets the default deferrable status of new transactions.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.68 15271

Whether to defer a read-only serializable transaction until it can be executed with no possible serialization failures.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.69 15272

Check function bodies during CREATE FUNCTION.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.70 15273

Enable input of NULL elements in arrays.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.71 15275

Start a subprocess to capture stderr output and/or csvlogs into log files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.72 15276

Truncate existing log files of same name during log rotation.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.73 15277

Emit information about resource usage in sorting.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.74 15278

Generate debugging output for synchronized scanning.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.75 15279

Enable bounded sorting using heap sort.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.76 15280

Emit WAL-related debugging output.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.77 15281

Datetimes are integer based.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.78 15282

Sets whether Kerberos and GSSAPI user names should be treated as case-insensitive.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.79 15283

Warn about backslash escapes in ordinary string literals.

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.49.80 15284

Causes '...' strings to treat backslashes literally.

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.49.81 15285

Enable synchronized sequential scans.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.82 15286

Allows archiving of WAL files using archive_command.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.83 15287

Allows connections and queries during recovery.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.84 15288

Allows feedback from a hot standby to the primary that will avoid query conflicts.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.85 15289

Allows modifications of the structure of system tables.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.86 15290

Disables reading from system indexes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.87 15291

Enables backward compatibility mode for privilege checks on large objects.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.88 15292

When generating SQL fragments, quote all identifiers.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.89 15293

Forces a switch to the next WAL file if a new file has not been started within N seconds.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.49.90 15294

Waits N seconds on connection startup after authentication.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.91 15295

Sets the default statistics target.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.92 15296

Sets the FROM-list size beyond which subqueries are not collapsed.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.93 15297

Sets the FROM-list size beyond which JOIN constructs are not flattened.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.94 15298

Sets the threshold of FROM items beyond which GEQO is used.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.49.95 15299

GEQO: effort is used to set the default for other GEQO parameters.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50 Message Numbers Beginning with 15300

2.50.1 15300

GEQO: number of individuals in the population.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.2 15301

GEQO: number of iterations of the algorithm.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.3 15302

Sets the time to wait on a lock before checking for deadlock.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.4 15303

Sets the maximum delay before canceling queries when a hot standby server is processing archived WAL data.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.5 15304

Sets the maximum delay before canceling queries when a hot standby server is processing streamed WAL data.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.6 15305

Sets the maximum interval between WAL receiver status reports to the sending server

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.7 15306

Sets the maximum number of concurrent connections.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.8 15307

Sets the number of connection slots reserved for superusers.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.9 15308

Sets the number of shared memory buffers used by the server.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.10 15309

Sets the maximum number of temporary buffers used by each session.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.11 15310

Sets the TCP port the server listens on.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.12 15311

Sets the access permissions of the Unix-domain socket.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.13 15312

Sets the file permissions for log files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.14 15313

Sets the maximum memory to be used for query workspaces.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.15 15314

Sets the maximum memory to be used for maintenance operations.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.16 15315

Sets the maximum stack depth, in kilobytes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.17 15316

Limits the total size of all temporary files used by each process.

[Description]

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.50.18 15317

Vacuum cost for a page found in the buffer cache.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.19 15318

Vacuum cost for a page not found in the buffer cache.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.20 15319

Vacuum cost for a page dirtied by vacuum.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.21 15320

Vacuum cost amount available before napping.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.22 15321

Vacuum cost delay in milliseconds.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.23 15322

Vacuum cost delay in milliseconds, for autovacuum.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.24 15323

Vacuum cost amount available before napping, for autovacuum.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.25 15324

Sets the maximum number of simultaneously open files for each server process.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.26 15325

Sets the maximum number of simultaneously prepared transactions.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.27 15326

Sets the maximum allowed duration of any statement.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.28 15327

Minimum age at which VACUUM should freeze a table row.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.29 15328

Age at which VACUUM should scan whole table to freeze tuples.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.30 15329

Number of transactions by which VACUUM and HOT cleanup should be deferred, if any.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.31 15330

Sets the maximum number of locks per transaction.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.32 15331

Sets the maximum number of predicate locks per transaction.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.33 15332

Sets the maximum allowed time to complete client authentication.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.34 15333

Waits N seconds on connection startup before authentication.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.35 15334

Sets the number of WAL files held for standby servers.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.36 15336

Sets the maximum time between automatic WAL checkpoints.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.37 15337

Enables warnings if checkpoint segments are filled more frequently than this.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.38 15338

Sets the number of disk-page buffers in shared memory for WAL.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.39 15339

Time between WAL flushes performed in the WAL writer.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.40 15340

Sets the maximum number of simultaneously running WAL sender processes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.41 15341

Sets the maximum time to wait for WAL replication.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.42 15342

Sets the delay in microseconds between transaction commit and flushing WAL to disk.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.43 15343

Sets the minimum concurrent open transactions before performing commit_delay.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.44 15344

Sets the number of digits displayed for floating-point values.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.45 15345

Sets the minimum execution time above which statements will be logged.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.46 15346

Sets the minimum execution time above which autovacuum actions will be logged.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.47 15347

Background writer sleep time between rounds.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.48 15348

Background writer maximum number of LRU pages to flush per round.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.49 15349

Number of simultaneous requests that can be handled efficiently by the disk subsystem.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.50 15350

Automatic log file rotation will occur after N minutes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.51 15351

Automatic log file rotation will occur after N kilobytes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.52 15352

Shows the maximum number of function arguments.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.53 15353

Shows the maximum number of index keys.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.54 15354

Shows the maximum identifier length.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.55 15355

Shows the size of a disk block.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.56 15356

Shows the number of pages per disk file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.57 15357

Shows the block size in the write ahead log.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.58 15358

Shows the number of pages per write ahead log segment.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.59 15359

Time to sleep between autovacuum runs.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.60 15360

Minimum number of tuple updates or deletes prior to vacuum.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.61 15361

Minimum number of tuple inserts, updates, or deletes prior to analyze.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.62 15362

Age at which to autovacuum a table to prevent transaction ID wraparound.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.63 15363

Sets the maximum number of simultaneously running autovacuum worker processes.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.64 15364

Time between issuing TCP keepalives.**[Description]**

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.65 15365

Time between TCP keepalive retransmits.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.66 15366

SSL renegotiation is no longer supported; this can only be 0.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.67 15367

Maximum number of TCP keepalive retransmits.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.68 15368

Sets the maximum allowed result for exact search by GIN.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.69 15369

Sets the planner's assumption about the size of the disk cache.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.70 15370

Shows the server version as an integer.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.71 15371

Log the use of temporary files larger than this number of kilobytes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.72 15372

Sets the size reserved for pg_stat_activity.query, in bytes.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.73 15373

Sets the planner's estimate of the cost of a sequentially fetched disk page.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.74 15374

Sets the planner's estimate of the cost of a nonsequentially fetched disk page.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.75 15375

Sets the planner's estimate of the cost of processing each tuple (row).

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.76 15376

Sets the planner's estimate of the cost of processing each index entry during an index scan.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.77 15377

Sets the planner's estimate of the cost of processing each operator or function call.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.78 15378

Sets the planner's estimate of the fraction of a cursor's rows that will be retrieved.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.79 15379

GEQO: selective pressure within the population.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.80 15380

GEQO: seed for random path selection.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.81 15381

Multiple of the average buffer usage to free per round.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.82 15382

Sets the seed for random-number generation.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.83 15383

Number of tuple updates or deletes prior to vacuum as a fraction of reltuples.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.84 15384

Number of tuple inserts, updates, or deletes prior to analyze as a fraction of reltuples.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.85 15385

Time spent flushing dirty buffers during checkpoint, as fraction of checkpoint interval.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.86 15386

Sets the shell command that will be called to archive a WAL file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.87 15387

Sets the client's character set encoding.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.88 15388

Controls information prefixed to each log line.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.89 15389

Sets the time zone to use in log messages.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.90 15390

Sets the display format for date and time values.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.91 15391

Sets the default tablespace to create tables and indexes in.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.92 15392

Sets the tablespace(s) to use for temporary tables and sort files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.93 15393

Sets the path for dynamically loadable modules.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.94 15394

Sets the location of the Kerberos server key file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.95 15396

Sets the Bonjour service name.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.96 15397

Shows the collation order locale.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.97 15398

Shows the character classification and case conversion locale.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.50.98 15399

Sets the language in which messages are displayed.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51 Message Numbers Beginning with 15400

2.51.1 15400

Sets the locale for formatting monetary amounts.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.2 15401

Sets the locale for formatting numbers.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.3 15402

Sets the locale for formatting date and time values.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.4 15403

Lists shared libraries to preload into server.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.5 15404

Lists shared libraries to preload into each backend.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.6 15405

Sets the schema search order for names that are not schema-qualified.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.7 15406

Sets the server (database) character set encoding.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.8 15407

Shows the server version.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.9 15408

Sets the current role.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.10 15409

Sets the session user name.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.11 15410

Sets the destination for server log output.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.12 15411

Sets the destination directory for log files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.13 15412

Sets the file name pattern for log files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.14 15413

Sets the program name used to identify PostgreSQL messages in syslog.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.15 15414

Sets the application name used to identify PostgreSQL messages in the event log.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.16 15415

Sets the time zone for displaying and interpreting time stamps.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.17 15416

Selects a file of time zone abbreviations.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.18 15417

Sets the current transaction's isolation level.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.19 15418

Sets the owning group of the Unix-domain socket.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.20 15419

Sets the directories where Unix-domain sockets will be created.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.21 15420

Sets the host name or IP address(es) to listen to.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.22 15421

Sets the server's data directory.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.23 15422

Sets the server's backup directory.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.24 15423

Sets the directory where multiplexed transaction log files are stored.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.25 15424

Sets the directory where server's core files are dumped.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.26 15425

Sets the location where the keystore is stored

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.27 15426

Sets the server's main configuration file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.28 15427

Sets the server's "hba" configuration file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.29 15428

Sets the server's "ident" configuration file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.30 15429

Writes the postmaster PID to the specified file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.31 15430

Location of the SSL server certificate file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.32 15431

Location of the SSL server private key file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.33 15432

Location of the SSL certificate authority file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.34 15433

Location of the SSL certificate revocation list file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.35 15434

Writes temporary statistics files to the specified directory.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.36 15435

Number of synchronous standbys and list of names of potential synchronous ones.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.37 15436

Sets default text search configuration.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.38 15437

Sets the list of allowed SSL ciphers.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.39 15438

Sets the application name to be reported in statistics and logs.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.40 15439

Sets whether "\" is allowed in string literals.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.41 15440

Sets the output format for bytea.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.42 15441

Sets the message levels that are sent to the client.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.43 15442

Enables the planner to use constraints to optimize queries.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.44 15443

Sets the transaction isolation level of each new transaction.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.45 15444

Sets the display format for interval values.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.46 15445

Sets the verbosity of logged messages.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.47 15446

Sets the message levels that are logged.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.48 15447

Causes all statements generating error at or above this level to be logged.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.49 15448

Sets the type of statements logged.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.50 15449

Sets the syslog "facility" to be used when syslog enabled.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.51 15450

Sets the session's behavior for triggers and rewrite rules.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.52 15451

Sets the current transaction's synchronization level.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.53 15452

Enables logging of recovery-related debugging information.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.54 15453

Collects function-level statistics on database activity.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.55 15454

Set the level of information written to the WAL.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.56 15455

Selects the method used for forcing WAL updates to disk.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.57 15456

Sets how binary values are to be encoded in XML.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.58 15457

Sets whether XML data in implicit parsing and serialization operations is to be considered as documents or content fragments.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.59 15458

Sets what to dump in core files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.60 15459

Selects the algorithm for encrypting tablespaces.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.51.61 15460

@1@: could not access the server configuration file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.62 15461

SET LOCAL TRANSACTION SNAPSHOT is not implemented

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.63 15464

Bonjour is not supported by this build

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.64 15465

SSL is not supported by this build

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.65 15466

internal error: unrecognized run-time parameter type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.66 15467

time zone abbreviation "@1@" is too long (maximum @2@ characters) in time zone file "@3@", line @4@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.67 15468

invalid number for time zone offset in time zone file "@1@", line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.68 15469

time zone offset @1@ is out of range in time zone file "@2@", line @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.69 15470

missing time zone abbreviation in time zone file "@1@", line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.70 15471

missing time zone offset in time zone file "@1@", line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.71 15473

invalid syntax in time zone file "@1@", line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.72 15474

time zone abbreviation "@1@" is multiply defined

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.73 15475

invalid time zone file name "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.74 15476

time zone file recursion limit exceeded in file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.75 15477

line is too long in time zone file "@1@", line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.76 15478

@INCLUDE without file name in time zone file "@1@", line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.77 15479

cannot export a snapshot from a subtransaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.78 15480

invalid snapshot data in file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.79 15481

@1@ must be called before any query

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.80 15482

a snapshot-importing transaction must have isolation level SERIALIZABLE or REPEATABLE READ

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.81 15483

invalid snapshot identifier: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.82 15484

a serializable transaction cannot import a snapshot from a non-serializable transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.83 15485

a non-read-only serializable transaction cannot import a snapshot from a read-only transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.84 15486

cannot import a snapshot from a different database

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.85 15487

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.51.86 15488

could not open file "@1@" for reading: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.87 15489

could not open file "@1@" for writing: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.88 15490

could not write file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.89 15491

could not execute command "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.90 15492

removing data directory "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.91 15493

failed to remove data directory

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.92 15494

removing contents of data directory "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.51.93 15495

failed to remove contents of data directory

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52 Message Numbers Beginning with 15500

2.52.1 15500

data directory "@1@" not removed at user's request

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.2 15503

user name lookup failure: error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.3 15504

"@1@" is not a valid server encoding name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.4 15505

could not create directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.5 15506

file "@1@" does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.6 15507

could not access file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.7 15508

file "@1@" is not a regular file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.8 15509

Passwords didn't match.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.9 15510

could not read password from file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.10 15515

could not write to child process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.11 15516

ok

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.52.12 15517

failed to restore old locale "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.13 15518

invalid locale name "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.14 15519

encoding mismatch

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.15 15525

@1@ initializes a PostgreSQL database cluster.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.16 15527

invalid authentication method "@1@" for "@2@" connections

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.17 15528

must specify a password for the superuser to enable @1@ authentication

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.18 15529

too many command-line arguments (first is "@1@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.19 15530

password prompt and password file cannot be specified together

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.20 15533

The program "postgres" is needed by @1@ but was not found in the same directory as "@2@". Check your installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.21 15534

The program "postgres" was found by "@1@"but was not the same version as @2@.Check your installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.22 15535

input file location must be an absolute path

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.23 15536

could not find suitable encoding for locale "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.24 15537

locale "@1@" requires unsupported encoding "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.25 15538

could not find suitable text search configuration for locale "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.26 15539

suitable text search configuration for locale "@1@" is unknown

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.52.27 15540

specified text search configuration "@1@" might not match locale "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.52.28 15541

The default text search configuration will be set to "@1@".

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.52.29 15542

directory "@1@" exists but is not empty

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.30 15543

could not access directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.31 15544

WAL directory location must be an absolute path

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.32 15545

could not create symbolic link "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.33 15546

symlinks are not supported on this platform

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.34 15547

could not read from ready pipe: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.35 15548

could not parse write-ahead log location "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.36 15549

could not create pipe for background process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.37 15550

could not create background process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.38 15551

could not create background thread: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.39 15552

could not create directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.40 15553

directory "@1@" exists but is not empty

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.41 15554

could not access directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.42 15555

@1@s/@2@ kB (100@3@), @4@/@5@ tablespace @6@s

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.52.43 15556

@1@s/@2@ kB (@3@@4@), @5@/@6@ tablespace (@7@%-*.*s)

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.52.44 15560

@1@s/@2@ kB (@3@@4@), @5@/@6@ tablespace

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.52.45 15561

could not set compression level @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.46 15562

could not create compressed file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.47 15563

could not create file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.48 15564

could not get COPY data stream: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.49 15565

could not write to compressed file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.50 15566

could not write to file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.51 15567

could not close compressed file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.52 15568

could not close file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.53 15569

could not read COPY data: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.54 15570

invalid tar block header size: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.55 15573

could not set permissions on directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.56 15574

could not create symbolic link from "@1@" to "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.57 15575

unrecognized link indicator "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.58 15576

could not set permissions on file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.59 15577

COPY stream ended before last file was finished

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.60 15578

could not send replication command "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.61 15579

could not identify system: got @1@ rows and @2@ fields, expected @3@ rows and @4@ or more fields

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.62 15580

could not initiate base backup: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.63 15581

no data returned from server

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.64 15582

could not get backup header: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.65 15584

can only write single tablespace to stdout, database has @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.66 15585

starting background WAL receiver

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.67 15586

could not get write-ahead log end position from server: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.68 15587

no write-ahead log end position returned from server

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.69 15588

final receive failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.70 15589

could not send command to background pipe: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.71 15590

could not wait for child process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.72 15591

child @1@ died, expected @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.73 15594

could not wait for child thread: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.74 15595

could not get child thread exit status: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.75 15596

child thread exited with error @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.76 15597

invalid output format "@1@", must be "plain" or "tar"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.52.77 15599

invalid compression level "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53 Message Numbers Beginning with 15600

2.53.1 15600

invalid checkpoint argument "@1@", must be "fast" or "spread"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.2 15601

invalid status interval "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.3 15602

too many command-line arguments (first is "@1@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.4 15603

no target directory specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.5 15604

only tar mode backups can be compressed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.6 15606

this build does not support compression

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.7 15607

finished segment at @1 @/@2@ (timeline @3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.8 15608

received interrupt signal, exiting

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.9 15609

could not open directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.10 15611

could not stat file "@1@": @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.11 15612

segment file "@1@" has incorrect size @2@, skipping**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.12 15613

starting log streaming at @1@/@2@ (timeline @3@)**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.13 15614

invalid port number "@1@"**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.14 15615

disconnected

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.15 15616

disconnected; waiting @1@ seconds to try again

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.16 15617

could not open existing write-ahead log file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.17 15619

write-ahead log file "@1@" has @2@ byte, should be 0 or @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.18 15622

could not determine seek position in file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.19 15623

could not fsync file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.20 15625

not renaming "@1@@2@", segment is not complete

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.21 15626

system identifier does not match between base backup and streaming connection

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.22 15628

could not send feedback packet: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.23 15629

select() failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.24 15630

could not receive data from WAL stream: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.25 15632

unrecognized streaming header: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.26 15633

streaming header too small: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.27 15634

received write-ahead log record for offset @1@ with no file open

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.28 15635

got WAL data offset @1@, expected @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.29 15636

could not write @1@ bytes to WAL file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.30 15637

unexpected termination of replication stream: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.31 15638

replication stream was terminated before stop point

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.32 15640

could not connect to server

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.33 15642

could not determine server setting for integer_datetimes

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.34 15643

integer_datetimes compile flag does not match server

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.35 15645

@1@: could not find own program executable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.36 15646

@1@: invalid argument: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.37 15647

no data directory specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.38 15648

could not open file "@1@" for reading: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.39 15649

could not read file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.40 15652

child process exited with unrecognized status @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.41 15653

@1@: could not open PID file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.42 15654

@1@: invalid data in PID file "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.43 15658

@1@: cannot set core file size limit; disallowed by hard limit

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.44 15659

@1@: could not read file "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.45 15660

@1@: option file "@2@" must have exactly one line

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.46 15661

The program "@1@" is needed by @2@ but was not found in the same directory as "@3@". Check your installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.47 15662

The program "@1@" was found by "@2@" but was not the same version as @3@. Check your installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.48 15663

@1@: database system initialization failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.49 15664

@1@: another server might be running; trying to start server anyway

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.50 15666

@1@: could not start serverExamine the log output.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.51 15668

@1@: PID file "@2@" does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.52 15669

Is server running?

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.53 15670

@1@: cannot stop server; single-user server is running (PID: @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.54 15671

@1@: could not send stop signal (PID: @2@): @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.55 15673

@1@: server does not shut down

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.56 15674

@1@: cannot restart server; single-user server is running (PID: @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.57 15675

@1@: old server process (PID: @2@) seems to be gone

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.58 15676

@1@: cannot reload server; single-user server is running (PID: @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.59 15677

@1@: could not send reload signal (PID: @2@): @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.60 15678

@1@: cannot promote server; single-user server is running (PID: @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.61 15679

@1@: cannot promote server; server is not in standby mode

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.62 15680

@1@: could not create promote signal file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.63 15681

@1@: could not write promote signal file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.64 15682

@1@: could not send promote signal (PID: @2@): @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.65 15683

@1@: could not send signal @2@ (PID: @3@): @4@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.66 15684

@1@: could not find own program executable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.67 15685

@1@: could not find postgres program executable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.68 15686

@1@: could not open service manager

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.69 15687

@1@: service "@2@" already registered

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.70 15688

@1@: could not register service "@2@" : error code @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.71 15689

@1@: service "@2@" not registered

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.72 15690

@1@: could not open service "@2@" : error code @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.73 15691

@1@: could not unregister service "@2@": error code @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.74 15692

Timed out waiting for server startup

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.75 15693

@1@: could not start service "@2@": error code @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.76 15695

@1@: could not open process token: error code @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.77 15696

@1@: could not allocate SIDs: error code @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.78 15697

@1@: could not create restricted token: error code @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.53.79 15699

@1@: unrecognized shutdown mode "@2@"**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54 Message Numbers Beginning with 15700

2.54.1 15700

@1@: unrecognized signal name "@2@"**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.2 15701

@1@: unrecognized start type "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.3 15702

@1@: could not determine the data directory using command "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.4 15703

@1@: -S option not supported on this platform

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.5 15704

@1@: too many command-line arguments (first is "@2@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.6 15705

@1@: missing arguments for kill mode

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.7 15706

@1@: unrecognized operation mode "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.8 15707

@1@: no operation specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.9 15708

child process exited with unrecognized status @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.10 15709

failed sanity check, parent OID @1@ of table "@2@" (OID @3@) not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.11 15710

could not parse numeric array "@1@": too many numbers

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.12 15711

could not parse numeric array "@1@": invalid character in number

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.13 15712

invalid compression code: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.14 15713

not built with zlib support

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.15 15714

could not initialize compression library: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.16 15715

could not close compression stream: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.17 15716

could not compress data: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.18 15718

could not uncompress data: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.19 15719

could not close compression library: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.20 15720

cannot duplicate null pointer (internal error)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.21 15721

@1@: unrecognized section name: "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.22 15722

out of on_exit_nicely slots

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.23 15723

could not close output file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.24 15725

unexpected section code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.25 15726

parallel restore is not supported with this archive file format

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.26 15727

parallel restore is not supported with archives made by pre-8.0 pg_dump

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.27 15728

cannot restore from compressed archive (compression not supported in this installation)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.28 15729

connecting to database for restore

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.54.29 15730

direct database connections are not supported in pre-1.3 archives

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.30 15731

warning from original dump file: @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.54.31 15732

internal error -- WriteData cannot be called outside the context of a DataDumper routine

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.32 15733

large-object output not supported in chosen format

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.33 15734

restored @1@ large object

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.34 15736

could not create large object @1@: @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.54.35 15737

could not open large object @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.36 15738

could not open TOC file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.37 15740

could not find entry for ID @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.38 15741

could not close TOC file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.39 15742

could not open output file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.40 15743

could not open output file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.41 15744

wrote @1@ byte of large object data (result = @2@)

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.54.42 15746

could not write to large object (result: @1@, expected: @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.43 15748

while INITIALIZING:

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.44 15749

while PROCESSING TOC:

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.45 15750

while FINALIZING:

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.46 15751

from TOC entry @1@; @2@ @3@ @4@ @5@ @6@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.47 15752

bad dumpld

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.48 15753

bad table dumpId for TABLE DATA item

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.49 15754

unexpected data offset flag @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.50 15755

file offset in dump file is too large

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.51 15757

directory name too long: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.52 15758

directory "@1@" does not appear to be a valid archive ("toc.dat" does not exist)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.53 15759

could not open input file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.54 15760

could not open input file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.55 15761

could not read input file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.56 15762

input file is too short (read @1@, expected 5)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.57 15763

input file appears to be a text format dump. Please use psql.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.58 15764

input file does not appear to be a valid archive (too short?)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.59 15765

input file does not appear to be a valid archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.60 15766

could not close input file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.61 15767

unrecognized file format "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.62 15768

entry ID @1@ out of range -- perhaps a corrupt TOC

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.63 15770

unrecognized encoding "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.64 15771

invalid ENCODING item: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.65 15772

invalid STDSTRINGS item: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.66 15773

could not set session user to "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.67 15775

could not set search_path to "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.68 15776

could not set default_tablespace to @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.69 15779

did not find magic string in file header

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.70 15780

unsupported version (@1@.@2@) in file header

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.71 15781

sanity check on integer size (@1@) failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.72 15783

expected format (@1@) differs from format found in file (@2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.73 15786

a worker process died unexpectedly

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.74 15787

processing missed item @1@ @2@ @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.75 15789

could not create worker process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.76 15793

worker process failed: exit code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.77 15795

table "@1@" could not be created, will not restore its data

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.78 15796

invalid OID for large object

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.79 15797

unrecognized data block type (@1@) while searching archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.80 15798

error during file seek: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.54.81 15799

could not find block ID @1@ in archive -- possibly due to out-of-order restore request, which cannot be handled due to lack of data offsets in archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55 Message Numbers Beginning with 15800

2.55.1 15800

could not find block ID @1@ in archive -- possibly due to out-of-order restore request, which cannot be handled due to non-seekable input file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.2 15801

could not find block ID @1@ in archive -- possibly corrupt archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.3 15802

found unexpected block ID (@1@) when reading data -- expected @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.4 15803

unrecognized data block type @1@ while restoring archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.5 15804

could not read from input file: end of file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.6 15805

could not read from input file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.7 15807

could not close archive file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.8 15808

can only reopen input archives

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.9 15809

parallel restore from standard input is not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.10 15810

parallel restore from non-seekable file is not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.11 15811

could not determine seek position in archive file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.12 15812

could not set seek position in archive file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.13 15814

@1@: could not parse server version "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.14 15815

could not get server_version from libpq

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.15 15816

aborting because of server version mismatch

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.16 15817

could not reconnect to database

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.17 15818

could not reconnect to database: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.18 15819

connection needs password

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.19 15820

already connected to a database

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.20 15821

could not connect to database

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.21 15822

connection to database "@1@" failed: @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.22 15823

query failed: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.23 15824

query was: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.24 15825

@1@: @2@ Command was: @3@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.25 15826

could not execute query

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.26 15827

error returned by PQputCopyData: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.27 15828

error returned by PQputCopyEnd: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.28 15829

COPY failed for table "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.29 15830

could not start database transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.30 15831

could not commit database transaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.31 15832

no output directory specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.32 15833

could not create directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.33 15834

could not close data file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.34 15835

could not open large object TOC file "@1@" for input: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.35 15836

invalid line in large object TOC file "@1@": "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.36 15837

error reading large object TOC file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.37 15838

could not close large object TOC file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.38 15840

could not write to blobs TOC file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.39 15841

file name too long: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.40 15842

this format cannot be read

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.41 15843

could not open TOC file "@1@" for output: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.42 15844

could not open TOC file for output: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.43 15845

compression is not supported by tar archive format**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.44 15846

could not open TOC file "@1@" for input: @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.45 15847

could not open TOC file for input: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.46 15848

could not find file "@1@" in archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.47 15849

could not generate temporary file name: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.48 15850

could not open temporary file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.49 15851

could not close tar member

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.50 15852

internal error -- neither th nor fh specified in tarReadRaw()

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.51 15856

invalid OID for large object (@1@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.52 15858

could not close temporary file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.53 15859

actual file length (@1@) does not match expected (@2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.54 15861

could not find header for file "@1@" in tar archive

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.55 15863

restoring data out of order is not supported in this archive format: "@1@" is required, but comes before "@2@" in the archive file.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.56 15864

incomplete tar header found (@1@ byte)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.57 15867

corrupt tar header found in @1@ (expected @2@, computed @3@) file position @4@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.58 15868

@1@: too many command-line arguments (first is "@2@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.59 15870

no matching schemas were found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.60 15871

no matching tables were found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.61 15872

invalid client encoding "@1@" specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.62 15873

invalid output format "@1@" specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.63 15875

dumping contents of table "@1@.@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.64 15876

Dumping the contents of table "@1@" failed: PQgetCopyData() failed.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.65 15877

Dumping the contents of table "@1@" failed: PQgetResult() failed.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.66 15878

error reading large object @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.67 15879

could not find parent extension for @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.68 15881

schema with OID @1@ does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.69 15889

failed sanity check, parent table with OID @1@ of sequence with OID @2@ not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.70 15890

query produced null referenced table name for foreign key trigger "@1@" on table "@2@" (OID of table: @3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.71 15891

invalid column numbering in table "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.72 15892

invalid adnum value @1@ for table "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.73 15893

expected @1@ check constraint on table "@2@" but found @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.55.74 15895

(The system catalogs might be corrupted.)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56 Message Numbers Beginning with 15900

2.56.1 15902

unrecognized provolatile value for function "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.2 15907

could not parse default ACL list (@1 @)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.3 15908

could not parse GRANT ACL list (@1 @) or REVOKE ACL list (@2 @) for object "@3@" (@4 @)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.4 15909

query to obtain definition of view "@1@" returned no data

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.5 15910

query to obtain definition of view "@1@" returned more than one definition

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.6 15911

definition of view "@1@" appears to be empty (length zero)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.7 15912

invalid column number @1@ for table "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.8 15913

missing index for constraint "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.9 15914

unrecognized constraint type: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.10 15915

query to get data of sequence "@1@" returned @2@ row (expected 1)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.11 15918

unexpected tgtype value: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.12 15919

invalid argument string (@1@) for trigger "@2@" on table "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.13 15920

query to get rule "@1@" for table "@2@" failed: wrong number of rows returned

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.14 15921

query returned @1@ row instead of one: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.15 15923

invalid dumpId @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.16 15924

invalid dependency @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.17 15925

could not identify dependency loop

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.18 15927

The program "pg_dump" is needed by @1@ but was not found in the same directory as "@2@". Check your installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.19 15928

The program "pg_dump" was found by "@1@" but was not the same version as "@2@". Check your installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.20 15929

@1@: could not connect to database "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.21 15930

@1@: could not connect to databases "postgres" or "template1" Please specify an alternative database.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.22 15931

@1@: could not open the output file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.23 15932

@1@: could not parse ACL list (@2@) for tablespace "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.24 15933

@1@: could not parse ACL list (@2@) for database "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.25 15934

@1@: pg_dump failed on database "@2@", exiting

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.26 15935

@1@: could not re-open the output file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.27 15936

@1@: running "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.28 15937

@1@: could not connect to database "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.29 15938

could not get server version

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.30 15941

executing @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.31 15942

query failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.32 15943

query was: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.33 15944

unrecognized archive format "@1@"; please specify "c", "d", or "t"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.34 15946

@1@: invalid argument for option @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.35 15947

@1@: transaction ID epoch (-e) must not be -1

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.36 15949

@1@: transaction ID (-x) must not be 0

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.37 15951

@1@: OID (-o) must not be 0

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.38 15953

@1@: multitransaction ID (-m) must not be 0

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.39 15955

@1@: multitransaction offset (-O) must not be -1

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.40 15957

@1@: no data directory specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.41 15958

@1@: cannot be executed by "root"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.42 15959

@1@: could not change directory to "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.43 15960

@1@: could not open file "@2@" for reading: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.44 15961

If these values seem acceptable, use -f to force reset.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.45 15962

Transaction log reset

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.46 15963

@1@: could not read file "@2@" : @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.47 15964

@1@: pg_control exists but has invalid CRC; proceed with caution

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.48 15965

@1@: pg_control exists but is broken or unknown version; ignoring it

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.49 15966

@1@: internal error -- sizeof(ControlFileData) is too large ... fix PG_CONTROL_SIZE

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.50 15967

@1@: could not create pg_control file: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.51 15968

@1@: could not write pg_control file: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.52 15969

@1@: fsync error: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.53 15970

@1@: could not open directory "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.54 15971

@1@: could not read directory "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.55 15972

@1@: could not delete file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.56 15973

@1@: could not open file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.57 15974

@1@: could not write file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.58 15975

could not create directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.59 15976

could not open directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.60 15977

could not stat file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.61 15978

could not read symbolic link "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.62 15979

could not create symbolic link "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.63 15981

could not open file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.64 15982

could not create file "@1@": @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.65 15983

could not read file "@1@": @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.66 15984

could not write to file "@1@": @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.67 15985

could not fsync file "@1@": @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.68 15986

could not close file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.69 15987

could not find own program executable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.70 15988

invalid checkpoint argument "@1@", must be "fast" or "spread"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.71 15989

invalid argument @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.72 15990

option @1@ conflicts with option @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.73 15991

the configured database storage directory differs from the data_directory parameter

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.74 15992

an invalid value was specified for the option -@1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.75 15993

backup data "@1@" is lost

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.76 15994

cannot be run as root

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.77 15995

invalid option --@1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.78 15996

invalid option -@1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.79 15997

backup of the database has not yet been performed, or an incorrect backup storage directory was specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.80 15998

the database storage directory and the \$PGDATA environment variable have not been specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.56.81 15999

option @1@ is necessary for option @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57 Message Numbers Beginning with 16000

2.57.1 16000

the requested recovery point is earlier than the date and time that the backup finished

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.2 16001

the specified backup does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.3 16002

the directory "@1@" for the tablespace with OID "@2@" does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.4 16003

the specified backup storage directory "@1@" is not correct

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.5 16004

the specified database storage directory is not correct

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.6 16005

the token in the file "pg_hba.conf" is too long and will be skipped: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.7 16006

the directory "@1@" for storing WAL does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.8 16007

"@1@" is being executed by another user

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.9 16008

the "@1@" parameter was not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.10 16009

could not find the configuration file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.11 16010

could not open the configuration file "@1@" : maximum nesting depth exceeded

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.12 16011

the PID file "@1@" does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.13 16012

the server is running

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.14 16013

the server is not running

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.15 16014

caught signal @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.16 16015

failed to build the absolute path "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.17 16016

failed to check the completion of archiving WAL files

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.18 16017

failed to connect to the database

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.19 16018

failed to get the database OID : @1@ (@2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.20 16019

failed to remove old backup data

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.21 16020

failed to restore the database storage directory "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.22 16021

failed to restore the tablespace directory "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.23 16022

retried backup @1@ times, but failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.24 16023

SQL command failed (@1@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.25 16024

the database with OID @1@ was created during backup

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.26 16025

backup control function "@1@" failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.27 16026

command failed: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.28 16027

could not close the file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.29 16028

could not close the PID file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.30 16029

could not create the directory "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.31 16030

could not create the file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.32 16031

could not create the PID file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.33 16032

could not create the symbolic link "@1@": @2@ (errno=@3@)**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.34 16033

could not identify the current directory: @1@ (errno=@2@)**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.35 16034

could not open the directory "@1@": @2@ (errno=@3@)**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.36 16035

could not open the file "@1@": @2@ (errno=@3@)**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.37 16036

could not open the PID file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.38 16037

could not read the file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.39 16038

could not read the PID file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.40 16039

could not read the symbolic link "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.41 16040

could not remove the file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.42 16041

could not remove the PID file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.43 16042

could not rename the directory "@1@" to "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.44 16043

could not rename the file "@1@" to "@2@": @3@ (errno=@4@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.45 16044

could not write the file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.46 16045

could not write the PID file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.47 16046

failed to find the internal file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.48 16047

failed to parse the internal file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.49 16048

failed to parse the internal file: "@1@" (@2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.50 16049

failed to parse the configuration file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.51 16050

failed to remove archived transaction log files

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.52 16051

failed to replace the contents of the pg_wal directory

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.53 16052

failed to restore the configuration files

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.54 16053

invalid data in the PID file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.55 16055

cannot find the server process (PID: @1@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.56 16056

an error occurred during recovery

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.57 16057

could not remove the directory "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.58 16058

target "@1@" mismatch (internal error)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.59 16059

the program "@1@" is needed by @2@ but was not found in the same directory as "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.60 16060

the program "@1@" was found in "@2@" but was not the same version as @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.61 16061

failed to get port number (internal error)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.62 16062

backup of configuration files completed successfully

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.57.63 16063

backup of database and configuration files completed successfully

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.57.64 16064

Confirm that the specified directory is correct. If it is correct, the backup data may be corrupted. Copy the backup data to the backup storage directory from backup media.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.65 16065

Check the installation.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.66 16066

Continue the backup.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.57.67 16067

Create an empty directory "@1@" on which the database administrator has full permissions, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.68 16068

Create an empty directory "@1@" on which the database administrator has full permissions.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.69 16069

Recover the corrupt resource.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.70 16070

Is the server running?

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.71 16071

Please check whether the backup data exists or is not in the backup storage directory.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.72 16072

Please decrease the length of the path and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.73 16073

Please decrease the number of digits and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.74 16074

Please log in as the user that owns the server process.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.75 16075

Please remove the cause of the error, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.76 16076

Please set the database storage directory "@1@" to -D option, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.77 16077

Please set the recovery point to be after the date and time that the backup finished, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.78 16078

Please set the backup storage directory to the 'backup_destination' parameter and restart the server.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.79 16079

Please specify the database storage directory as "@1@" and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.80 16080

Please specify the database storage directory correctly and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.81 16081

Please specify the port number correctly and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.82 16082

Please specify an integer greater than 0, and try again.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.83 16083

Please specify an integer greater than 0, or the 'all' keyword, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.84 16084

Please specify an integer greater than or equal to 0, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.85 16085

Please specify the backup storage directory correctly and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.86 16086

Please specify the time stamp using the correct length and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.87 16087

Please start the server and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.88 16088

Please stop the server and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.89 16089

Please wait for a short period and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.90 16090

Recovery of database completed successfully.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.91 16091

Retrying backup. (@1@ times).

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.92 16092

Specify the backup storage directory with the -B option, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.93 16093

Refer to "@1@ --help" for more information.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.94 16094

Retry after the other process terminates.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.95 16095

Failed to identify backup data.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.96 16096

restore point name is too long (maximum @1@ bytes)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.97 16097

Try "@1@ --help" for more information.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.98 16098

keystore location is not specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.57.99 16099

too many command-line arguments (first is "@1@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58 Message Numbers Beginning with 16100

2.58.1 16100

no operation is specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.2 16101

could not open file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.3 16102

could not read file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.4 16103

keystore "@1@" is corrupted: size = @2@ bytes, expected size = @3@ bytes

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.5 16104

file "@1@" is not a keystore

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.6 16105

key is too long

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.7 16106

key is wrong

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.8 16107

passphrase-based key derivation failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.9 16108

decryption of the keystore failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.10 16109

decryption of the keystore failed: passphrase is wrong

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.11 16110

keystore "@1@" is corrupted: invalid CRC

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.12 16111

encryption of the keystore failed: error code = @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.13 16112

encryption of the keystore failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.14 16113

could not create file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.15 16114

could not write file "@1@": @2@ (errno=@3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.16 16115

child process exited with unrecognized status @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.17 16117

invalid command \@1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.18 16118

\\@1@: extra argument "@2@" ignored

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.19 16119

could not get home directory for user ID @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.20 16120

\\@1@: could not change directory to "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.21 16121

You are currently not connected to a database.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.22 16122

no query buffer

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.23 16123

@1@: invalid encoding name or conversion procedure not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.24 16124

\@1@: missing required argument

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.25 16125

Passwords didn't match.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.26 16128

out of memory

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.27 16129

\\@1@: environment variable name must not contain "="

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.28 16130

The server (version @1@) does not support showing function source.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.29 16131

function name is required

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.30 16132

@1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.31 16137

environment variable PSQL_EDITOR_LINENUMBER_ARG must be set to specify a line number

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.32 16138

could not start editor "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.33 16139

could not start /bin/sh

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.34 16140

could not locate temporary directory: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.35 16141

could not open temporary file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.36 16142

\pset: allowed formats are aligned, asciidoc, csv, html, latex, latex-longtable, troff-ms, unaligned, wrapped

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.37 16143

\pset: allowed line styles are ascii, old-ascii, unicode

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.38 16144

\pset: unknown option: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.39 16145

\\: failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.40 16146

cannot duplicate null pointer (internal error)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.41 16147

connection to server was lost

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.42 16148

Failed.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.58.43 16149

unexpected PQresultStatus: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.44 16150

The server (version @1@) does not support savepoints for ON_ERROR_ROLLBACK.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.45 16151

unexpected transaction status (@1@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.46 16152

\\copy: arguments required

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.47 16153

\\copy: parse error at "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.48 16154

\\copy: parse error at end of line

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.49 16155

@1@: cannot copy from/to a directory

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.50 16156

could not write COPY data: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.51 16158

Enter data to be copied followed by a newline.End with a backslash and a period on a line by itself, or an EOF signal.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.52 16159

aborted because of read failure

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.53 16160

The server (version @1 @) does not support tablespaces.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.54 16161

\ddf only takes [antwS+] as options

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.55 16162

\ldf does not take a "w" option with server version @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.56 16163

The server (version @1@) does not support altering default privileges.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.57 16164

Did not find any relation named "@1@".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.58 16165

Did not find any relation with OID @1@.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.59 16166

The server (version @1@) does not support per-database role settings.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.60 16167

Did not find any settings for role "@1@".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.61 16168

Did not find any settings.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.62 16169

Did not find any relation named "@1@".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.63 16170

Did not find any relations.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.64 16171

The server (version @1@) does not support collations.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.65 16172

The server (version @1@) does not support full text search.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.66 16173

Did not find any text search configuration named "@1@".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.67 16174

The server (version @1@) does not support foreign-data wrappers.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.68 16175

The server (version @1 @) does not support foreign servers.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.69 16176

The server (version @1 @) does not support user mappings.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.70 16177

The server (version @1 @) does not support foreign tables.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.71 16178

The server (version @1 @) does not support extensions.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.72 16179

Did not find any extension named "@1@".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.73 16180

Did not find any extensions.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.74 16181

user name lookup failure: error code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.75 16182

could not read from input file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.76 16183

could not save history to file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.77 16184

history is not supported by this installation

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.78 16185

@1@: not connected to a database

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.79 16186

@1@: current transaction is aborted

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.80 16187

@1@: unknown transaction status**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.81 16188

Cannot add header to table content: column count of @1@ exceeded.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.82 16189

Cannot add cell to table content: total cell count of @1@ exceeded.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.83 16190

invalid output format (internal error): @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.84 16191

skipping recursive expansion of variable "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.85 16192

unterminated quoted string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.86 16193

@1@: out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.58.87 16194

cannot escape without active connection

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.88 16195

could not open log file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.89 16196

could not set printing parameter "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.90 16197

\\@1@: could not read value for variable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.58.91 16199

extra command-line argument "@1@" ignored

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59 Message Numbers Beginning with 16200

2.59.1 16200

tab completion query failed: @1@Query was:@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.2 16201

unrecognized value "@1@" for "@2@" Available values are: @3@.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.3 16202

Try "@1@ --help" for more information.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.4 16203

too many command-line arguments (first is "@1@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.5 16204

cannot cluster all databases and a specific one at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.6 16205

cannot cluster specific table(s) in all databases

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.7 16206

clustering of table "@1@" in database "@2@" failed: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.8 16207

clustering of database "@1@" failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.9 16208

@1@: clustering database "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.10 16213

could not connect to database @1@: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.11 16214

query failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.12 16215

cannot duplicate null pointer (internal error)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.13 16216

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.59.14 16217

Cancel request sent

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.15 16218

Could not send cancel request: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.16 16219

only one of --locale and --lc-ctype can be specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.17 16220

only one of --locale and --lc-collate can be specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.18 16221

"@1@" is not a valid encoding name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.19 16222

database creation failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.20 16223

comment creation failed (database was created): @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.21 16228

Passwords didn't match.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.22 16229

password encryption failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.23 16230

creation of new role failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.24 16231

missing required argument database name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.25 16232

Database "@1@" will be permanently removed.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.26 16233

database removal failed: @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.27 16236

missing required argument role name**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.28 16237

Role "@1@" will be permanently removed.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.29 16238

removal of role "@1@" failed: @2@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.30 16239

cannot reindex all databases and a specific one at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.31 16240

cannot reindex all databases and system catalogs at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.32 16241

cannot reindex specific table(s) in all databases

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.33 16242

cannot reindex specific index(es) in all databases

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.34 16243

cannot reindex specific table(s) and system catalogs at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.35 16244

cannot reindex specific index(es) and system catalogs at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.36 16245

reindexing of table "@1@" in database "@2@" failed: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.37 16246

reindexing of index "@1@" in database "@2@" failed: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.38 16247

reindexing of database "@1@" failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.39 16248

@1@: reindexing database "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.40 16249

reindexing of system catalogs failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.41 16250

cannot use the "@1@" option when performing only analyze

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.42 16252

cannot vacuum all databases and a specific one at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.43 16253

cannot vacuum specific table(s) in all databases

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.44 16254

vacuuming of table "@1@" in database "@2@" failed: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.45 16255

vacuuming of database "@1@" failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.46 16256

SQL error: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.47 16257

variable "@1@" must have a numeric type**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.48 16258

descriptor "@1@" does not exist**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.49 16259

descriptor header item "@1@" does not exist**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.50 16260

nullable is always 1**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.51 16261

key_member is always 0

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.52 16262

descriptor item "@1@" is not implemented

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.53 16263

descriptor item "@1@" cannot be set

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.54 16264

@1@: could not open file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.55 16265

Try "@1@ --help" for more information.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.56 16266

@1@: parser debug support (-d) not available

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.57 16268

@1@: no input files specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.58 16269

cursor "@1@" has been declared but not opened

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.59 16270

could not remove output file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.60 16272

invalid bit string literal

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.61 16273

unterminated bit string literal

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.62 16274

unterminated hexadecimal string literal

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.63 16275

unterminated quoted string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.64 16276

zero-length delimited identifier

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.65 16277

unterminated quoted identifier

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.66 16278

missing identifier in EXEC SQL UNDEF command

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.67 16279

missing matching "EXEC SQL IFDEF" / "EXEC SQL IFNDEF"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.68 16280

missing "EXEC SQL ENDIF;"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.69 16281

more than one EXEC SQL ELSE

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.70 16282

unmatched EXEC SQL ENDIF

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.71 16283

too many nested EXEC SQL IFDEF conditions

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.72 16284

missing identifier in EXEC SQL IFDEF command

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.73 16285

missing identifier in EXEC SQL DEFINE command

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.74 16286

syntax error in EXEC SQL INCLUDE command

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.75 16287

internal error: unreachable state; If the cause of errors cannot be found, contact the Fujitsu Systems Engineer (SE).

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause. If the cause of errors cannot be found, contact the Fujitsu Systems Engineer (SE).

2.59.76 16288

Error: include path "@1@/@2@" is too long on line @3@, skipping

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.77 16289

could not open include file "@1@" on line @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.78 16290

cursor "@1@" does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.79 16291

initializer not allowed in type definition

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.80 16292

type name "string" is reserved in Informix mode

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.81 16293

type "@1@" is already defined

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.82 16294

multidimensional arrays for simple data types are not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.83 16295

AT option not allowed in CLOSE DATABASE statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.84 16296

AT option not allowed in CONNECT statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.85 16297

AT option not allowed in DISCONNECT statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.86 16298

AT option not allowed in SET CONNECTION statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.59.87 16299

AT option not allowed in TYPE statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60 Message Numbers Beginning with 16300

2.60.1 16300

AT option not allowed in VAR statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.2 16301

AT option not allowed in WHENEVER statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.3 16302

unsupported feature will be passed to server

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.4 16303

SHOW ALL is not implemented

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.5 16304

COPY FROM STDIN is not implemented

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.6 16308

using variable "@1@" in different declare statements is not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.7 16309

cursor "@1@" is already defined

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.8 16310

no longer supported LIMIT #,# syntax passed to server

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.9 16311

subquery in FROM must have an alias

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.10 16312

CREATE TABLE AS cannot specify INTO

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.11 16313

expected "@", found "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.12 16314

only protocols "tcp" and "unix" and database type "postgresql" are supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.13 16315

expected "://", found "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.14 16316

Unix-domain sockets only work on "localhost" but not on "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.15 16317

expected "postgresql", found "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.16 16318

invalid connection type: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.17 16319

expected "@" or "://", found "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.18 16320

invalid data type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.19 16321

incomplete statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.20 16322

unrecognized token "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.21 16323

only data types numeric and decimal have precision/scale argument

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.22 16324

interval specification not allowed here

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.23 16325

too many levels in nested structure/union definition

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.24 16326

pointers to varchar are not implemented

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.25 16327

using unsupported DESCRIBE statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.26 16328

initializer not allowed in EXEC SQL VAR command

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.27 16329

arrays of indicators are not allowed on input

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.28 16330

@1@ at or near "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.29 16331

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.60.30 16332

unrecognized variable type code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.31 16333

variable "@1@" is hidden by a local variable of a different type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.32 16334

variable "@1@" is hidden by a local variable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.33 16335

indicator variable "@1@" is hidden by a local variable of a different type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.34 16336

indicator variable "@1@" is hidden by a local variable

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.35 16337

indicator for array/pointer has to be array/pointer

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.36 16338

nested arrays are not supported (except strings)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.37 16339

indicator for struct has to be a struct

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.38 16340

indicator for simple data type has to be simple

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.39 16341

unrecognized descriptor item code @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.40 16342

incorrectly formed variable "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.41 16343

variable "@1@" is not a pointer

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.42 16344

variable "@1@" is not a pointer to a structure or a union

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.43 16345

variable "@1@" is neither a structure nor a union

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.44 16346

variable "@1@" is not an array

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.45 16347

variable "@1@" is not declared

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.46 16348

indicator variable must have an integer type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.47 16349

unrecognized data type name "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.48 16350

multidimensional arrays are not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.49 16351

multilevel pointers (more than 2 levels) are not supported; found @1@ level

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.50 16353

pointer to pointer is not supported for this data type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.51 16354

multidimensional arrays for structures are not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.52 16355

invalid URI propagated to internal parser routine: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.53 16356

end of string reached when looking for matching "]" in IPv6 host address in URI: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.54 16357

IPv6 host address may not be empty in URI: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.55 16358

unexpected character "@1@" at position @2@ in URI (expected ":" or "/"): "@3@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.56 16359

extra key/value separator "=" in URI query parameter: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.57 16360

missing key/value separator "=" in URI query parameter: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.58 16361

invalid URI query parameter: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.59 16362

invalid percent-encoded token: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.60 16363

forbidden value @1@00 in percent-encoded value: "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.61 16364

insufficient data in "T" message

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.62 16365

extraneous data in "T" message

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.63 16366

insufficient data in "D" message

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.64 16367

extraneous data in "D" message

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.65 16368

at character @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.66 16369

unrecognized socket error: 0x@1@/@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.67 16370

If true, trusted and untrusted Perl code will be compiled in strict mode.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.68 16371

Perl initialization code to execute when a Perl interpreter is initialized.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.69 16372

Perl initialization code to execute once when plperl is first used.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.70 16373

Perl initialization code to execute once when plperl is first used.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.71 16374

duplicate declaration

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.72 16375

diagnostics item @1@ is not allowed in GET STACKED DIAGNOSTICS

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.73 16376

diagnostics item @1@ is not allowed in GET CURRENT DIAGNOSTICS

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.74 16377

unrecognized GET DIAGNOSTICS item

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.75 16378

unexpected end of function definition

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.76 16379

syntax error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.77 16380

invalid SQLSTATE code

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.78 16381

syntax error, expected "FOR"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.79 16382

mismatched parentheses

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.80 16383

missing expression

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.81 16384

missing SQL statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.82 16385

incomplete data type declaration

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.83 16386

missing data type declaration

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.84 16387

INTO specified more than once

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.85 16388

expected FROM or IN

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.86 16389

cursor "@1@" has no argument named "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.87 16390

value for parameter "@1@" of cursor "@2@" specified more than once

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.88 16391

unrecognized RAISE statement option

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.89 16392

syntax error, expected "="

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.90 16393

during initialization of execution state

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.91 16394

while storing call arguments into local variables

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.92 16395

during function entry

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.93 16396

while casting return value to function's return type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.94 16397

returned record type does not match expected record type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.95 16398

during function exit

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.60.96 16399

returned row structure does not match the structure of the triggering table

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61 Message Numbers Beginning with 16400

2.61.1 16400

during statement block local variable initialization

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.2 16401

during statement block entry

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.3 16402

during statement block exit

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.4 16403

during exception cleanup

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.5 16404

structure of query does not match function result type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.6 16405

**query "@1@" returned @2@ column
query "@3@" returned @4@ columns**

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.7 16406

Sets handling of conflicts between PL/pgSQL variable names and table column names.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.8 16407

plpy.cursor expected a query or a plan

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.9 16408

plpy.cursor takes a sequence as its second argument

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.10 16409

could not execute plan

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.11 16410

Expected sequence of @1@ argument, got @2@: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.12 16412

iterating a closed cursor

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.13 16413

iterating a cursor in an aborted subtransaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.14 16414

fetch from a closed cursor

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.15 16415

closing a cursor in an aborted subtransaction

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.16 16416

error fetching next item from iterator

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.17 16417

PyList_SetItem() failed, while setting up arguments

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.18 16418

PyDict_SetItemString() failed, while setting up arguments

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.19 16419

could not create new dictionary while building trigger arguments

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.20 16420

untrapped error in initialization

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.21 16421

could not import "__main__" module

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.22 16422

could not create globals

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.23 16424

could not import "plpy" module

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.24 16425

could not add the spiexceptions module

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.25 16427

could not generate SPI exceptions

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.26 16428

could not unpack arguments in plpy.elog

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.27 16429

could not parse error message in plpy.elog

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.28 16430

could not compile PL/Python function "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.29 16431

could not compile anonymous PL/Python code block

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.30 16432

command did not produce a result set

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.31 16433

second argument of plpy.prepare must be a sequence

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.32 16434

plpy.execute expected a query or a plan

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.33 16435

plpy.execute takes a sequence as its second argument

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.34 16437

this subtransaction has already been entered

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.35 16438

this subtransaction has already been exited

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.36 16439

this subtransaction has not been entered

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.37 16440

there is no subtransaction to exit from

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.38 16441

could not create new dictionary

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.39 16443

could not create bytes representation of Python object

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.40 16444

could not create string representation of Python object

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.41 16445

return value of function with array return type is not a Python sequence

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.42 16446

could not extract bytes from encoded string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.43 16447

The name: @1@ is invalid.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.44 16448

";" is not permitted in COBOL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.45 16449

"END-EXEC" is not permitted in C

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.46 16450

missing "EXEC SQL ENDIF END-EXEC."

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.47 16451

debug line with EXEC SQL is not permitted

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.48 16452

SQL string literal cannot continue multiline by COBOL syntax

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.49 16453

COBOL string literal cannot continue multiline by SQL syntax

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.50 16454

syntax error at or near "END-EXEC" in declare section

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.51 16455

syntax error in include file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.52 16456

internal error: unreachable state;

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.53 16457

could not open temporary file "@1@" for continue line

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.54 16458

FILLER or implicit FILLER is not available in EXEC SQL TYPE statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.55 16459

VALUE clause is not available in EXEC SQL TYPE statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.56 16460

REDEFINES clause is not available in EXEC SQL TYPE statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.57 16461

FILLER or implicit FILLER is not available in EXEC SQL VAR statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.58 16462

VALUE clause is not available in EXEC SQL VAR statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.59 16463

syntax error in WHENEVER statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.60 16464

FILLER or implicit FILLER is not available in TYPEDEF statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.61 16465

VALUE clause is not available in TYPEDEF statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.62 16466

REDEFINES clause is not available in TYPEDEF statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.63 16467

FILLER or implicit FILLER can use only for elementary item in group item

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.64 16468

USAGE clause is not available for group item name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.65 16469

SIGN clause is not available for group item name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.66 16470

VALUE clause is not available for group item name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.67 16471

more than one USAGE clause

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.68 16472

more than one OCCURS clause

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.69 16473

more than one VALUE clause

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.70 16474

more than one SIGN clause

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.71 16475

more than one REDEFINES clause

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.72 16476

syntax error at or near "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.73 16477

length of varchar type is not assigned

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.74 16478

invalid NULL is set

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.61.75 16479

you can not be set to more than 1024 bytes of the string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.61.76 16480

group item is too deep

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.77 16481

multidimensional array is not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.78 16482

syntax is not available

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.79 16483

there is a character code that can not be determined

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.80 16484

the number of variables reached the max number 1000000

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.81 16485

host array variable is needed when using FOR ARRAY_SIZE

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.82 16486

unsupported datatype found at FOR statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.83 16487

FOR value should be positive integer

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.84 16488

SELECT..INTO returns too many rows on line @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.85 16491

@1@ failed

[Description]

Aborted the processing of this operation because an error occurred.

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the messages shown before this message, and then work around if necessary.

2.61.86 16492

CREATE TRIGGER will create implicit function "@1@."@2@()" for TRIGGER "@3@" on TABLE "@4@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.61.87 16493

The cursor is invalid on line @1@

[Description]

An error occurred during execution of the command.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.61.88 16494

Constraint trigger "@1@" for relation "@2@" cannot be replaced with non-constraint trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.61.89 16495

Trigger "@1@" for relation "@2@" cannot be replaced with constraint trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.61.90 16497

unterminated /*+ comment for hint of pg_hint_plan

[Description]

An unterminated /*+ comment for hint of pg_hint_plan is detected.

[System Processing]

Processing will be aborted.

[Action]

Terminate /*+ comment for hint of pg_hint_plan.

2.61.91 16498

trigger created with EXECUTE PROCEDURE cannot be replaced by DO block

[Description]

Trigger created with EXECUTE PROCEDURE cannot be replaced by DO block.

[System Processing]

Processing is aborted.

[Action]

Please redefine it after deleting the trigger.

2.61.92 16499

trigger created with DO block cannot be replaced by EXECUTE PROCEDURE

[Description]

Trigger created with DO block cannot be replaced by EXECUTE PROCEDURE.

[System Processing]

Processing is aborted.

[Action]

Please redefine it after deleting the trigger.

2.62 Message Numbers Beginning with 16500

2.62.1 16500

the connection is not the same as the connection in DECLARE STATEMENT, on line @1@

[Description]

The connection is not the same as the connection in DECLARE STATEMENT, on line @1@

[System Processing]

Processing is aborted.

[Action]

Please do not specify the connection when you use SQL statement identifier declared with DECLARE STATEMENT.

2.62.2 16501

cannot copy window "@1@" because it has a frame clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.62.3 16502

could not find any WAL files

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.62.4 16503

exceeded maxAllocatedDescs (@1@) while trying to open file "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.62.5 16504

exceeded maxAllocatedDescs (@1@) while trying to open directory "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.62.6 16505

tsquery is too large

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.62.7 16506

bit string length exceeds the maximum allowed (@1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.62.8 16507

error occurred at @1@: @2@ before error message processing is available

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.62.9 16508

language validation function @1@ called for language @2@ instead of @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.62.10 16510

The sslservercertcn "@1@" could not be verified

[Description]

value of sslservercertcn is different from common name in the server certificate.

[System Processing]

Processing is aborted.

[Action]

Set SSL certificate's common name to sslservercertcn.

2.62.11 16511

@1@: must be superuser to run this command

[Description]

Must be superuser to run this command.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command by the superuser.

2.62.12 16512

@1@: must be database super user to run this command

[Description]

Must be database super user to run this command.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command by the database super user.

2.62.13 16513

@1@: no subcommand specified

[Description]

No subcommand specified.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options or operands.

2.62.14 16514

@1@: unrecognized subcommand "@2@"

[Description]

Unknown subcommand is specified.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct subcommand.

2.62.15 16515

@1@: too many command-line arguments (first is "@2@")

[Description]

Too many command-line arguments.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options or operands.

2.62.16 16516

@1@: argument to an option "@2@" must be a list of port numbers

[Description]

Argument to the option must be a list of port numbers.

[System Processing]

Processing will be aborted.

[Action]

Specify multiple port number, separated by commas argument to an option, and re-execute the command. Specify a number from 1024 to 32767 for the port number.

2.62.17 16517

@1@: invalid argument for an option "@2@"

[Description]

Invalid argument for an option.

[System Processing]

Processing will be aborted.

[Action]

Check the options specified in command-line, and re-execute the command with correct operands.

2.62.18 16518

@1@: option "@2@" is required

[Description]

The indispensable option is not specified.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options or confirm the indispensable option is being used correctly.

2.62.19 16519

@1@: requires an option "@2@" or setting the "@3@" environment variable

[Description]

Requires an option or setting the environment variable.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options. Or, set a correct value to the environment variable, and re-execute the command.

2.62.20 16520

@1@: successfully completed

[Description]

Command successfully completed.

[System Processing]

Continues processing.

[Action]

No action required.

2.62.21 16521

@1@: user "@2@" does not exist

[Description]

The user is not registered into OS.

[System Processing]

Processing will be aborted.

[Action]

Register the user into OS, and re-execute the command. Or, re-execute the command which specified the registered user.

2.62.22 16522

@1@: data directory "@2@" does not exist

[Description]

The data directory does not exist.

[System Processing]

Processing will be aborted.

[Action]

Confirm that an option "--cluster-standbynode" is being used correctly. Or, check the command-line, and re-execute the command with existing data directory.

2.62.23 16523

@1@: "@2@" is not a valid data directory

[Description]

The data directory is not valid.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with valid data directory.

2.62.24 16524

@1@: database cluster is not stopped

[Description]

Database cluster is not stopped.

[System Processing]

Processing will be aborted.

[Action]

Stop the database cluster, and re-execute the command.

2.62.25 16525

@1@: domain root "@2@" already exists

[Description]

The domain root already exists.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct domain root.

2.62.26 16526

@1@: could not create directory "@2@"

[Description]

Could not create the directory.

[System Processing]

Processing will be aborted.

[Action]

Check the following and eliminate the cause of errors, and re-execute the command.

- the state of a disk and file system to creating the directory
- permission of the upper directory of specified directory

2.62.27 16527

@1@: start of PL/extJava has timed out : @2@

[Description]

Timed out waiting for start of PL/extJava.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command after the load on the system has decreased.

2.62.28 16528

@1@: stop of PL/extJava has timed out : @2@

[Description]

Timed out waiting for stop of PL/extJava.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command after the load on the system has decreased.

2.62.29 16529

@1@: port number "@2@" is already in use

[Description]

The port number is already in use.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command with a port number which is not used in other processes.

2.62.30 16530

@1@: domain name can only be specified "domain1"

[Description]

Domain name can only be specified "domain1".

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct domain name.

2.62.31 16531

@1@: domain "@2@" has already been created

[Description]

The domain has already been created.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct domain name.

2.62.32 16532

@1@: domain "@2@" has not been created

[Description]

The domain has not been created.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct domain name.

2.62.33 16533

@1@: permission denied to update file "@2@"

[Description]

Permission denied to update the file.

[System Processing]

Processing will be aborted.

[Action]

Permit writing to the file by execution user, and re-execute the command.

2.62.34 16534

@1@: container for database "@2@" does not exist

[Description]

Container for database does not exist.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct database name.

2.62.35 16535

@1@: container for database "@2@" already exists

[Description]

Container for database already exists.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct database name.

2.62.36 16536

@1@: command error occurred

[Description]

Internal command error occurred.

[System Processing]

Processing will be aborted.

[Action]

Fix the problem by referring to the messages prior to this one.

2.62.37 16537

@1@: the domain was not able to be deleted because there was a container

[Description]

The domain was not able to be deleted because the domain have a container.

[System Processing]

Processing will be aborted.

[Action]

Delete all containers on the domain, and re-execute the command. Or, re-execute the command with "--force" option.

2.62.38 16538

@1@: could not access the data directory

[Description]

Could not access the data directory.

[System Processing]

Processing will be aborted.

[Action]

Confirm that an option "--cluster-standbynode" is being used correctly. Or, specify database super user in "--dbadminuser" option and re-execute the command.

2.62.39 16539

@1@: server instance "@2@" does not exist

[Description]

Server instance does not exist.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct server instance.

2.62.40 16540

@1@: specified database name "@2@" does not follow the naming rules

[Description]

Specified database name does not follow the naming rules.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct database name.

2.62.41 16541

@1@: all the server instances of the container cannot be deleted

[Description]

All the server instances of the container cannot be deleted.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct database name.

2.62.42 16542

@1@: the mount does the shared-file system of the domain root or the data directory

[Description]

A command executing node is not a standby node.

[System Processing]

Processing will be aborted.

[Action]

Execute the command on standby node.

2.62.43 16543

@1@: cannot execute this subcommand on standby node

[Description]

Cannot execute this subcommand on standby node.

[System Processing]

Processing will be aborted.

[Action]

Execute the command on primary node.

2.62.44 16544

@1@: cannot execute this command concurrently

[Description]

Cannot execute this command concurrently.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command after a command executing was finished.

2.62.45 16545

@1@: domain root "@2@" does not exist

[Description]

Domain root does not exist.

[System Processing]

Processing will be aborted.

[Action]

Confirm that the shared-file system of the domain root is mounted. Or, restore domain root from backup and re-execute the command.

2.62.46 16546

parameter "@1@" necessary for the PL/extJava environment was not set

[Description]

PL/extJava environment was not set.

[System Processing]

Processing will be aborted.

[Action]

Set the PL/extJava environment.

2.62.47 16547

mismatched parentheses

[Description]

Missing parenthesis '(' or ')' in Java function definition.

[System Processing]

Processing will be aborted.

[Action]

Check the definition of Java function.

2.62.48 16548

invalid format specification for Java function

[Description]

Invalid format specification for Java function.

[System Processing]

Processing will be aborted.

[Action]

Check the definition of Java function.

Java function definition format is [package].[class].[method].

2.62.49 16549

Java function cannot return type @1@

[Description]

The specified data type is not supported as Java function.

[System Processing]

Processing will be aborted.

[Action]

Check the data type of return value.

2.62.50 16550

Java function cannot accept type @1@

[Description]

The specified data type is not supported as Java function arguments.

[System Processing]

Processing will be aborted.

[Action]

Check the data type of arguments value.

2.62.51 16551

could not execute the Java function at the application server: HTTP status code @1@ details: "@2@"

[Description]

The application server could not execute the Java function.

[System Processing]

Processing will be aborted.

[Action]

Check the Java function of registered in application server.

Check the details.

- The classpath is not found. (plextjava_lib_dir=%s2)

%s2: directory

The directory that stores the Java function is not in the application server. Check the directory and register the Java function.

- The return type is different. (%s3)

%s3: data type

The return value of the Java function is not corresponding to the CREATE FUNCTION definition. Check the data type of Java function.

- The method is not found. (%s4)

%s4: data type

The Java function to which the data type is corresponding is not found. Check the data type of Java function.

- The class is not found. (%s5)

%s5: class name

The Java function to which the class name is corresponding is not found. Check the class name of Java function.

- The method is not static modifier. (%s6)

%s6: Java function name

The Java function is not defined by "Static". Check the Java function definition.

here is no executed authority. (%s7)

%s7: Java function name

The Java function is not defined by "Public". Check the Java function definition.

- Java application throws exception(%s8).

%s8: exception

The exception was generated by the Java function. Check the Java function definition.

- no message

The following causes are thought.

- There is a possibility that the container is not made. Make the container in application server.

a) There is a possibility where the number of server instances is insufficient. Add server instance (JavaVM) to the application server.

b) There is a possibility that memory shortage occurs. Check the Java application.

c) There is a possibility that the time-out is generated. Check the Java application.

d) There is a possibility that abnormality occurs by the application server. Check the following logs.

- Event log (For Windows(R))/system log (For Solaris/Linux).

- Server log of container

- JavaVM log of container
- Trace log of Web server
- Internal log of Web server

2.62.52 16552

could not connect to application server: @1@

[Description]

Could not connect to application server.

[System Processing]

Processing will be aborted.

[Action]

Check the plextjava.http_port parameter in postgresql.conf.

2.62.53 16553

could not create socket for application server connection: @1@

[Description]

Could not create socket.

[System Processing]

Processing will be aborted.

[Action]

There is possible where an open number of files that can be used with the system is insufficient. Please confirm the total of the file that can be used with the system.

2.62.54 16554

could not send data to application server: @1@

[Description]

The application server was disconnected during execution of the Java function.

[System Processing]

Processing will be aborted.

[Action]

Check the message of application server.

2.62.55 16555

could not receive data from application server

[Description]

The application server was disconnected during execution of the Java function.

[System Processing]

Processing will be aborted.

[Action]

Check the message of application server.

2.62.56 16556

could not receive data from application server: @1@

[Description]

The application server was disconnected during execution of the Java function.

[System Processing]

Processing will be aborted.

[Action]

Check the message of application server.

2.62.57 16563

@1@: at least one option of "@2@" must be specified

[Description]

Must specify at least one option.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options.

2.62.58 16574

@1@: could not write directory "@2@"

[Description]

Could not write the directory.

[System Processing]

Processing will be aborted.

[Action]

Check that the disk of the directory has free space, and check that the abnormalities of the disk have not occurred.

2.62.59 16575

@1@: cannot execute with "@2@" option in primary server

[Description]

Do not specify the option to execute the command in primary server.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options.

Restore it because PL/extJava environment may be corrupted when the server is member nodes of the cluster.

2.62.60 16576

@1@: specify "@2@" option in standby server

[Description]

Specify the option to execute the command in standby server.

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options.

Restore it because PL/extJava environment may be corrupted when the server is member nodes of the cluster.

2.62.61 16577

Could not translate client host name "@1@" to IP address: @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.62.62 16578

Could not resolve client IP address to a host name: @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.62.63 16579

SELECT target entry is named "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.62.64 16580

SELECT target entry has type @1@, but column has type @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.62.65 16581

RETURNING list entry has type @1@, but column has type @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.62.66 16582

pg_largeobject entry for OID @1@, page @2@ has invalid data field size @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.62.67 16583

could not close directory "@1@": @2@

[Description]

Terminated normally but a warning was output.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.62.68 16584

could not create shared memory segment "@1@": @2@

[Description]

Could not create shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.69 16585

could not open shared memory segment "@1@": @2@

[Description]

Could not open shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.70 16586

could not map shared memory segment "@1@": @2@

[Description]

Could not map shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.71 16587

could not unmap shared memory segment "@1@": @2@

[Description]

Could not unmap shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.72 16588

could not remove shared memory segment "@1@": @2@

[Description]

Could not remove shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.73 16589

background worker "@1@": must attach to shared memory in order to request a database connection

[Description]

Could not register background worker.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.74 16590

background worker "@1@": cannot request database access if starting at postmaster start

[Description]

Could not register background worker.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.75 16591

background worker "@1@": invalid restart interval

[Description]

Could not register background worker.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.76 16592

terminating background worker "@1@" due to administrator command

[Description]

Could not register background worker.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.77 16596

dynamic shared memory control segment is not valid

[Description]

dynamic shared memory control segment is not valid.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.78 16597

too many dynamic shared memory segments

[Description]

Too many dynamic shared memory segments exist.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.62.79 16599

could not stat shared memory segment "@1@": @2@

[Description]

Could not get details about dynamic shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.63 Message Numbers Beginning with 16600

2.63.1 16600

could not resize shared memory segment "@1@" to @2@ bytes: @3@

[Description]

Could not resize shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.63.2 16601

could not get shared memory segment: @1@

[Description]

Could not get shared memory segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.63.3 16604

cannot add more timeout reasons

[Description]

cannot add more timeout reasons

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.63.4 16606

aborting because lock on relation "@1@"."@2@" is not available

[Description]

Aborting because lock on relation is not available.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.5 16607

affix file contains both old-style and new-style commands

[Description]

Affix file conatins commands in both old and new format.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.6 16608

aggregate cannot accept shell type @1@

[Description]

aggregate cannot accept shell type.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.7 16609

aggregate functions are not allowed in a recursive query's recursive term

[Description]

aggregate functions are not allowed in a recursive query's recursive term.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.8 16610

aggregate functions are not allowed in check constraints

[Description]

aggregate functions are not allowed in check constraints.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.9 16611

aggregate functions are not allowed in DEFAULT expression

[Description]

aggregate functions are not allowed in DEFAULT expressions.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.10 16612

aggregate functions are not allowed in EXECUTE parameters

[Description]

aggregate functions are not allowed in EXECUTE parameter.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.11 16613

aggregate functions are not allowed in FROM clause of their own query level

[Description]

Should only be possible in a LATERAL subquery.aggregate functions are not allowed in FROM clause of their own query level.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.12 16614

aggregate functions are not allowed in functions in FROM

[Description]

aggregate functions are not allowed in functions in FROM.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.13 16615

aggregate functions are not allowed in index expression

[Description]

aggregate functions are not allowed in index expression.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.14 16616

aggregate functions are not allowed in index predicates

[Description]

aggregate functions are not allowed in index predicates.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.15 16617

aggregate functions are not allowed in JOIN conditions

[Description]

aggregate functions are not allowed in JOIN conditions.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.16 16618

aggregate functions are not allowed in @1@

[Description]

aggregate functions are not allowed in some kinds of expressions we are parsing such as
EXPR_KIND_WHERE,EXPR_KIND_FILTER, EXPR_KIND_INSERT_TARGET, EXPR_KIND_UPDATE_SOURCE,
EXPR_KIND_UPDATE_TARGET, EXPR_KIND_GROUP_BY, EXPR_KIND_LIMIT, EXPR_KIND_OFFSET,
EXPR_KIND_RETURNING,EXPR_KIND_VALUES.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.17 16620

aggregate functions are not allowed in trigger WHEN conditions

[Description]

aggregate functions are not allowed in trigger WHEN conditions.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.18 16621

aggregate functions are not allowed in window RANGE

[Description]

aggregate functions are not allowed in window RANGE.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.19 16622

aggregate functions are not allowed in window ROWS

[Description]

aggregate functions are not allowed in window ROWS.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.20 16623

aggregate mfinalfunc must not be specified without mstype

[Description]

aggregate mfinalfunc must not be specified without mstype.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.21 16624

aggregate minitcond must not be specified without mstype

[Description]

aggregate minitcond must not be specified without mstype.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.22 16625

aggregate minvfunc must be specified when mstype is specified

[Description]

aggregate minvfunc must be specified when mstype is specified. if mtransType is given, mtransfuncName and minvtransfuncName must be as well; if not, then none of the moving-aggregate options should have been given.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.23 16626

aggregate minvfunc must not be specified without mstype

[Description]

aggregate minvfunc must not be specified without mstype. if mtransType is given, mtransfuncName and minvtransfuncName must be as well; if not, then none of the moving-aggregate options should have been given.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.24 16627

aggregate msfunc must be specified when mstype is specified

[Description]

aggregate msfunc must be specified when mstype is specified. if mtransType is given, mtransfuncName and minvtransfuncName must be as well; if not, then none of the moving-aggregate options should have been given.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.25 16628

aggregate msfunc must not be specified without mstype

[Description]

aggregate msfunc must not be specified without mstype. if mtransType is given, mtransfuncName and minvtransfuncName must be as well; if not, then none of the moving-aggregate options should have been given.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.26 16629

aggregate msspace must not be specified without mstype

[Description]

aggregate msspace must not be specified without mstype. if mtransType is given, mtransfuncName and minvtransfuncName must be as well; if not, then none of the moving-aggregate options should have been given.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.27 16630

aggregates cannot accept set arguments

[Description]

aggregates cannot accept set arguments.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.28 16631

aggregates cannot have more than @1@ argument

[Description]

aggregates cannot have more than 99 argument. Aggregates can have at most FUNC_MAX_ARGS-1 args, else the transfnand/or finalfn will be unrepresentable in pg_proc. We must check now to protect fixed-size arrays here and possibly in called functions.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.29 16632

aggregates cannot have output arguments

[Description]

aggregates cannot have output arguments.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.30 16633

a hypothetical-set aggregate must have direct arguments matching its aggregated arguments

[Description]

a hypothetical-set aggregate must have direct arguments matching its aggregated arguments.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.31 16634

All connection parameters must be supplied because no database connection exists

[Description]

All connection parameters must be supplied because no database connection exists. We don't know the supplied connection parameters and don't want to connect to the wrong database by using defaults, so require all parameters to be specified.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.32 16635

all replication slots are in use

[Description]

all replication slots are in use.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.33 16636

an aggregate with DISTINCT must have at least one argument

[Description]

an aggregate with DISTINCT must have at least one argument. Returning an empty list would cause the parsed Query to look like it didn't have DISTINCT, with results that would probably surprise the user. Note: this case is presently impossible for aggregates because of grammar restrictions, but we check anyway.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.34 16637

an ordered-set aggregate with a VARIADIC direct argument must have one VARIADIC aggregated argument of the same data type

[Description]

an ordered-set aggregate with a VARIADIC direct argument must have one VARIADIC aggregated argument of the same data type.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.35 16638

argument declared "anyrange" is not a range type but type @1@

[Description]

argument declared \"anyrange\" is not a range type but type format type of range_type.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.36 16639

argument list must have even number of elements

[Description]

argument list must have even number of elements.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.37 16640

argument of lo_read exceeds integer range

[Description]

argument of lo_read exceeds integer range. Long ago, somebody thought it'd be a good idea to declare this function as taking size_t ... but the underlying backend function only accepts a signed int32 length. So throw error if the given value overflows int32.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.38 16641

argument of lo_truncate exceeds integer range

[Description]

argument of lo_truncate exceeds integer range\n.Long ago, somebody thought it'd be a good idea to declare this function as taking size_t ... but the underlying backend function only accepts a signed int32 length. So throw error if the given value overflows int32. (A possible alternative is to automatically redirect the call to lo_truncate64; but if the caller wanted to rely on that backend function being available, he could have called lo_truncate64 for himself.)

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.39 16642

argument of lo_write exceeds integer range

[Description]

argument of lo_write exceeds integer range\n.Long ago, somebody thought it'd be a good idea to declare this function as taking size_t ... but the underlying backend function only accepts a signed int32 length. So throw error if the given value overflows int32.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.40 16643

argument of @1@ must be an array of objects

[Description]

argument of funcname must be an array of objects.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.41 16644

Array contents must start with "{"

[Description]

Array contents must start with \"{\".intuit dimensions from brace structure -- it better match what we were given.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.42 16645

array must be one-dimensional

[Description]

array must be one-dimensional.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.43 16646

array must have even number of elements

[Description]

array must have even number of elements.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.44 16647

array must have two columns

[Description]

array must have two columns.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.45 16648

array must not contain nulls

[Description]

array must not contain nulls.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.46 16649

Array value must start with "{" or dimension information

[Description]

Array value must start with "{" or dimension information. No array dimensions, so intuit dimensions from brace structure.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.47 16650

authentication file line too long

[Description]

authentication file line too long. Line too long!

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.48 16651

a variadic ordered-set aggregate must use VARIADIC type ANY

[Description]

a variadic ordered-set aggregate must use VARIADIC type ANY. An ordered-set aggregate that is VARIADIC must be VARIADIC ANY. In principle we could support regular variadic types, but it would make things much more complicated because we'd have to assemble the correct subsets of arguments into array values. Since no standard aggregates have use for such a case, we aren't bothering for now.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.49 16652

a worker process died unexpectedly

[Description]

a worker process died unexpectedly.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.50 16653

canceling statement due to lock timeout

[Description]

canceling statement due to lock timeout.If LOCK_TIMEOUT and STATEMENT_TIMEOUT indicators are both set, we prefer to report the former; but be sure to clear both.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.51 16654

cannot extract elements from an object

[Description]

cannot extract elements from an object.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.52 16655

cannot extract elements from a scalar

[Description]

cannot extract elements from a scalar.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.53 16656

cannot get array length of a non-array

[Description]

cannot get array length of a non-array.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.54 16657

cannot get array length of a scalar

[Description]

cannot get array length of a scalar.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.55 16658

cannot have more than 2³²-2 commands in a transaction

[Description]

cannot have more than 2³²-2 commands in a transaction.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.56 16659

cannot insert into column "@1@" of view "@2@"

[Description]

cannot insert into column non_updatable_col of view RelationGetRelationName(view). This is a different error, caused by an attempt to update a non-updatable column in an otherwise updatable view.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.57 16660

cannot insert into foreign table "@1@"

[Description]

cannot insert into foreign table RelationName of resultRel.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.58 16661

cannot lock rows in materialized view "@1@"

[Description]

cannot lock rows in materialized view RelationName of provided rel.Allow referencing a matview, but not actual locking clauses.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.59 16662

cannot move relations in to or out of pg_global tablespace

[Description]

cannot move relations in to or out of pg_global tablespace.Can't move shared relations in to or out of pg_global. This is also checked by ATExecSetTableSpace, but nice to stop earlier.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.60 16663

cannot perform FREEZE because of prior transaction activity

[Description]

cannot perform FREEZE because of prior transaction activity.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.61 16664

cannot perform FREEZE because the table was not created or truncated in the current subtransaction

[Description]

cannot perform FREEZE because the table was not created or truncated in the current subtransaction.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.62 16665

cannot refresh materialized view "@1@" concurrently

[Description]

cannot refresh materialized view matviewname concurrently.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.63 16666

cannot rename inherited constraint "@1@"

[Description]

cannot rename inherited constraint oldconname.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.64 16667

cannot return non-composite value from function returning composite type

[Description]

cannot return non-composite value from function returning composite type.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.65 16668

cannot rewrite table "@1@" used as a catalog table

[Description]

cannot rewrite table Relation name used as a catalog table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.66 16669

cannot update column "@1@" of view "@2@"

[Description]

cannot update column non_updatable_col of view RelationGetRelationName(view).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.67 16670

cannot update foreign table "@1@"

[Description]

cannot update foreign table resultRel relation name.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.68 16671

cannot use a logical replication slot for physical replication

[Description]

Logical replication slots, similar to physical slots except that they are attached to a single database.cannot use a logical replication slot for physical replication.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.69 16672

cannot use DISTINCT with WITHIN GROUP

[Description]

cannot use DISTINCT with WITHIN GROUP.The order clause for WITHIN GROUP and the one for plain-aggregate ORDER BY share a field, so we have to check here that at most one is present. We also check for DISTINCT here to give a better error location.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.70 16673

cannot use expression index "@1@" as replica identity

[Description]

cannot use expression index Relation name of indexRel as replica identity. Expression indexes aren't supported.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.71 16674

cannot use invalid index "@1@" as replica identity

[Description]

cannot use invalid index Relation name of indexRel as replica identity.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.72 16675

cannot use ldapbasedn, ldapbinddn, ldapbindpasswd, ldapsearchattribute, or ldapurl together with ldaprefix

[Description]

cannot use ldapbasedn, ldapbinddn, ldapbindpasswd, ldapsearchattribute, or ldapurl together with ldaprefix. LDAP can operate in two modes: either with a direct bind, using ldaprefix and ldapsuffix, or using a search+bind, using ldapbasedn, ldapbinddn, ldapbindpasswd and ldapsearchattribute. Disallow mixing these parameters.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.73 16676

cannot use multiple ORDER BY clauses with WITHIN GROUP

[Description]

cannot use multiple ORDER BY clauses with WITHIN GROUP.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.74 16677

cannot use non-immediate index "@1@" as replica identity

[Description]

cannot use non-immediate index Relation name of indexRel as replica identity. Deferred indexes are not guaranteed to be always unique.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.75 16678

cannot use non-unique index "@1@" as replica identity

[Description]

cannot use non-unique index Relation name of indexRel as replica identity. The Access Method must support uniqueness, and the index must in fact be unique.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.76 16679

cannot use partial index "@1@" as replica identity

[Description]

cannot use partial index Relation name of indexRel as replica identity.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.77 16680

cannot use physical replication slot for logical decoding

[Description]

cannot use physical replication slot for logical decoding.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.78 16681

cannot use subquery in DEFAULT expression

[Description]

cannot use subquery in DEFAULT expression. Check to see if the sublink is in an invalid place within the query. We allow sublinks everywhere in SELECT/INSERT/UPDATE/DELETE, but generally not in utility statements.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.79 16682

cannot use VARIADIC with WITHIN GROUP

[Description]

cannot use VARIADIC with WITHIN GROUP.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.80 16683

check constraints for domains cannot be marked NO INHERIT

[Description]

check constraints for domains cannot be marked NO INHERIT. Check constraints are handled after domain creation, as they require the Oid of the domain; at this point we can only check that they're not marked NO INHERIT, because that would be bogus.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.81 16684

CONCURRENTLY and WITH NO DATA options cannot be used together

[Description]

CONCURRENTLY and WITH NO DATA options cannot be used together. Check that conflicting options have not been specified.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.82 16685

CONCURRENTLY cannot be used when the materialized view is not populated

[Description]

CONCURRENTLY cannot be used when the materialized view is not populated. Check that CONCURRENTLY is not specified if not populated.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.83 16687

constraint "@1@" of relation "@2@" is not a foreign key or check constraint

[Description]

constraint constrName of relation RelationName(rel) is not a foreign key or check constraint.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.84 16688

could not change directory to "@1@": @2@

[Description]

could not change directory to path: strerror(errno). could not change directory to orig_wd: strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.85 16689

could not close directory "@1@": @2@

[Description]

could not close directory ctx->directory and the corresponding error will be printed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.86 16690

could not close log file @1 @: @2@

[Description]

could not close log file XLogFileNameP(ThisTimeLineID, openLogSegNo) and the reason failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.87 16691

could not close log segment @1 @: @2@

[Description]

could not close log segment XLogFileNameP(recvFileTLI, recvSegNo) and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.88 16692

could not close pipe to external command: @1 @

[Description]

could not close pipe to external command and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.89 16693

could not close pipe to external command: @1 @

[Description]

could not close pipe to external command: strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.90 16694

could not complete SSL handshake on renegotiation, too many failures

[Description]

could not complete SSL handshake on renegotiation, too many failures. A handshake can fail, so be prepared to retry it, but only a few times and in this case we considered maximum limit is 20 times.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.91 16695

could not create any Unix-domain sockets

[Description]

could not create any Unix-domain sockets.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.92 16696

could not create communication channels: @1@

[Description]

could not create communication channels: strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.93 16697

could not create shared memory segment "@1@": @2@

[Description]

could not create shared memory segment name and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.94 16698

could not create Unix-domain socket in directory "@1@"

[Description]

could not create Unix-domain socket in one of the `Unix_socket_directories`.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.63.95 16699

could not determine data type for argument @1@

[Description]

could not determine data type for argument 1. since `json_object_agg()` is declared as taking type "any", the parser will not do any type conversion on unknown-type literals (that is, undecorated strings or NULLs). Such values will arrive here as type UNKNOWN, which fortunately does not matter to us, since `unknownout()` works fine.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64 Message Numbers Beginning with 16700

2.64.1 16700

could not determine encoding for codeset "@1@"

[Description]

could not determine encoding for codeset `cp` followed by the provided unsigned integer.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.2 16701

could not duplicate handle for "@1@": @2@

[Description]

could not duplicate handle for handle name and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.3 16702

could not execute command "@1@": @2@

[Description]

could not execute command filename and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.4 16703

could not execute command "@1@": @2@

[Description]

could not execute command options->file and the strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.5 16704

could not fdatsync log file @1@: @2@

[Description]

could not fdatsync log file XLogFileNameP(ThisTimeLineID, segno) and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.6 16705

could not fork worker process: @1@

[Description]

could not fork worker process. The reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.7 16706

could not fsync log file @1@: @2@

[Description]

could not fsync log file XLogFileNameP(ThisTimeLineID, segno) and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.8 16707

could not fsync log segment @1@: @2@

[Description]

could not fsync log segment XLogFileNameP(ThisTimeLineID, openLogSegNo) and reason for failure also printed along with error. XLogFileNameP(ThisTimeLineID, openLogSegNo) currently open log segment (if any). Also, if the open flag is changing, close the log file so it will be reopened (with new flag bit) at next use.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.9 16708

could not fsync write-through log file @1@: @2@

[Description]

could not fsync write-through log file XLogFileNameP(ThisTimeLineID, segno) and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.10 16709

could not get current working directory: @1@

[Description]

could not get current working directory: strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.11 16710

could not get home directory for user ID @1@: @2@

[Description]

could not get home directory for user ID user_id and strerror(errno) if errno set otherwise print _("user does not exist").

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.12 16711

could not get junction for "@1@": @2@

[Description]

could not get junction for path :msg.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.13 16712

could not get relation name for OID @1@: @2@

[Description]

could not get relation name for OID te->catalogId.oid, PQerrorMessage(AH->connection).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.14 16713

could not get shared memory segment: @1@

[Description]

could not get shared memory segment and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.15 16714

Could not identify system: got @1@ rows and @2@ fields, expected @3@ rows and @4@ or more fields

[Description]

Could not identify system: got res->ntups rows and res->numAttributes fields, expected 3 rows and 1 or more fields.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.16 16715

could not import a module for Decimal constructor

[Description]

could not import a module for Decimal constructor. Try to import cdecimal. If it doesn't exist, fall back to decimal.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.17 16716

could not initialize LDAP: @1@

[Description]

could not initialize LDAP and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.18 16719

could not look up local user ID @1@: @2@

[Description]

could not look up local user ID geteuid() and error string for the corresponding errno will be printed or if it is unknown error it will print "Unknown error".

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.19 16720

could not look up local user ID @1@: @2@

[Description]

could not look up local user ID (long)uid and if errno is set error string for the corresponding errno will be printed otherwise "user does not exist" will be printed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.20 16721

could not map anonymous shared memory: @1@

[Description]

could not map anonymous shared memory and the reason for failure will be printed along with error.If errno is ENOMEM means This error usually means that PostgreSQL's request for a shared memory segment exceeded available memory, swap space, or huge pages. To reduce the request size (currently size bytes), reduce PostgreSQL's shared memory usage, perhaps by reducing shared_buffers or max_connections.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.21 16722

could not map shared memory segment "@1@": @2@

[Description]

could not map shared memory segment handle name and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.22 16723

could not obtain lock on relation "@1@"

[Description]

could not obtain lock on relation relation name. Lock relation. This will also accept any pending invalidation messages. If we got back InvalidOid, indicating not found, then there's nothing to lock, but we accept invalidation messages anyway, to flush any negative catcache entries that may be lingering.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.23 16724

could not open backend variables file "@1@": @2@

[Description]

could not open backend variables file id and stterror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.24 16725

could not open configuration directory "@1@": @2@

[Description]

could not open configuration directory absolute location of includedir and the reason for failure also be printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.25 16726

could not open shared memory segment "@1@": @2@

[Description]

could not open shared memory segment dsm handle name and reason for failure also printed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.26 16727

could not open transaction log file "@1@": @2@

[Description]

could not open transaction log file path and reason for failure also prined along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.27 16728

could not parse file name "@1@"

[Description]

could not parse file name path name. temporary filenames from SnapBuildSerialize() include the LSN and everything but are postfixed by \$.pid.tmp. We can just remove them the same as other files because there can be none that are currently being written that are older than cutoff. We just log a message if a file doesn't fit the pattern, it's probably some editors lock/state file or similar...

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.28 16729

could not parse LDAP URL "@1@": @2@

[Description]

could not parse LDAP URL val and ldap_err2string on the return value of ldap_url_parse.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.29 16730

could not perform initial LDAP bind for ldapbinddn "@1@" on server "@2@": @3@

[Description]

could not perform initial LDAP bind for ldapbinddn port->hba->ldapbinddn on server port->hba->ldapservers and ldap_err2string on the return value of ldap_simple_bind_s. Bind with a pre-defined username/password (if available) for searching. If none is specified, this turns into an anonymous bind.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.30 16731

could not read directory "@1@": @2@

[Description]

could not read directory path and strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.31 16732

could not read file "@1@", read @2@ of @3@: @4@

[Description]

could not read file path, read readBytes of (int) SnapBuildOnDiskConstantSize) and the reason for failure also printed along with error. This error can occur during reading statically sized portion of snapshot or reading SnapBuild or during restore running xacts information or during restore committed xacts information.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.32 16733

could not read file "@1@", read @2@ of @3@: @4@

[Description]

could not read file , path read readBytes of (uint32) ReplicationSlotOnDiskConstantSize) and the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.33 16734

could not read from backend variables file "@1@": @2@

[Description]

could not read from backend variables file id and strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.34 16735

could not read from file "@1@": read @2@ instead of @3@ bytes

[Description]

could not read from file path: read readBytes instead of (int32) sizeof(LogicalRewriteMappingData) bytes.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.35 16736

could not read from log segment @1@, offset @2@, length @3@: @4@

[Description]

could not read from log segment XLogFileNameP(curFileTimeLine, sendSegNo), offset sendOff, length (unsigned long) segbytes) and the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.36 16737

could not read from log segment @1@, offset @2@: @3@

[Description]

could not read from log segment fname, offset readOff and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.37 16738

could not read from reorderbuffer spill file: @1@

[Description]

could not read from reorderbuffer spill file and the reason for failure also be printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.38 16739

could not read from reorderbuffer spill file: read @1@ instead of @2@ bytes

[Description]

could not read from reorderbuffer spill file: read readBytes instead of (uint32) sizeof(ReorderBufferDiskChange) bytes.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.39 16740

could not read from tuplestore temporary file: @1@

[Description]

could not read from tuplestore temporary file and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.40 16741

could not read time zone file "@1@": @2@

[Description]

could not read time zone file filename and the reason for failure also be printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.41 16742

could not receive timeline history file from "the primary server: @1@

[Description]

could not receive timeline history file from "the primary server:PQerrorMessage(streamConn).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.42 16743

could not remove directory "@1@"

[Description]

could not remove directory tmp_path. If removing the directory fails, the worst thing that will happen is that the user won't be able to create a new slot with the same name until the next server restart. We crashed while a slot was being setup or deleted, clean up. If we crashed with an ephemeral slot active, don't restore but delete it.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.43 16744

could not remove shared memory segment "@1@": @2@

[Description]

could not remove shared memory segment name and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.44 16746

could not resize shared memory segment "@1@" to @2@ bytes: @3@

[Description]

could not resize shared memory segment name to request_size bytes.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.45 16747

Could not resolve client IP address to a host name: @1@

[Description]

Could not resolve client IP address to a host name gai_strerror(port->remote_hostname_errcode).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.46 16748

could not restore file "@1@" from archive: @2@

[Description]

could not restore file xlogfname from archive: Returns a human-readable string explaining the reason a child process terminated by taking the argument as rc.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.47 16749

could not search LDAP for filter "@1@" on server "@2@" : @3@

[Description]

could not search LDAP for filter filter on server port->hba->ldapservers: ldap_err2string(return value of ldap_search_s).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.48 16750

could not seek in log file @1@ to offset @2@: @3@

[Description]

could not seek in log file XLogFileNameP(ThisTimeLineID, openLogSegNo) to offset startoffset and reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.49 16751

could not seek in log segment @1@ to offset @2@: @3@

[Description]

could not seek in log segment fname to offset readOff: the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.50 16752

could not seek in tuplestore temporary file: @1@

[Description]

could not seek in tuplestore temporary file and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.51 16753

could not seek to beginning of file "@1@": @2@

[Description]

could not seek to beginning of file path and the reason for failure also printed along with error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.52 16754

could not send end-of-streaming message to primary: @1@

[Description]

could not send end-of-streaming message to primary: PQerrorMessage(streamConn).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.53 16755

could not set LDAP protocol version: @1@

[Description]

could not set LDAP protocol version: ldap_err2string(return value of ldap_set_option).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.54 16756

could not set socket to nonblocking mode: @1@

[Description]

could not set socket to nonblocking mode: the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.55 16757

could not set socket to nonblocking mode: @1@

[Description]

could not set socket to nonblocking mode: SOCK_STRERROR(SOCK_ERRNO, sebuf, sizeof(sebuf)).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.56 16758

could not set variable "@1@"

[Description]

could not set variable varname.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.57 16759

could not start LDAP TLS session: @1@

[Description]

could not start LDAP TLS session: ldap_err2string(return value of _ldap_start_tls_sA).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.58 16760

could not stat control file "@1@": @2@

[Description]

could not stat control file XLOG_CONTROL_FILE and reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.59 16761

could not stat file or directory "@1@": @2@

[Description]

could not stat file or directory path/TABLESPACE_VERSION_DIRECTORY :the reason for failure printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.60 16762

could not stat file "@1@": @2@

[Description]

could not stat file options->file,strerror(errno).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.61 16763

could not stat shared memory segment "@1@": @2@

[Description]

could not stat shared memory segment name:the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.62 16764

could not stat trigger file "@1@": @2@

[Description]

Check to see whether the user-specified trigger file exists and whether a promote request has arrived. If either condition holds, return true.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.63 16765

Could not translate client host name "@1@" to IP address: @2@

[Description]

could not translate the client host name to ip address.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.64 16766

could not truncate file "@1@" to @2@: @3@

[Description]

Truncate all data that's not guaranteed to have been safely fsynced (by previous record or by the last checkpoint).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.65 16767

could not unmap shared memory segment "@1@": @2@

[Description]

could not unmap shared memory segment name: the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.66 16768

could not write to COPY program: @1@

[Description]

could not write to COPY program: the reason for failure is printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.67 16769

could not write to data file for XID @1@: @2@

[Description]

could not write to data file for XID (txn->xid) and the reason for failure is also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.68 16770

could not write to file "@1@", wrote @2@ of @3@: @4@

[Description]

could not write to file src->path, wrote written of len: the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.69 16771

could not write to log file @1@ at offset @2@, length @3@: @4@

[Description]

could not write to log file XLogFileNameP(ThisTimeLineID, openLogSegNo) at offset openLogOff length nbytes: the reason for failure also printed along with the error.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.70 16772

could not write to log segment @1@ at offset @2@, length @3@: @4@

[Description]

if write didn't set errno, assume no disk space

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.71 16773

could not write to the communication channel: @1@

[Description]

- 1.This function is executed in the worker process.It sends a message to the master on the communication channel.
- 2.This function is executed in the master process.It sends a message to a certain worker on the communication channel.If we're already aborting anyway, don't care if we succeed or not.The child might have gone already.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.72 16774

could not write to tuplestore temporary file: @1@

[Description]

could not write to tuplestore temporary file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.73 16775

database connection requirement not indicated during registration

[Description]

This flag means the bgworker requires a database connection. The connection is not established automatically; the worker must establish it later. It requires that BGWORKER_SHMEM_ACCESS was passed too.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.74 16776

database is not accepting commands that generate new MultiXactIds to avoid wraparound data loss in database "@1@"

[Description]

database is not accepting commands that generate new MultiXactIds to avoid wraparound data loss in database Execute a database-wide VACUUM in that database You might also need to commit or roll back old prepared transactions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.75 16777

database is not accepting commands that generate new MultiXactIds to avoid wraparound data loss in database with OID

[Description]

Execute a database-wide VACUUM in that database. You might also need to commit or roll back old prepared transactions.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.76 16778

database "@1@" is used by a logical replication slot

[Description]

Check whether there are, possibly unconnected, logical slots that refer to the to-be-dropped database. The database lock we are holding prevents the creation of new slots using the database. ReplicationSlotsCountDBSlots -- count the number of slots that refer to the passed database oid. Returns true if there are any slots referencing the database. *nslots will be set to the absolute number of slots in the database, *nactive to ones currently active.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.77 16779

date field value out of range: @1@-@2@-@3@

[Description]

date field value out of range Note: we'll reject zero or negative year values. Perhaps negativesshould be allowed to represent BC years?

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.78 16780

date out of range: @1@-@2@-@3@

[Description]

date out of range Note: we'll reject zero or negative year values. Perhaps negativesshould be allowed to represent BC years?

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.79 16781

DECLARE CURSOR WITH HOLD ... @1@ is not supported

[Description]

DECLARE CURSOR WITH HOLD is not supported .FOR UPDATE and WITH HOLD are not compatible

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.80 16782

DECLARE INSENSITIVE CURSOR ... @1@ is not supported

[Description]

DECLARE INSENSITIVE CURSOR is not supportedFOR UPDATE and INSENSITIVE are not compatible

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.81 16783

DECLARE SCROLL CURSOR ... @1@ is not supported

[Description]

DECLARE SCROLL CURSOR is not supportedFOR UPDATE and SCROLL are not compatible

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.82 16784

ECDH: could not create key

[Description]

ECDH: could not create key

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.83 16785

ECDH: unrecognized curve name: @1@

[Description]

ECDH: unrecognized curve name

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.84 16786

enum label "@1@" already exists

[Description]

Check if label is already in use. The unique index on pg_enum would catch this anyway, but we prefer a friendlier error message, and besides we need a check to support IF NOT EXISTS.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.85 16788

error processing a parallel work item

[Description]

error processing a parallel work itemIt looks for an idle worker process and only returns if there is one.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.86 16789

error reading result of streaming command: @1@

[Description]

error reading result of streaming command

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.87 16790

event trigger functions cannot have declared arguments

[Description]

event trigger functions cannot have declared argumentsshouldn't be any declared arguments

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.88 16791

event trigger name cannot be qualified

[Description]

event trigger name cannot be qualifiedThe types of names handled by this function are not permitted to beschema-qualified or catalog-qualified.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.89 16792

event trigger "@1@" already exists

[Description]

An event trigger of same name is already exist

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.90 16793

event triggers are not supported for @1@

[Description]

Validate DDL command tags.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.91 16794

event trigger "@1@" does not exist

[Description]

event trigger does not exist.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.92 16795

event trigger "@1@" does not exist, skipping

[Description]

Generate a NOTICE stating that the named object was not found, and is being skipped. This is only relevant when "IF EXISTS" is used; otherwise, `get_object_address()` in `RemoveObjects` would have thrown an ERROR.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.93 16796

event trigger with OID @1@ does not exist

[Description]

event trigger with OID does not exist

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.94 16797

exceeded maxAllocatedDescs (@1@) while trying to execute command "@2@"

[Description]

exceeded maxAllocatedDescs while trying to execute command

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.95 16798

Expected 1 tuple with 2 fields, got @1@ tuples with @2@ fields.

[Description]

Expected 1 tuple with 2 fields

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.64.96 16799

Expected array element or "]", but found "@1@\"

[Description]

The context of the parser is maintained by the recursive descent mechanism, but is passed explicitly to the error reporting routine for better diagnostics.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65 Message Numbers Beginning with 16800

2.65.1 16800

Expected a transaction log switchpoint location.

[Description]

Expected a transaction log switchpoint location.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.2 16801

Expected ":", but found "@1@"

[Description]

invalid input syntax for type json The context of the parser is maintained by the recursive descent mechanism, but is passed explicitly to the error reporting routine for better diagnostics.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.3 16802

extended query protocol not supported in a replication connection

[Description]

'firstchar' specifies what kind of a forbidden message was received, and is used to construct the error message.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.4 16803

fastpath function calls not supported in a replication connection

[Description]

'firstchar' specifies what kind of a forbidden message was received, and is used to construct the error message.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.5 16804

field name must not be null

[Description]

If function is not marked "proisstrict" in pg_proc, it must check for null arguments using this macro. Do not try to GETARG a null argument!

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.6 16805

FILTER is not implemented for non-aggregate window functions

[Description]

FILTER is not yet supported with true window functions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.7 16806

filters not supported in LDAP URLs.

[Description]

filters not supported in LDAP URLs.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.8 16807

FILTER specified, but @1@ is not an aggregate function

[Description]

FILTER specified, but the function is not an aggregate function

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.9 16808

filter value "@1@" not recognized for filter variable "@2@"

[Description]

Validate DDL command tags

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.10 16809

filter variable "@1@" specified more than once

[Description]

Complain about a duplicate filter variable.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.11 16810

final function with extra arguments must not be declared STRICT

[Description]

When finalfnExtraArgs is specified, the finalfn will certainly be passed at least one null argument, so complain if it's strict.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.12 16811

first argument of @1@ must be a row type

[Description]

Convenience function to determine whether a type OID represents a "rowtype" type --- either RECORD or a named composite type.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.13 16812

FORCE NULL column "@1@" not referenced by COPY

[Description]

Convert FORCE NULL name list to per-column flags, check validity

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.14 16813

foreign key referenced-columns list must not contain duplicates

[Description]

Reject duplicate appearances of columns in the referenced-columns list. Such a case is forbidden by the SQL standard, and even if we thought it useful to allow it, there would be ambiguity about how to match the list to unique indexes (in particular, it'd be unclear which indexopclass goes with which FK column).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.15 16814

Foreign tables cannot have constraint triggers.

[Description]

Foreign key table does not contain constraint triggers

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.16 16815

Foreign tables cannot have INSTEAD OF triggers.

[Description]

Foreign tables cannot have INSTEAD OF triggers.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.17 16816

Foreign tables cannot have TRUNCATE triggers.

[Description]

Foreign tables cannot have TRUNCATE triggers.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.18 16817

foreign table "@1@" does not allow deletes

[Description]

foreign table does not allow deletes

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.19 16818

foreign table "@1@" does not allow inserts

[Description]

foreign table does not allow inserts

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.20 16819

foreign table "@1@" does not allow updates

[Description]

foreign table \"%s\" does not allow updates

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.21 16820

foreign table "@1@" does not exist, skipping

[Description]

the foreign table is not existing.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.22 16821

format specifies argument 0, but arguments are numbered from 1

[Description]

Explicit 0 for argument index is immediately refused

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.23 16822

function returning record called in context that cannot accept type record

[Description]

- 1.failed to determine actual type of RECORDfunction returning record called in context that cannot accept type record
- 2.get the tupdesc from the result set info - it must be a record typebecause we already checked that arg1 is a record type, or we're in ato_record function which returns a setof record.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.24 16823

function @1@ must accept VARIADIC ANY to be used in this aggregate

[Description]

If the agg is declared to take VARIADIC ANY, the underlying functions had better be declared that way too, else they may receive too many parameters; but func_get_detail would have been happy with plain ANY.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.25 16824

function "@1@" must return type "event_trigger"

[Description]

Find and validate the trigger function.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.26 16825

hot standby is not possible because wal_level was not set to "hot_standby" or higher on the master server

[Description]

For Hot Standby, the WAL must be generated with 'hot_standby' mode, and we must have at least as many backend slots as the primary.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.27 16826

huge pages not supported on this platform

[Description]

huge pages not supported on this platform if the value is 1

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.28 16827

huge TLB pages not supported on this platform

[Description]

huge pages not supported on this platform if the value is 1

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.29 16829

index row size @1@ exceeds hash maximum @2@

[Description]

Check whether the item can fit on a hash page at all. (Eventually, we ought to try to apply TOAST methods if not.) Note that at this point, itemsz doesn't include the ItemId.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.30 16830

index row size @1@ exceeds maximum @2@ for index "@3@"

[Description]

If the tuple would be too big to be stored, function throws a suitable error if errorTooBig is TRUE, or returns NULL if errorTooBig is FALSE.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.31 16831

index "@1@" cannot be used as replica identity because column "@2@" is nullable

[Description]

Check index for nullable columns.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.32 16832

index "@1@" contains a half-dead internal page

[Description]

Pre-9.4 page deletion only marked internal pages as half-dead, but now we only use that flag on leaf pages.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.33 16833

interval time zone "@1@" must not include months or days

[Description]

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.34 16834

interval units "@1@" not supported because months usually have fractional weeks

[Description]

default condition of the switch statement with condition val

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.35 16835

invalid backup block size in record at @1@/@2@

[Description]

Add in the backup blocks, if any

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.36 16836

invalid contrecord length @1 @ at @2 @/@3 @

[Description]

Cross-check that xlp_rem_len agrees with how much of the record we expect there to be left.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.37 16837

invalid flags for opening a large object: @1 @

[Description]

Large object descriptor, appropriately filled in. The descriptor and subsidiary data are allocated in the specified memory context, which must be suitably long-lived for the caller's purposes.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.38 16839

invalid input syntax for numeric time zone: "@1@"

[Description]

Note pg_tzset happily parses numeric input that DecodeTimezone would reject. To avoid having it accept input that would otherwise be seen as invalid, it's enough to disallow having a digit in the first position of our input string.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.39 16840

invalid input syntax for type json

[Description]

Per RFC4627, these characters MUST be escaped. Since *s isn't printable, exclude it from the context string.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.40 16841

invalid input syntax for type pg_isn: "@1@"

[Description]

Sanity check input format.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.41 16842

invalid large object write request size: @1 @

[Description]

the addition in the condition can't overflow because nbytes is only int32

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.42 16843

invalid line number: @1 @

[Description]

validating the line number.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.43 16844

invalid line specification: A and B cannot both be zero

[Description]

invalid line specification: A and B cannot both be zero

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.44 16845

invalid line specification: must be two distinct points

[Description]

invalid line specification: must be two distinct points

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.45 16846

invalid locale name: "@1@"

[Description]

Check that the chosen locales are valid, and get canonical spellings

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.46 16847

invalid magic number @1@ in log segment @2@, offset @3@

[Description]

invalid magic number in log segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.47 16848

invalid message received from worker: @1@

[Description]

Invalid message received from worker.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.48 16849

invalid MultiXactId: @1@

[Description]

No work except at first MultiXactId of a page. But beware: just after wraparound, the first MultiXactId of page zero is FirstMultiXactId.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.49 16850

invalid page in block @1@ of relation @2@

[Description]

verifying the page in block of relations

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.50 16851

invalid page in block @1@ of relation @2@; zeroing out page

[Description]

invalid page in block of relation, zeroing out page

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.51 16852

invalid processing mode in background worker

[Description]

it had better not gotten out of "init" mode yet

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.52 16853

invalid scale in external "numeric" value

[Description]

invalid scale in external

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.53 16854

invalid timeline @1@

[Description]

invalid timeline

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.54 16855

invalid value for "buffering" option

[Description]

Validator for "buffering" reoption on GiST indexes. Allows "on", "off" and "auto" values.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.55 16856

invalid value for "check_option" option

[Description]

Validator for "check_option" reoption on views. The allowed values are "local" and "cascaded".

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.56 16857

invalid value for parameter "replication"

[Description]

Try to interpret value as boolean value. Valid values are: true,false, yes, no, on, off, 1, 0; as well as unique prefixes thereof.If the string parses okay, return true, else false. If okay and result is not NULL, return the value in *result.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.57 16858

invalid value for recovery parameter "recovery_target"

[Description]

the recovery parameter name should be "recovery_target" and the recovery parameter value should be "immediate" .

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.58 16859

invalid value "@1@" for "@2@"

[Description]

- 1.checking if the parsed character is greater than 0 and that parsed character is less than required.
- 2.check if the source is equal to init
- 3.if the length is not valid

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.59 16860

invalid whence setting: @1@

[Description]

Note: overflow in the additions is possible, but since we will reject negative results, we don't need any extra test for that.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.60 16861

JSON does not support infinite date values.

[Description]

XSD doesn't support infinite values. Infinity and minus infinity must be the max and min values of DateADT. We could use INT_MIN and INT_MAX here, but seems better to not assume that int32 == int.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.61 16862

JSON does not support infinite timestamp values

[Description]

XSD doesn't support infinite values

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.62 16863

Junk after closing right brace

[Description]

only whitespace is allowed after the closing brace. We used to use isspace() for parsing array values, but that has undesirable results: an array value might be silently interpreted differently depending on the locale setting. Now we just hard-wire the traditional ASCII definition of isspace().

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.63 16864

Junk view columns are not updatable

[Description]

the only updatable columns we support are those that are Vars referring to user columns of the underlying base relation. The view targetlist may contain resjunk columns (e.g., a view defined like "SELECT * FROM t ORDER BY a+b" is auto-updatable) but such columns are not auto-updatable, and in fact should never appear in the outer query's targetlist.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.64 16865

large object read request is too large

[Description]

A result_length calculated from loSize may not fit in a size_t. Check that the size will satisfy this and subsequently-enforced size limits.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.65 16866

LIKE is not supported for creating foreign tables

[Description]

we could support LIKE in many cases, but worry about it another day

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.66 16867

lock file "@1@" is empty

[Description]

Either another server is starting, or the lock file is the remnant of a previous server startup crash.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.67 16868

logical decoding cannot be used while in recovery

[Description]

We check shared state each time only until we leave recovery mode. We can't re-enter recovery, so there's no need to keep checking after the shared variable has once been seen false. Note: We don't need a memory barrier when we're still in recovery. We might exit recovery immediately after return, so the caller can't rely on 'true' meaning that we're still in recovery anyway.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.68 16869

logical decoding requires a database connection

[Description]

Make sure the current settings & environment are capable of doing logicaldecoding.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.69 16870

logical decoding requires wal_level >= logical

[Description]

Make sure the current settings & environment are capable of doing logicaldecoding.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.70 16871

lo_lseek result out of range for large-object descriptor @1@

[Description]

guard against result overflow

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.71 16872

lo_tell result out of range for large-object descriptor @1@

[Description]

guard against result overflow

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.72 16873

malformed range literal: "@1@"

[Description]

first check for the empty range and then the rest should be whitespace. and then check if the string is not null terminated

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.73 16874

materialized views may not be defined using bound parameters

[Description]

A materialized view would either need to save parameters for use in maintaining/loading the data or prohibit them entirely. The latter seems safer and more sane.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.74 16875

materialized views must not use data-modifying statements in WITH

[Description]

Prohibit a data-modifying CTE in the query used to create a materialized view. It's not sufficiently clear what the user would want to happen if the MV is refreshed or incrementally maintained.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.75 16876

materialized views must not use temporary tables or views

[Description]

Check whether any temporary database objects are used in the creation query. It would be hard to refresh data or incrementally maintain it if a source disappeared.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.76 16877

mismatched array dimensions

[Description]

take separate key and value arrays of text to construct a json object pairwise.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.77 16878

Missing array dimension value

[Description]

Missing array dimension value

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.78 16879

more than one row returned for \gset

[Description]

StoreQueryTuple: assuming query result is OK, save data into variables

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.79 16880

moving-aggregate implementation returns type @1@, but plain implementation returns type @2@

[Description]

check if the moving-aggregate implementation returns type is not same as that of plain implementation returns type

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.80 16881

moving-aggregate transition function must not return null

[Description]

Moving-aggregate transition functions must not return null, for more see `advance_windowaggregate_base()`.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.81 16882

Multidimensional arrays must have sub-arrays with matching dimensions

[Description]

Multidimensional arrays must have sub-arrays with matching dimensions
`ArrayCount` will Determine the dimensions for an array string.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.82 16883

multiple column definition lists are not allowed for the same function

[Description]

check if the `codelist` and the `range functions codelist` ie., the multiple column definition list for the same function

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.83 16884

MultiXactId @1@ does no longer exist -- apparent wraparound

[Description]

`MultiXactId` does no longer exist -- apparent wraparound

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.84 16885

MultiXactId @1@ has not been created yet -- apparent wraparound

[Description]

MultiXactId has not been created yet -- apparent wraparound

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.85 16886

must be owner of event trigger @1@

[Description]

the MAX_ACL_KIND object types that can have privilege errors

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.86 16887

must be superuser or replication role to start walsender

[Description]

Check replication permissions needed for walsender processes.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.87 16888

must be superuser or replication role to use replication slots

[Description]

must be superuser or replication role to use replication slots

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.88 16889

must be superuser to alter settings globally

[Description]

Must be superuser to alter settings globally.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.89 16890

must be superuser to COPY to or from an external program

[Description]

Disallow COPY to/from file or program except to superusers.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.90 16891

Must be superuser to create an event trigger

[Description]

It would be nice to allow database owners or even regular users to do this, but there are obvious privilege escalation risks which would have to somehow be plugged first.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.91 16892

must be superuser to execute ALTER SYSTEM command

[Description]

must be superuser to execute ALTER SYSTEM command

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.92 16894

new data for "@1@" contains duplicate rows without any null columns

[Description]

Note that this ereport() is returning data to the user. Generally, we would want to make sure that the user has been granted access to this data. However, REFRESH MAT VIEW is only able to be run by the owner of the mat view (or a superuser) and therefore there is no need to check for access to data in the mat view.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.93 16895

new row violates WITH CHECK OPTION for view "@1@"

[Description]

WITH CHECK OPTION checks are intended to ensure that the new tuple is visible in the view. If the view's qual evaluates to NULL, then the new tuple won't be included in the view. Therefore we need to tell ExecQual to return FALSE for NULL (the opposite of what we do above for CHECK constraints).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.94 16896

no Decimal attribute in module

[Description]

the module is not contain any Decimal attribute.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.95 16897

no matching relations in tablespace "@1@" found

[Description]

there is no matching relations in tablespace.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.96 16898

no rows returned for \gset

[Description]

StoreQueryTuple: assuming query result is OK, save data into variables Returns true if successful, false otherwise.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.65.97 16899

not enough arguments for cursor "@1@"

[Description]

check the syntax immediately, instead of checking the final expression that may have the arguments reordered. Trailing whitespace must not be trimmed, because otherwise input of the form (param -- comment\n, param) would be translated into a form where the second parameter is commented out.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66 Message Numbers Beginning with 16900

2.66.1 16900

not enough shared memory for data structure "@1@" (@2@ bytes requested)

[Description]

If the shmem index doesn't exist, we are bootstrapping: we must be trying to init the shmem index itself. Notice that the ShmemIndexLock is released before the shmem index has been initialized. This should be OK because no other process can be accessing shared memory yet.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.2 16901

not enough shared memory for elements of data structure "@1@" (@2@ bytes requested)

[Description]

not enough shared memory for elements of data structure

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.3 16902

null value not allowed for object key

[Description]

null value not allowed for object key

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.4 16903

number is out of range

[Description]

check if the number is coming out of range ie.,in between 0 and 9.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.5 16904

number of jsonb array elements exceeds the maximum allowed (@1@)

[Description]

number of jsonb array elements exceeds the maximum allowed

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.6 16905

number of jsonb object pairs exceeds the maximum allowed (@1@)

[Description]

number of jsonb object pairs exceeds the maximum allowed

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.7 16906

number of parameters must be between 0 and 65535

[Description]

number of parameters must be between 0 and 65535

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.8 16907

Numeric time zones must have "-" or "+" as first character.

[Description]

The starting character of the numeric time zone should not digit.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.9 16908

numeric time zone "@1@" out of range

[Description]

DecodeTimezone()-Interpret string as a numeric timezone. Return 0 if okay (and set *tzip), a DTERR code if not okay.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.10 16909

Object keys should be text

[Description]

If function is not marked "proisstrict" in pg_proc, it must check for null arguments using this macro. Do not try to GETARG a null argument!

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.11 16910

only ordered-set aggregates can be hypothetical

[Description]

Symbolic values for aggkind column. We distinguish normal aggregates from ordered-set aggregates (which have two sets of arguments, namely direct and aggregated arguments) and from hypothetical-set aggregates (which are a subclass of ordered-set aggregates in which the last direct arguments have to match up in number and datatypes with the aggregated arguments).

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.12 16911

only tables, indexes, and materialized views exist in tablespaces

[Description]

only tables, indexes, and materialized views exist in tablespaces

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.13 16912

operator not allowed in variable definition

[Description]

operator not allowed in variable definition

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.14 16913

option --if-exists requires option -c/--clean

[Description]

option --if-exists requires option -c/--clean

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.15 16914

outer-level aggregate cannot contain a lower-level variable in its direct arguments

[Description]

Now check for vars/aggs in the direct arguments, and throw error if needed. Note that we allow a Var of the agg's semantic level, but not an Agg of that level. In principle such Aggs could probably be supported, but it would create an ordering dependency among the aggregates at execution time. Since the case appears neither to be required by spec nor particularly useful, we just treat it as a nested-aggregate situation.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.16 16915

out-of-sequence timeline ID @1@ (after @2@) in log segment @3@, offset @4@

[Description]

Since child timelines are always assigned a TLI greater than their immediate parent's TLI, we should never see TLI go backwards across successive pages of a consistent WAL sequence.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.17 16916

OVER is not supported for ordered-set aggregate @1@

[Description]

window functions must be called with a window definition.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.18 16917

page verification failed, calculated checksum @1@ but expected @2@

[Description]

Throw a WARNING if the checksum fails, but only after we've checked for the all-zeroes case.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.19 16918

parallel backup only supported by the directory format

[Description]

Parallel backup only in the directory archive format so far

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.20 16920

percentile value @1@ is not between 0 and 1

[Description]

percentile value should be in between 0 and 1.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.21 16921

permission denied for event trigger @1@

[Description]

the no_priv_msg array object is ACL_KIND_EVENT_TRIGGER

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.22 16922

permission denied to change owner of event trigger "@1@"

[Description]

New owner must be a superuser

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.23 16923

permission denied to create event trigger "@1@"

[Description]

It would be nice to allow database owners or even regular users to do this, but there are obvious privilege escalation risks which would have to somehow be plugged first.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.24 16924

[pg_largeobject entry for OID @1@, page @2@ has invalid data field size @3@](#)

[Description]

the size of the data field of pg_largeobject entry is less than 0 or greater than LOBLKSIZE.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.25 16926

[range constructor flags argument must not be null](#)

[Description]

range constructor flags argument must not be null

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.26 16927

[relation "@1@" in @2@ clause not found in FROM clause](#)

[Description]

the list cell is NULL for ensuring the SQL row locking clause such as FOR UPDATE is not found in FROM clause

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.27 16928

[removing elements from multidimensional arrays is not supported](#)

[Description]

We can't remove elements from multi-dimensional arrays, since the result might not be rectangular.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.28 16929

renaming an ON SELECT rule is not allowed

[Description]

We disallow renaming ON SELECT rules, because they should always be named "_RETURN".

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.29 16930

replication slot file @1@: checksum mismatch, is @2@, should be @3@

[Description]

verify the CRCs.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.30 16931

replication slot file "@1@" has corrupted length @2@

[Description]

boundary check on length

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.31 16932

replication slot file "@1@" has unsupported version

[Description]

verify version

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.32 16933

replication slot file "@1@" has wrong magic @2@ instead of @3@

[Description]

verify magic

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.33 16934

replication slot name "@1@" contains invalid character

[Description]

Replication slot names may only contain letters, numbers, and the underscore character

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.34 16935

replication slot name "@1@" is too long

[Description]

Maximum length for identifiers (e.g. table names, column names, function names). Names actually are limited to one less byte than this, because the length must include a trailing zero byte.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.35 16936

replication slot name "@1@" is too short

[Description]

Check whether the passed slot name is valid and report errors at elevel.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.36 16937

Replication slot names may only contain letters, numbers, and the underscore character.

[Description]

Replication slot names may only contain letters, numbers, and the underscore character.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.37 16938

replication slot "@1@" already exists

[Description]

Check for name collision, and identify an allocatable slot. We need to hold ReplicationSlotControlLock in shared mode for this, so that nobody else can change the in_use flags while we're looking at them.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.38 16939

replication slots can only be used if max_replication_slots > 0.

[Description]

replication slots can only be used if max_replication_slots > 0

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.39 16940

replication slots can only be used if wal_level >= archive

[Description]

replication slots can only be used if wal_level >= archive

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.40 16941

replication slot "@1@" does not exist

[Description]

replication slot does not exist

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.41 16942

replication slot "@1@" is already active

[Description]

replication slot is already active

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.42 16943

replication slot "@1@" was not created in this database

[Description]

replication slot was not created in this database

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.43 16944

requested character not valid for encoding: @1@

[Description]

requested character not valid for encoding

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.44 16945

requested starting point @1@/@2@ is ahead of the WAL flush position of this server @3@/@4@

[Description]

requested starting point is ahead of the WAL flush position of this server

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.45 16946

requested starting point @1@/@2@ on timeline @3@ is not in this server's history

[Description]

requested starting point on timeline is not in this server's history

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.46 16947

requested timeline @1@ does not contain minimum recovery point @2@/@3@ on timeline @4@

[Description]

requested timeline does not contain minimum recovery point on timeline

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.47 16948

requested timeline @1@ is not a child of this server's history

[Description]

requested timeline is not a child of this server's history

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.48 16949

requested timeline @1@ is not in this server's history

[Description]

requested timeline is not in this server's history

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.49 16950

RETURNING list entry has type @1@, but column has type @2@.

[Description]

RETURNING list entry and column are of different types.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.50 16951

RETURNING must have at least one column

[Description]

RETURNING must have at least one column.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.51 16952

return type of inverse transition function @1@ is not @2@

[Description]

return type of inverse transition function must exactly match declared mtranstype

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.52 16953

row is too big: size @1@, maximum size @2@**[Description]**

row is too big.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.53 16954

ROWS FROM() with multiple functions cannot have a column definition list**[Description]**

ROWS FROM() with multiple functions cannot have a column definition list

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.54 16955

rules on materialized views are not supported**[Description]**

rules on materialized views are not supported

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.55 16956

@1@ cannot be applied to a function**[Description]**

cannot be applied to a function

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.56 16957

@1@ cannot be applied to a join

[Description]

cannot be applied to a join

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.57 16958

@1@ cannot be applied to a WITH query

[Description]

cannot be applied to a WITH query

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.58 16959

@1@ cannot be applied to the nullable side of an outer join

[Description]

cannot be applied to the nullable side of an outer join

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.59 16960

@1@ cannot be applied to VALUES

[Description]

cannot be applied to VALUES

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.60 16961

@1@: cannot cluster specific table(s) in all databases

[Description]

cannot cluster specific table(s) in all databases

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.61 16962

@1@: cannot reindex specific index(es) and system catalogs at the same time

[Description]

cannot reindex specific index(es) and system catalogs at the same time

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.62 16963

@1@: cannot reindex specific index(es) in all databases

[Description]

cannot reindex specific index(es) in all databases

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.63 16964

@1@: cannot reindex specific table(s) and system catalogs at the same time

[Description]

cannot reindex specific table(s) and system catalogs at the same time

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.64 16965

@1@: cannot reindex specific table(s) in all databases

[Description]

cannot reindex specific table(s) in all databases

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.65 16966

@1@: cannot use --create-slot or --drop-slot together with --startpos

[Description]

cannot use create-slot or drop-slot together with startpos

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.66 16967

@1@: cannot use --create-slot or --start together with --drop-slot

[Description]

cannot use create-slot or start-slot together while doing a drop-slot

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.67 16968

@1@: cannot vacuum specific table(s) in all databases

[Description]

cannot vacuum specific table(s) in all databases

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.68 16969

@1@ can only be called in a sql_drop event trigger function

[Description]

can only be called in a sql_drop event trigger function

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.69 16970

@1@: could not access directory "@2@": @3@

[Description]

Trouble in accessing directory

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.70 16971

@1@: could not allocate SIDs: error code @2@

[Description]

could not allocate security identifier(SID) and displays the last error returned by GetLastError().(GetLastError() is a windows specific call which returns one of the 500 System Error Codes)

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.71 16972

@1@: could not change permissions of directory "@2@": @3@

[Description]

could not change permissions of directory

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.72 16973

@1@: could not change permissions of "@2@": @3@

[Description]

Here chmod takes the PGPATH as path and options as S_IRUSR | S_IWUSR

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.73 16974

@1@: could not close directory "@2@": @3@

[Description]

closedir syscall called and errno set accordingly

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.74 16975

@1@: could not create archive status file "@2@": @3@

[Description]

This open syscall takes a temporary path name and flags O_WRONLY | O_CREAT | PG_BINARY and mode as S_IRUSR | S_IWUSR

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.75 16976

@1@: could not create replication slot "@2@": got @3@ rows and @4@ fields, expected @5@ rows and @6@ fields

[Description]

could not create replication slot as rows is not equal to 1 and fields is not greater than or equal to 4

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.76 16977

@1@: could not create symbolic link "@2@": @3@

[Description]

while creating symbolic path for a Xlog directory or tablespace path

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.77 16978

@1@: could not create timeline history file "@2@": @3@

[Description]

This open syscall takes a temporary path name and flags O_WRONLY | O_CREAT | PG_BINARY and mode as S_IRUSR | S_IWUSR

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.78 16979

@1@: could not drop replication slot "@2@": got @3@ rows and @4@ fields, expected @5@ rows and @6@ fields

[Description]

could not drop replication slot as rows and fields are not equal to zero

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.79 16980

@1@: could not fetch default options

[Description]

The function Pqconndefaults() Constructs a default connection options array, which identifies all the available options and shows any default values that are available from the environment etc. On error (eg out of memory), NULL is returned.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.80 16981

@1@: could not find own program executable

[Description]

find_my_exec() finds an absolute path to a valid executable

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.81 16982

@1@: could not fsync file "@2@": @3@

[Description]

could not fsync file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.82 16983

@1@: could not fsync log file "@2@": @3@

[Description]

could not fsync Log file.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.83 16984

@1@: could not identify system: got @2@ rows and @3@ fields, expected @4@ rows and @5@ or more fields

[Description]

Could not identify system as expected number of rows is not equal to 1 and number of fields is not greater than or equal to 3

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.84 16985

@1@: could not locate my own executable path

[Description]

find_my_exec() finds an absolute path to a valid executable

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.85 16986

@1@: could not open directory "@2@": @3@

[Description]

could not open directory

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.86 16987

@1@: could not open file "@2@": @3@

[Description]

could not open file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.87 16988

@1@: could not open log file "@2@": @3@

[Description]

could not open log file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.88 16989

@1@: could not open timeline history file "@2@": @3@

[Description]

could not open timeline history file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.89 16990

@1@: could not parse next timeline's starting point "@2@"

[Description]

could not parse next timeline's starting point

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.90 16991

@1@: could not parse start position "@2@"

[Description]

could not parse start position

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.91 16992

@1@: could not read directory "@2@": @3@

[Description]

could not read directory

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.92 16993

@1@: could not remove promote signal file "@2@": @3@

[Description]

could not remove promote signal file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.93 16994

@1@: could not rename file "@2@" to "@3@": @4@

[Description]

could not rename file(Here we move the completed history file into place with its final name)

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.94 16995

@1@: could not send copy-end packet: @2@

[Description]

PQputCopyEnd - send EOF indication to the backend during COPY IN. After calling this, use PQgetResult() to check command completion status. Returns 1 if successful, 0 if data could not be sent (only possible in nonblock mode), or -1 if an error occurs.

pqFlush - send any data waiting in the output buffer. Return 0 on success, -1 on failure and 1 when not all data could be sent because the socket would block and the connection is non-blocking.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.95 16996

@1@: could not stat file "@2@": @3@

[Description]

could not stat file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.66.96 16997

@1@: could not write timeline history file "@2@": @3@

[Description]

This write operation happens while Writing the history file to pg_xlog or Writing the history file to disk

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.66.97 16998

@1@: could not write @2@ bytes to log file "@3@": @4@**[Description]**

could not write the bytes to log file

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.66.98 16999

@1@: directory name too long**[Description]**

directory name too long

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67 Message Numbers Beginning with 17000

2.67.1 17000

@1@: directory "@2@" does not exist**[Description]**

directory does not exist,The errno ENOENT indicates that component of path does not exist, or path is an empty string.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.2 17001

@1@: directory "@2@" is not a database cluster directory**[Description]**

directory is not a database cluster directory

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.3 17002

SELECT rule's target entry @1@ has different column name from column "@2@"cluster directory

[Description]

resname is required to represent the correct column name in non-resjunk entries of top-level SELECT targetlists, since it will be used as the column title sent to the frontend.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.4 17003

SELECT target entry has type @1@, but column has type @2@.

[Description]

SELECT column does not match target entry

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.5 17004

ShmemIndex entry size is wrong for data structure "@1@": expected @2@, actual @3@

[Description]

ShmemIndex entry size is wrong for data structure.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.6 17005

@1@: incompatible server version @2@; client does not support streaming from server versions newer than @3@

[Description]

incompatible server version ,client does not support streaming from server .ServerMajor and maxServerMajor are calculated as follows; (serverMajor = PQserverVersion(conn) / 100 and maxServerMajor = PG_VERSION_NUM / 100;)where PG_VERSION_NUM is 90401 and PQserverVersion returns the sversion; /* server version, e.g. 70401 for 7.4.1 */

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.7 17006

@1@: incompatible server version @2@; client does not support streaming from server versions older than @3@

[Description]

incompatible server version ,client does not support streaming from server .ServerMajor and minServerMajor are calculated as follows;
(serverMajor = PQserverVersion(conn) / 100 and minServerMajor = 903;)where PQserverVersion returns the sversion; /* server version, e.g. 70401 for 7.4.1 */

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.8 17007

@1@: incompatible server version @2@

[Description]

incompatible server version; ServerMajor and maxServerMajor are calculated as follows;(minServerMajor = 903,serverMajor = PQserverVersion(conn) / 100 and maxServerMajor = PG_VERSION_NUM / 100;)where PG_VERSION_NUM is 90401 and PQserverVersion returns the sversion; /* server version, e.g. 70401 for 7.4.1 */

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.9 17008

@1@: invalid --max-rate unit: "@2@"

[Description]

after_num is obtained by passing src string to strtod

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.10 17009

@1@: invalid number of parallel jobs

[Description]

invalid number of parallel jobs

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.11 17010

@1@: invalid tablespace mapping format "@2@", must be "OLDDIR=NEWDIR"

[Description]

invalid tablespace mapping format

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.12 17011

@1@: invalid transfer rate "@2@": @3@

[Description]

invalid transfer rate

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.13 17012

@1@: invalid xlog-method option "@2@", must be "fetch" or "stream"

[Description]

invalid xlog-method option

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.14 17013

@1@ is not allowed with aggregate functions

[Description]

The return type of function LCS_asString is not allowed with aggregate functions. In this error case, the return type of LCS_asString is "FOR some"

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.15 17014

@1@ is not allowed with DISTINCT clause

[Description]

The return type of function LCS_asString is not allowed with aggregate functions. In this error case, the return type of LCS_asString is "FOR some"

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause

2.67.16 17015

@1@ is not allowed with GROUP BY clause

[Description]

The return string of LCS_asString() is not allowed with GROUP BY clause

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.17 17016

@1@ is not allowed with HAVING clause

[Description]

The return string of LCS_asString() is not allowed with HAVING clause

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.18 17017

@1@ is not allowed with set-returning functions in the target list

[Description]

The return string of LCS_asString() is not allowed with set-returning functions in the target list

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.19 17018

@1@ is not allowed with UNION/INTERSECT/EXCEPT

[Description]

The return string of LCS_asString() is not allowed with UNION/INTERSECT/EXCEPT

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.20 17019

@1@ is not allowed with window functions

[Description]

The return string of LCS_asString() is not allowed with window functions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.21 17020

"@1@" is not a materialized view

[Description]

The Relation that is returned by RelationGetRelationName() is not a materialized view

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.22 17021

@1@ is not an ordered-set aggregate, so it cannot have WITHIN GROUP

[Description]

Normal aggregate, so it can't have WITHIN GROUP

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.23 17022

"@1@" is not a table, materialized view, composite type, or foreign table

[Description]

If the particular relation is not a table, materialized view, composite type, or foreign table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.24 17023

"@1@" is not a table, materialized view, index, or foreign table

[Description]

The relation returned by the function RelationGetRelationName() is not a table, materialized view, index, or foreign table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.25 17024

"@1@" is not a table, materialized view, or index

[Description]

The relation is not a table, materialized view, or index

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.26 17025

"@1@" is not a table or materialized view

[Description]

The relation is not a table or materialized view

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.27 17026

"@1@" is not a table, view, materialized view, composite type, index, or foreign table

[Description]

The relation is not a table, view, materialized view, composite type, index, or foreign table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.28 17027

"@1@" is not a table, view, materialized view, composite type, or foreign table

[Description]

The relation is not a table, view, materialized view, composite type, or foreign table.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.29 17028

"@1@" is not a table, view, materialized view, index, or TOAST table

[Description]

The relation is not a table, view, materialized view, index, or TOAST table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.30 17030

"@1@" is not a table, view, materialized view, sequence, or foreign table

[Description]

The relation is not a table, view, materialized view, sequence, or foreign table. Note: Don't allow ALTER TABLE. SET SCHEMA on relations that can't be moved to a different schema, such as indexes and TOAST tables.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.31 17031

"@1@" is not a table, view, or foreign table

[Description]

The relation is not a table, view, or foreign table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.32 17032

"@1@" is not a table, view, sequence, or foreign table

[Description]

The relation is not a table, view, sequence, or foreign table

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.33 17033

@1@ must specify unqualified relation names

[Description]

The return type of LCS_asString() must specify unqualified relation names

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.34 17034

snapbuild state file @1@: checksum mismatch, is @2@, should be @3@

[Description]

snapbuild state file : checksum mismatch

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.35 17035

snapbuild state file "@1@" has unsupported version @2@ instead of @3@**[Description]**

snapbuild state file has unsupported version.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.36 17036

snapbuild state file "@1@" has wrong magic @2@ instead of @3@**[Description]**

snapbuild state file has wrong magic number

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.37 17037

@1@: new directory is not an absolute path in tablespace mapping: @2@**[Description]**

new directory is not an absolute path in tablespace mapping

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.38 17038

@1@: no database specified**[Description]**

no database specified for the given program name

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.39 17039

@1@: no slot specified

[Description]

no slot specified for the given program name

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.40 17040

SP-GiST inner tuple size @1@ exceeds maximum @2@

[Description]

SPGiST leaf tuple carries a datum and a heap tuple TID. Inner tuple should be small enough to fit on a page. Values larger than a buffer page cannot be indexed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.41 17041

SSL failed to renegotiate connection before limit expired

[Description]

SSL failed to renegotiate connection before limit expired

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.42 17042

@1@: symlinks are not supported on this platform

[Description]

symlinks are not supported on this platform . Note : Define to 1 if you have the `symlink' function.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.43 17043

@1@: transaction log directory location can only be specified in plain mode

[Description]

transaction log directory location can only be specified in plain mode

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.44 17044

@1@: transaction log directory location must be an absolute path

[Description]

transaction log directory location must be an absolute path

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.45 17045

@1@: transfer rate must be greater than zero

[Description]

transfer rate must be greater than zero

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.46 17046

@1@: transfer rate "@2@" exceeds integer range

[Description]

transfer rate exceeds integer range

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.47 17047

@1@: transfer rate "@2@" is not a valid value

[Description]

transfer rate is not a valid value Note: The second parameter is a out - parameter.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.48 17049

strictness of aggregate's forward and inverse transition functions must match

[Description]

strictness of aggregate's forward and inverse transition functions must match. Note: Insist that forward and inverse transition functions have the same strictness setting. Allowing them to differ would require handling more special cases in `advance_windowaggregate` and `advance_windowaggregate_base`, for no discernible benefit. This should have been checked at agg definition time, but we must check again in case either function's strictness property has been changed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.49 17050

string too long to represent as jsonb string

[Description]

string too long to represent as jsonb string. Note :Due to an implementation restriction, jsonb strings cannot exceed 0x0FFFFFFF

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.50 17051

@1@: unexpected response to TIMELINE_HISTORY command: got @2@ rows and @3@ fields, expected @4@ rows and @5@ fields

[Description]

unexpected response to TIMELINE_HISTORY command. Note: The response to TIMELINE_HISTORY is a single row result set with two fields: filename and content

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.51 17052

@1@: unexpected result set after end-of-timeline: got @2@ rows and @3@ fields, expected @4@ rows and @5@ fields

[Description]

unexpected result set after end-of-timeline

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.52 17053

[@1@: WAL streaming can only be used in plain mode](#)

[Description]

WAL streaming can only be used in plain mode

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.53 17054

[system column "@1@" reference in check constraint is invalid](#)

[Description]

system column reference in check constraint is invalid

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.54 17055

[time field value out of range: @1@:@2@:@3@](#)

[Description]

time field value out of range

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.55 17056

[timestamp out of range: @1@-@2@-@3@ @4@:@5@:@6@](#)

[Description]

timestamp out of range

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.56 17057

too many background workers

[Description]

too many background workers

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.57 17058

too many column names were specified

[Description]

too many column names were specified

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.58 17059

too many dynamic shared memory segments

[Description]

too many dynamic shared memory segments

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.59 17060

too many lexemes in thesaurus entry

[Description]

too many lexemes in thesaurus entry. Note: currently, tsearch_readline can't return lines exceeding 4KB,so overflow of the word counts is impossible.But that may not always be true, so let's check.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.60 17061

too many replication slots active before shutdown

[Description]

too many replication slots active before shutdown

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.61 17062

total size of jsonb array elements exceeds the maximum of @1@ bytes

[Description]

Total size of jsonb array elements exceeds the maximum of 0xFFFFFFFF bytes

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.62 17063

total size of jsonb object elements exceeds the maximum of @1@ bytes

[Description]

total size of jsonb object elements exceeds the maximum of 0xFFFFFFFFbytes

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.63 17064

tuple to be updated was already modified by an operation triggered by the current command

[Description]

tuple to be updated was already modified by an operation triggered by the current command

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.64 17065

type modifier cannot have ORDER BY

[Description]

type modifier cannot have ORDER BY

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.65 17066

"TZ"/"tz"/"OF" format patterns are not supported in to_date

[Description]

format patterns are not supported in to_date

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.66 17067

\\u0000 cannot be converted to text.

[Description]

\\u0000 cannot be converted to text. Note: The function report_json_context() reports a CONTEXT line for bogus JSON input.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.67 17068

Unexpected array element.

[Description]

Unexpected array element.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.68 17070

unexpected pageaddr @1 @/@2@ in log segment @3@, offset @4@

[Description]

unexpected pageaddr in log segment offset

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.69 17071

unexpected previous timeline ID @1@ (current timeline ID @2@) in checkpoint record

[Description]

unexpected previous timeline ID in checkpoint record

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.70 17072

unexpected result after CommandComplete: @1@

[Description]

unexpected result after CommandComplete

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.71 17073

unexpected result set after end-of-streaming

[Description]

unexpected result set after end-of-streaming

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.72 17074

unexpected result status for \watch

[Description]

unexpected result status for \ watch

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.73 17075

unexpected standby message type "@1@", after receiving CopyDone

[Description]

unexpected standby message type ,after receiving CopyDone . Note :If we already received a CopyDone from the frontend, the frontend should not send us anything until we've closed our end of the COPY.XXX: In theory, the frontend could already send the next command before receiving the CopyDone, but libpq doesn't currently allow that.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.74 17076

unexpected timeline ID @1@ in checkpoint record, before reaching minimum recovery point @2@/@3@ on timeline @4@

[Description]

unexpected timeline ID %u in checkpoint record, before reaching minimum recovery point %X/%X on timeline %u

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.75 17077

unexpected timeline ID @1@ in log segment @2@, offset @3@

[Description]

unexpected timeline ID in log segment.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.76 17078

Unicode escape values cannot be used for code point values above 007F when the server encoding is not UTF8.

[Description]

Unicode escape values cannot be used for code point values above 007F when the server encoding is not UTF8.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.77 17079

Unicode high surrogate must not follow a high surrogate.

[Description]

Unicode high surrogate must not follow a high surrogate.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.78 17080

Unicode low surrogate must follow a high surrogate.

[Description]

Unicode low surrogate must follow a high surrogate.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.79 17081

UNNEST() with multiple arguments cannot have a column definition list

[Description]

UNNEST() with multiple arguments cannot have a column definition list

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.80 17082

unsupported LDAP URL scheme: @1@

[Description]

unsupported LDAP URL scheme

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.81 17083

unsupported Unicode escape sequence

[Description]

unsupported Unicode escape sequence

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.82 17084

unterminated format specifier

[Description]

unterminated format specifier

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.83 17085

UTC timezone offset is out of range.

[Description]

UTC timezone offset is out of range.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.84 17086

variable "@1@" shadows a previously defined variable

[Description]

shadows a previously defined variable

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.85 17087

VARIADIC argument must be an array

[Description]

VARIADIC argument must be an array

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.86 17088

\watch cannot be used with an empty query

[Description]

watch cannot be used with an empty query.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.87 17089

\watch cannot be used with COPY

[Description]

watch cannot be used with COPY

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.88 17090

WHERE CURRENT OF is not supported for this table type

[Description]

WHERE CURRENT OF is not supported for this table type

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.89 17091

window functions are not allowed in check constraints

[Description]

window functions are not allowed in check constraints.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.90 17092

window functions are not allowed in DEFAULT expressions

[Description]

window functions are not allowed in DEFAULT expressions.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.91 17093

window functions are not allowed in EXECUTE parameters

[Description]

window functions are not allowed in EXECUTE parameters

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.92 17094

window functions are not allowed in functions in FROM

[Description]

window functions are not allowed in functions in FROM

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.93 17095

window functions are not allowed in index expressions

[Description]

window functions are not allowed in index expressions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.94 17096

window functions are not allowed in index predicates

[Description]

window functions are not allowed in index predicates

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.95 17097

window functions are not allowed in JOIN conditions

[Description]

window functions are not allowed in JOIN conditions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.96 17098

window functions are not allowed in @1@

[Description]

window functions are not allowed in expression kind

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.67.97 17099

window functions are not allowed in transform expressions

[Description]

window functions are not allowed in transform expressions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68 Message Numbers Beginning with 17100

2.68.1 17100

window functions are not allowed in trigger WHEN conditions

[Description]

window functions are not allowed in trigger WHEN conditions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.2 17101

window functions are not allowed in window definitions

[Description]

window functions are not allowed in window definitions

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.3 17102

window function @1@ cannot have WITHIN GROUP

[Description]

window function cannot have WITHIN GROUP Note:And, per spec, WITHIN GROUP isn't allowed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.4 17103

window function @1@ requires an OVER clause

[Description]

window function requires an OVER clause. Note: True window functions must be called with a window definition.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.5 17104

WITH CHECK OPTION is supported only on automatically updatable views

[Description]

WITH CHECK OPTION is supported only on automatically updatable views

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.6 17105

WITH CHECK OPTION not supported on recursive views

[Description]

WITH CHECK OPTION not supported on recursive views

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.7 17106

WITHIN GROUP is required for ordered-set aggregate @1@

[Description]

WITHIN GROUP is required for ordered-set aggregate

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.8 17107

WITHIN GROUP specified, but @1@ is not an aggregate function

[Description]

WITHIN GROUP specified, but the function is not an aggregate function

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.9 17108

WITH ORDINALITY cannot be used with a column definition list

[Description]

WITH ORDINALITY cannot be used with a column definition list

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.10 17109

tablespace encryption algorithm option can not be changed

[Description]

tablespace_encryption_algorithm option can not be changed with alter tablespace.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.11 17110

result of USING clause for column "@1@" cannot be cast automatically to type @2@

[Description]

USING clause column value cannot be typecasted automatically to new column type specified.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.12 17111

could not parse contents of file "@1@"

[Description]

Postgresql auto configuration file cannot be parsed

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.13 17115

could not change directory to "@1@": @2@

[Description]

pg_resetxlog process cannot change the directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.14 17116

pclose failed: @1@

[Description]

pclose system call failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.15 17117

cannot duplicate null pointer (internal error)

[Description]

Null pointer cannot be duplicated

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.16 17118

out of memory

[Description]

Process runs out of memory

[System Processing]

Process aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.17 17119

cannot create restricted tokens on this platform

[Description]

Restricted Tokens cannot be created

[System Processing]

WARNING is issued

[Action]

To investigate the cause of the occurrence from the message, and remove cause for the WARNING.

2.68.18 17120

could not open process token: error code @1@

[Description]

Cannot open the process Token

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.19 17121

could not allocate SIDs: error code @1@

[Description]

Cannot allocate the SIDs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.20 17122

could not create restricted token: error code @1@

[Description]

Restricted token could not be created

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.21 17123

could not start process for command "@1@": error code @2@

[Description]

Process could not be started

[System Processing]

Processing could not be initiated

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.22 17124

could not re-execute with restricted token: error code @1@

[Description]

Restricted Token cannot be re-executed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.23 17125

could not get exit code from subprocess: error code @1@

[Description]

Cannot exit from the sub process

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.24 17126

user does not exist

[Description]

user does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.25 17127

user name lookup failure: error code @1@

[Description]

user does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.26 17128

command not found

[Description]

Command cannot be found

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.27 17129

command not executable

[Description]

Command is not executable

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.28 17130

could not determine encoding for codeset "@1@"

[Description]

Corresponding local could not found in PostgreSQL

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.29 17131

could not get junction for "@1@": @2@

[Description]

could not get junction

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.30 17132

could not get junction for "@1@": @2@

[Description]

could not get junction

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.31 17133

lock violation

[Description]

Antivirus software or some other similar software has locked the database file

[System Processing]

Process trying to access the file continues and retries after every 30 seconds

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.32 17134

sharing violation

[Description]

Antivirus software or some other similar software has locked the database file

[System Processing]

Process trying to access the file continues and retries after every 30 seconds

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.33 17135

could not get current working directory: @1@**[Description]**

The current working directory path cannot be found

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.34 17138

index row size @1@ exceeds maximum @2@ for index "@3@"**[Description]**

The row size of the Index exceeded the maximum limit

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.35 17139

unexpected page type 0x@1@ in BRIN index "@2@" block @3@**[Description]**

Unexpected page type in BRIN index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.36 17141

invalid value for "tablespace encryption algorithm" option**[Description]**

Value specified for tablespace encryption algorithm is invalid. Acceptable values are \"none\", \"AES128\" and \"AES256\".

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.37 17142

invalid value for "buffering" option

[Description]

Invalid value provided for reoption on buffering of Gist Indexes. Acceptable valid values are \"on\", \"off\", and \"auto\"

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.38 17143

cannot access temporary tables during a parallel operation

[Description]

Temporary tables cannot be accessed during parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.39 17144

cannot insert tuples during a parallel operation

[Description]

Tuples cannot be inserted during the parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.40 17146

attempted to delete invisible tuple

[Description]

An attempt has been made to delete an invisible tuple

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.41 17147

cannot update tuples during a parallel operation

[Description]

Tuples cannot be updated during the parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.42 17148

attempted to update invisible tuple

[Description]

An attempt has been made to update an invisible tuple

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.43 17149

could not truncate file "@1@" to @2@: @3@

[Description]

File could not be truncated due to inaccessibility of the file or file's location

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.44 17150

index "@1@" contains a half-dead internal page

[Description]

Index page is corrupted. This is no harm for processes performing searches. This can be fixed by RE-INDEXING.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.45 17151

sample percentage must be between 0 and 100

[Description]

Sample percentage for sample scan must be between 0 and 100

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.46 17152

cannot retrieve commit timestamp for transaction @1@

[Description]

Cannot retrieve commit timestamp for uncommitted transactions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.47 17153

could not get commit timestamp data

[Description]

Could not get commit timestamp data. "track_commit_timestamp" parameter must be configured

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.48 17154

database is not accepting commands that generate new MultiXactIds to avoid wraparound data loss in database "@1@"

[Description]

Database is not accepting any commands due to transaction wrap around issue. This can be fixed by vacuuming the database and committing/rolling-back the old unfinished prepared transactions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.49 17155

database is not accepting commands that generate new MultiXactIds to avoid wraparound data loss in database with OID @1@

[Description]

Database is not accepting any commands due to transaction wrap around issue. This can be fixed by vacuuming the database and committing/rolling-back the old unfinished prepared transactions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.50 17156

multixact "members" limit exceeded

[Description]

Multixact members limit exceeded.

Execute a database-wide VACUUM in database with OID %u with reduced vacuum_multixact_freeze_min_age and vacuum_multixact_freeze_table_age settings.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.51 17157

MultiXactId @1 @ does no longer exist -- apparent wraparound

[Description]

MultiXactID does not exist. Transaction wrap around completed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.52 17158

MultiXactId @1 @ has not been created yet -- apparent wraparound

[Description]

multixactId has not been created. Possible transaction wrap around has happend.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.53 17160

postmaster exited during a parallel transaction

[Description]

postmaster exited during a parallel transaction

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.54 17165

cannot PREPARE a transaction that has exported snapshots

[Description]

cannot PREPARE a transaction that has exported snapshots

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.55 17166

cannot commit during a parallel operation

[Description]

cannot commit during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.56 17167

cannot abort during a parallel operation

[Description]

cannot during during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.57 17168

cannot define savepoints during a parallel operation

[Description]

cannot define savepoints during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.58 17169

cannot release savepoints during a parallel operation

[Description]

cannot release savepoints during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.59 17170

cannot rollback to savepoints during a parallel operation

[Description]

cannot rollback to savepoints during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.60 17171

cannot start subtransactions during a parallel operation

[Description]

cannot start subtransactions during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.61 17172

cannot commit subtransactions during a parallel operation

[Description]

cannot commit subtransactions during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.62 17174

new timeline @1@ forked off current database system timeline @2@ before current recovery point @3@/ @4@

[Description]

new timeline %u forked off current database system timeline %u before current recovery point %X/%X

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.63 17178

requested timeline @1@ does not contain minimum recovery point @2@/ @3@ on timeline @4@

[Description]

minimum recovery point must be part of requested timeline's history

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.64 17179

This means that the backup is corrupted and you will have to use another backup for recovery.

[Description]

This means that the backup is corrupted and you will have to use another backup for recovery

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.65 17180

unexpected previous timeline ID @1@ (current timeline ID @2@) in checkpoint record

[Description]

unexpected previous timeline ID in checkpoint record. Check that the checkpoint record agrees with the current time line.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.66 17181

unexpected timeline ID @1@ in checkpoint record, before reaching minimum recovery point @2@/@3@ on timeline @4@

[Description]

unexpected timeline ID in checkpoint record, before reaching minimum recovery point on timeline

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.67 17182

could not fsync log file @1@: @2@

[Description]

could not fsync the log file. Check that the file exists and is available/accessible with appropriate permissions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.68 17183

could not stat promote trigger file "@1@": @2@

[Description]

Could not stat trigger file. Checking for the existence of trigger file. ensure that the trigger file exists with appropriate permissions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.69 17184

invalid privilege type @1@ for type

[Description]

invalid privilege type for object

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.70 17185

invalid privilege type @1@ for column

[Description]

invalid privilege type for the column

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.71 17186

permission denied for event trigger @1@

[Description]

permission denied on the trigger

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.72 17187

event trigger with OID @1@ does not exist

[Description]

Trigger being accessed does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.73 17188

constant of the type @1@ cannot be used here

[Description]

constant of the type regrole cannot be used here

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.74 17189

pg_class index OID value not set when in binary upgrade mode

[Description]

pg_class index OID value not set when in binary upgrade mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.75 17190

could not obtain lock on relation "@1@"

[Description]

Lock on a relation could not be obtained. Check the blocking process

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.76 17191

cannot create temporary tables during a parallel operation

[Description]

cannot create temporary tables in parallel mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.77 17197

"@1@" is not a materialized view

[Description]

The object type being accessed is not a materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.78 17198

default value for column "@1@" of relation "@2@" does not exist

[Description]

default value for column of relation does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.68.79 17199

operator @1@ (@2@, @3@) of @4@ does not exist

[Description]

operator does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69 Message Numbers Beginning with 17200

2.69.1 17200

function @1@ (@2@, @3@) of @4@ does not exist

[Description]

function being accessed does not exist. Check if the function is existing with appropriate permissions and search_path settings

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.2 17201

user mapping for user "@1@" on server "@2@" does not exist

[Description]

user mapping for user in server does not exist. Check the mapping user while creating foreign tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.3 17202

unrecognized default ACL object type "@1@"

[Description]

ACL object type is unrecognized. Valid object types are "r", "S", "f", and "T"

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.4 17203

default ACL for user "@1@" in schema "@2@" on @3@ does not exist

[Description]

default ACL for user in schema on does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.5 17204

default ACL for user "@1@" on @2@ does not exist

[Description]

default ACL for user on does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.6 17205

name or argument lists may not contain nulls

[Description]

name or argument lists may not contain nulls

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.7 17206

unsupported object type "@1@"

[Description]

unsupported object type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.8 17207

name list length must be exactly @1@

[Description]

name list length must be exactly 1

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.9 17208

large object OID may not be null

[Description]

large object OID may not be null

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.10 17210

argument list length must be exactly @1@

[Description]

argument list length must be exactly 1

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.11 17211

name list length must be at least @1@

[Description]

name list length must be at least 1

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.12 17212

unrecognized object type "@1@"

[Description]

unrecognized object type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.13 17213

aggregates cannot have more than @1@ argument

[Description]

aggregates cannot have more than 1 argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.14 17215

a variadic ordered-set aggregate must use VARIADIC type ANY

[Description]

a variadic ordered-set aggregate must use VARIADIC type ANY

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.15 17216

a hypothetical-set aggregate must have direct arguments matching its aggregated arguments

[Description]

a hypothetical-set aggregate must have direct arguments matching its aggregated arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.16 17218

strictness of aggregate's forward and inverse transition functions must match

[Description]

strictness of aggregate's forward and inverse transition functions must match

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.17 17219

final function with extra arguments must not be declared STRICT

[Description]

final function with extra arguments must not be declared STRICT

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.18 17220

moving-aggregate implementation returns type @1@, but plain implementation returns type @2@

[Description]

moving-aggregate implementation returns type one type but plain implementation returns type other type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.19 17221

function @1@ must accept VARIADIC ANY to be used in this aggregate

[Description]

The function must accept VARIADIC ANY to be used in this aggregate

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.20 17222

constraint "@1@" for domain @2@ does not exist

[Description]

The constraint for domain does not exist. Check the constraint name

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.21 17223

enum label "@1@" already exists

[Description]

enum label already exists

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.22 17224

pg_enum OID value not set when in binary upgrade mode

[Description]

pg_enum OID value not set when in binary upgrade mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.23 17225

pg_type OID value not set when in binary upgrade mode

[Description]

pg_type OID value not set when in binary upgrade mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.24 17226

"@1@" is not a table or materialized view

[Description]

The object referenced by pgstattuple utility is not a table or materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.25 17227

only ordered-set aggregates can be hypothetical

[Description]

only ordered-set aggregates can be hypothetical

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.26 17228

aggregate msfunc must be specified when mstype is specified

[Description]

aggregate msfunc must be specified when mstype is specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.27 17229

aggregate minvfunc must be specified when mstype is specified

[Description]

aggregate minvfunc must be specified when mstype is specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.28 17230

aggregate msfunc must not be specified without mstype

[Description]

aggregate msfunc must not be specified without mstype

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.29 17231

aggregate minvfunc must not be specified without mstype

[Description]

aggregate minvfunc must not be specified without mstype

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.30 17232

aggregate msspace must not be specified without mstype

[Description]

aggregate msspace must not be specified without mstype

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.31 17233

aggregate minitcond must not be specified without mstype

[Description]

aggregate minitcond must not be specified without mstype

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.32 17234

event trigger "@1@" already exists

[Description]

event trigger already exists

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.33 17236

could not write to COPY program: @1@

[Description]

could not write to COPY program: %m

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.34 17237

must be superuser to COPY to or from an external program

[Description]

Only superuser can COPY to or from an external program

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.35 17238

COPY FROM not supported with row-level security

[Description]

COPY FROM an external file is not supported when row level security is enabled. Use INSERT statements instead

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.36 17239

COPY force null available only in CSV mode

[Description]

COPY force null available only in CSV mod

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.37 17240

COPY force null only available using COPY FROM

[Description]

COPY force null only available using COPY FROM

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.38 17241

relation referenced by COPY statement has changed

[Description]

relation referenced by COPY statement has changed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.39 17242

could not close pipe to external command: @1@

[Description]

could not close pipe to external command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.40 17243

program "@1@" failed

[Description]

program has failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.41 17244

could not execute command "@1@": @2@**[Description]**

could not execute command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.42 17245

cannot copy to materialized view "@1@"**[Description]**

cannot copy to materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.43 17246

cannot perform COPY FREEZE because of prior transaction activity**[Description]**

cannot perform FREEZE because of prior transaction activity

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.44 17247

cannot perform COPY FREEZE because the table was not created or truncated in the current subtransaction**[Description]**

cannot perform FREEZE because the table was not created or truncated in the current subtransaction

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.45 17248

too many column names were specified

[Description]

too many column names were specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.46 17249

policies not yet implemented for this command

[Description]

policies not yet implemented for this command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.47 17250

invalid locale name: "@1@"

[Description]

Check if the locale name mentioned is correct.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.48 17251

database "@1@" is used by an active logical replication slot

[Description]

The database referenced is used by a logical replication slot.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.49 17252

option "@1@" cannot be specified with other options

[Description]

When invoking alter database command option cannot be specified with other options

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.50 17253

cannot disallow connections for current database

[Description]

cannot disallow connections for current database

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.51 17254

permission denied to create event trigger "@1@"

[Description]

Permission denied to create event trigger. Must be superuser to create an event trigger. Check permissions on trigger

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.52 17255

unrecognized event name "@1@"

[Description]

Unrecognized event name. Acceptable event name must be provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.53 17256

unrecognized filter variable "@1@"

[Description]

unrecognized filter variable

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.54 17259

event triggers are not supported for @1@

[Description]

event triggers are not supported for certain type of SQL statements

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.55 17260

filter variable "@1@" specified more than once

[Description]

filter variable specified more than once

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.56 17261

event trigger "@1@" does not exist

[Description]

Referenced event trigger does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.57 17262

permission denied to change owner of event trigger "@1@"

[Description]

permission denied to change owner of event trigger. The owner of an event trigger must be a superuser

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.58 17263

@1@ can only be called in a sql_drop event trigger function

[Description]

The function `pg_event_trigger_dropped_objects()` can only be called in a `sql_drop` event trigger function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.59 17264

@1@ can only be called in a table_rewrite event trigger function

[Description]

The function `pg_event_trigger_table_rewrite_oid()` can only be called in a `table_rewrite` event trigger function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.60 17265

@1@ can only be called in an event trigger function

[Description]

The function `pg_event_trigger_ddl_commands()` can only be called in a event trigger function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.61 17267

aggregates cannot accept set arguments

[Description]

aggregates cannot accept set arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.62 17268

transform function must not be volatile

[Description]

transform function must not be volatile

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.63 17269

transform function must not be an aggregate function

[Description]

transform function must not be an aggregate function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.64 17270

transform function must not be a window function

[Description]

transform function must not be a window function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.65 17271

transform function must not return a set

[Description]

transform function must not return a set

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.66 17272

transform function must take one argument

[Description]

transform function must take one argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.67 17273

first argument of transform function must be type @1@

[Description]

first argument of transform function must be type internal

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.68 17274

data type @1@ is a pseudo-type

[Description]

data type referenced is a pseudo-type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.69 17275

data type @1@ is a domain

[Description]

data type is a domain

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.70 17276

return data type of FROM SQL function must be @1@

[Description]

return data type of FROM SQL function must be internal

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.71 17277

return data type of TO SQL function must be the transform data type

[Description]

return data type of TO SQL function must be the transform data type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.72 17278

transform for type @1@ language "@2@" already exists

[Description]

transform for type language already exists

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.73 17279

transform for type @1@ language "@2@" does not exist

[Description]

transform for type language does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.74 17280

operator class "@1@" does not exist for access method "@2@"

[Description]

operator class does not exist for access method

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.75 17281

CONCURRENTLY cannot be used when the materialized view is not populated

[Description]

CONCURRENTLY cannot be used when the materialized view is not populated

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.76 17282

CONCURRENTLY and WITH NO DATA options cannot be used together

[Description]

CONCURRENTLY and WITH NO DATA options cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.77 17283

new data for materialized view "@1@" contains duplicate rows without any null columns

[Description]

new data for materialized view contains duplicate rows without any null columns

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.78 17284

WITH CHECK cannot be applied to SELECT or DELETE

[Description]

WITH CHECK cannot be applied to SELECT or DELETE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.79 17285

only WITH CHECK expression allowed for INSERT

[Description]

only WITH CHECK expression allowed for INSERT

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.80 17286

policy "@1@" for table "@2@" already exists

[Description]

policy attempted to create for table already exists

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.81 17287

policy "@1@" for table "@2@" does not exist

[Description]

Policy being attempted to alter does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.82 17288

only USING expression allowed for SELECT, DELETE

[Description]

only USING expression allowed for SELECT, DELETE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.83 17289

referenced relation "@1@" is not a table or foreign table

[Description]

Relation referenced by CREATE OR ALTER TABLE is not a regular table or foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.84 17290

materialized view "@1@" does not exist

[Description]

materialized view \"%s\" does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.85 17291

Use DROP MATERIALIZED VIEW to remove a materialized view.

[Description]

Use DROP MATERIALIZED VIEW to remove a materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.86 17293

inherited constraint "@1@" must be renamed in child tables too

[Description]

inherited constraint must be renamed in child tables too

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.87 17294

cannot rename inherited constraint "@1@"

[Description]

cannot rename inherited constraint

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.88 17295

cannot rewrite table "@1@" used as a catalog table

[Description]

cannot rewrite table used as a catalog table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.89 17296

"@1@" is not a table, view, or foreign table

[Description]

this is not a table, view, or foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.90 17297

"@1@" is not a table, view, materialized view, or index

[Description]

object referenced is not a table, view, materialized view, or index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.91 17298

"@1@" is not a table, materialized view, or foreign table

[Description]

object referenced is not of a type table, materialized view, or foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.69.92 17299

constraint "@1@" of relation "@2@" is not a foreign key or check constraint

[Description]

constraint of relation is not a foreign key or check constraint

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70 Message Numbers Beginning with 17300

2.70.1 17301

"@1@" is not a table, view, sequence, or foreign table

[Description]

object type is not a table, view, sequence, or foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.2 17302

WITH CHECK OPTION is supported only on automatically updatable views

[Description]

WITH CHECK OPTION is supported only on automatically updatable views

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.3 17303

only tables, indexes, and materialized views exist in tablespaces

[Description]

only tables, indexes, and materialized views exist in tablespaces

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.4 17304

cannot move relations in to or out of pg_global tablespace

[Description]

cannot move relations in to or out of pg_global tablespace

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.5 17305

aborting because lock on relation "@1@.@2@" is not available

[Description]

aborting because lock on relation is not available

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.6 17306

no matching relations in tablespace "@1@" found

[Description]

no matching relations in tablespace found

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.7 17307

invalid page in block @1@ of relation @2@

[Description]

invalid page in block of relation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.8 17308

cannot use non-unique index "@1@" as replica identity

[Description]

cannot use non-unique index as replica identity

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.9 17309

cannot use non-immediate index "@1@" as replica identity

[Description]

cannot use non-immediate index as replica identity

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.10 17310

cannot use expression index "@1@" as replica identity

[Description]

cannot use expression index as replica identity

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.11 17311

cannot use partial index "@1@" as replica identity

[Description]

cannot use partial index \"%s\" as replica identity

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.12 17312

cannot use invalid index "@1@" as replica identity

[Description]

cannot use invalid index as replica identity

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.13 17313

index "@1@" cannot be used as replica identity because column "@2@" is nullable

[Description]

index \"%s\" cannot be used as replica identity because column \"%s\" is nullable

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.14 17319

could not create an encrypted tablespace because the keystore is not open

[Description]

could not create an encrypted tablespace because the keystore is not open. Open the existing keystore, or set the master encryption key to create and open a new keystore

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.15 17321

tablespace encryption algorithm option cannot be changed

[Description]

tablespace encryption algorithm option cannot be changed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.16 17323

Foreign tables cannot have INSTEAD OF triggers.

[Description]

Foreign tables cannot have INSTEAD OF triggers.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.17 17326

tuple to be updated was already modified by an operation triggered by the current command

[Description]

tuple to be updated was already modified by an operation triggered by the current command. Consider using an AFTER trigger instead of a BEFORE trigger to propagate changes to other rows

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.18 17327

function @1@ should return type @2@

[Description]

function should return an acceptable type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.19 17328

check constraints for domains cannot be marked NO INHERIT

[Description]

check constraints for domains cannot be marked NO INHERIT

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.20 17329

range subtype cannot be @1 @

[Description]

range subtype cannot be of psuedo type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.21 17330

range canonical function @1 @ must return range type

[Description]

range canonical function must return range type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.22 17331

pg_type array OID value not set when in binary upgrade mode

[Description]

pg_type array OID value not set when in binary upgrade mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.23 17332

constraint "@1@" of domain "@2@" is not a check constraint

[Description]

constraint of domain is not a check constraint

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.24 17333

constraint "@1@" for domain "@2@" already exists

[Description]

constraint for domain already exists

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.25 17334

must be superuser to change bypassrls attribute

[Description]

must be superuser to change bypassrls attribute

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.26 17335

pg_authid OID value not set when in binary upgrade mode

[Description]

pg_authid OID value not set when in binary upgrade mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.27 17336

must be superuser to alter settings globally

[Description]

must be superuser to alter settings globally

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.28 17338

@1@ cannot be executed from VACUUM or ANALYZE

[Description]

commands VACUUM or ANALYZE cannot be executed from VACUUM or ANALYZE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.29 17339

invalid value for "check_option" option

[Description]

invalid value for "check_option" option. Valid values are "local" and "cascaded".

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.30 17340

ON CONFLICT does not support deferrable unique constraints/exclusion constraints as arbiters

[Description]

ON CONFLICT does not support deferrable unique constraints/exclusion constraints as arbiters

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.31 17341

cannot change materialized view "@1@"

[Description]

cannot change materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.32 17342

cannot insert into foreign table "@1@"

[Description]

cannot insert into foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.33 17343

foreign table "@1@" does not allow inserts

[Description]

foreign table \"%s\" does not allow inserts

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.34 17344

cannot update foreign table "@1@"

[Description]

cannot update foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.35 17345

foreign table "@1@" does not allow updates

[Description]

foreign table does not allow updates

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.36 17346

cannot delete from foreign table "@1@"

[Description]

cannot delete from foreign table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.37 17347

foreign table "@1@" does not allow deletes

[Description]

foreign table does not allow deletes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.38 17348

cannot lock rows in materialized view "@1@"

[Description]

cannot lock rows in materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.39 17349

new row violates check option for view "@1@"

[Description]

new row violates check option for view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.40 17350

new row violates row-level security policy "@1@" for table "@2@"

[Description]

new row violates row-level security policy for table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.41 17351

new row violates row-level security policy for table "@1@"

[Description]

new row violates row-level security policy for table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.42 17352

new row violates row-level security policy "@1@" (USING expression) for table "@2@"

[Description]

new row violates row-level security policy (USING expression) for table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.43 17353

new row violates row-level security policy (USING expression) for table "@1@"

[Description]

new row violates row-level security policy (USING expression) for table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.44 17354

WHERE CURRENT OF is not supported for this table type

[Description]

WHERE CURRENT OF is not supported for this table type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.45 17355

materialized view "@1@" has not been populated

[Description]

materialized view has not been populated. Use the REFRESH MATERIALIZED VIEW command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.46 17356

custom scan "@1@" does not support MarkPos

[Description]

custom-scan does not support MarkPos

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.47 17357

lossy distance functions are not supported in index-only scans

[Description]

lossy distance functions are not supported in index-only scans

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.48 17358

ON CONFLICT DO UPDATE command cannot affect row a second time

[Description]

ON CONFLICT DO UPDATE command cannot affect row a second time. Ensure that no rows proposed for insertion within the same command have duplicate constrained values

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.49 17359

TABLESAMPLE parameter cannot be null

[Description]

TABLESAMPLE parameter cannot be null

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.50 17360

TABLESAMPLE REPEATABLE parameter cannot be null

[Description]

TABLESAMPLE REPEATABLE parameter cannot be null

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.51 17361

moving-aggregate transition function must not return null

[Description]

moving-aggregate transition function must not return null

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.52 17362

could not open configuration directory "@1@": @2@

[Description]

could not open configuration directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.53 17363

could not initialize LDAP: @1@

[Description]

could not initialize LDAP

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.54 17364

LDAP user "@1@" does not exist

[Description]

LDAP user does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.55 17365

LDAP user "@1@" is not unique

[Description]

LDAP user is not unique

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.56 17367

lo_lseek result out of range for large-object descriptor @1@

[Description]

lo_lseek result out of range for large-object descriptor %d

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.57 17368

lo_tell result out of range for large-object descriptor @1@

[Description]

lo_tell result out of range for large-object descriptor

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.58 17369

large object read request is too large

[Description]

large object read request is too large

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.59 17370

ECDH: unrecognized curve name: @1@

[Description]

ECDH: unrecognized curve name

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.60 17371

ECDH: could not create key

[Description]

ECDH: could not create key

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.61 17372

authentication file line too long

[Description]

authentication file line too long

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.62 17373

could not parse LDAP URL "@1@": @2@

[Description]

could not parse LDAP URL

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.63 17374

unsupported LDAP URL scheme: @1@

[Description]

unsupported LDAP URL scheme

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.64 17375

filters not supported in LDAP URLs

[Description]

filters not supported in LDAP URLs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.65 17376

LDAP URLs not supported on this platform

[Description]

LDAP URLs not supported on this platform

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.66 17377

unrecognized address family @1@

[Description]

unrecognized address family

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.67 17378

there is no client connection

[Description]

there is no client connection

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.68 17379

terminating connection because protocol synchronization was lost

[Description]

terminating connection because protocol sync was lost

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.69 17381

@1@ cannot be applied to the nullable side of an outer join

[Description]

SQL row locking clause cannot be applied to the nullable side of an outer join

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.70 17384

constraint in ON CONFLICT clause has no associated index

[Description]

constraint in ON CONFLICT clause has no associated index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.71 17385

ON CONFLICT DO UPDATE not supported with exclusion constraints

[Description]

ON CONFLICT DO UPDATE not supported with exclusion constraints

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.72 17386

there is no unique or exclusion constraint matching the ON CONFLICT specification

[Description]

there is no unique or exclusion constraint matching the ON CONFLICT specification

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.73 17387

@1@ cannot be applied to VALUES

[Description]

SQL row locking cannot be applied to VALUES

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.74 17388

RETURNING must have at least one column

[Description]

RETURNING must have at least one column

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.75 17389

DECLARE SCROLL CURSOR ... @1@ is not supported

[Description]

DECLARE SCROLL CURSOR ... is not supported

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.76 17390

materialized views must not use data-modifying statements in WITH

[Description]

materialized views must not use data-modifying statements in WITH

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.77 17391

materialized views must not use temporary tables or views

[Description]

materialized views must not use temporary tables or views

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.78 17392

materialized views may not be defined using bound parameters

[Description]

materialized views may not be defined using bound parameters

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.79 17393

materialized views cannot be unlogged

[Description]

materialized views cannot be UNLOGGED

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.80 17394

@1@ is not allowed with DISTINCT clause

[Description]

SQL row locking clause such as "FOR UPDATE" is not allowed with DISTINCT clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.81 17395

@1@ is not allowed with GROUP BY clause

[Description]

SQL row locking clause such as "FOR UPDATE" is not allowed with GROUP BY clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.82 17396

@1@ is not allowed with HAVING clause

[Description]

SQL row locking clause such as "FOR UPDATE" is not allowed with HAVING clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.83 17397

@1@ is not allowed with aggregate functions

[Description]

%s is not allowed with aggregate functions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.84 17398

@1@ is not allowed with window functions

[Description]

SQL row locking clause such as "FOR UPDATE" is not allowed with window functions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.70.85 17399

@1@ is not allowed with set-returning functions in the target list

[Description]

SQL row locking clause such as "FOR UPDATE" is not allowed with set-returning functions in the target list

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71 Message Numbers Beginning with 17400

2.71.1 17400

@1@ must specify unqualified relation names

[Description]

SQL row locking clause such as "FOR UPDATE" must specify unqualified relation names

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.2 17401

@1@ cannot be applied to a join

[Description]

SQL row locking clause such as "FOR UPDATE" cannot be applied to a join

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.3 17402

@1@ cannot be applied to a function

[Description]

SQL row locking clause such as "FOR UPDATE" cannot be applied to a function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.4 17403

@1@ cannot be applied to a WITH query

[Description]

SQL row locking clause such as "FOR UPDATE" cannot be applied to a WITH query

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.5 17404

relation "@1@" in "@2@" clause not found in FROM clause

[Description]

Relation referenced by the SQL in FROM clause is not found

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.6 17405

outer join operator (+) cannot be used with joined table

[Description]

outer join operator (+) cannot be used with joined table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.7 17406

outer join operator (+) cannot be used with subquery

[Description]

outer join operator (+) cannot be used with subquery

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.8 17407

outer join operator (+) is not allowed in operand OR or IN predicate

[Description]

outer join operator (+) is not allowed in operand OR or IN predicate

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.9 17408

incorrect specification in outer join operator(+)

[Description]

incorrect specification in outer join operator(+)

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.10 17409

outer join operator(+) cannot refer to other relations of same query level

[Description]

outer join operator(+) cannot refer to other relations of same query level

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.11 17410

a table may be outer joined to at most one other table

[Description]

a table may be outer joined to at most one other table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.12 17411

multiple outer join operators (+) cannot be specified for one table

[Description]

multiple outer join operators (+) cannot be specified for one table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.13 17412

two tables cannot be outer-joined to each other

[Description]

two tables cannot be outer-joined to each other

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.14 17413

invalid combination of outer join operator (+) and logical operators

[Description]

invalid combination of outer join operator (+) and logical operators

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.15 17414

GROUPING must have fewer than 32 arguments

[Description]

GROUPING must have fewer than 32 arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.16 17415

aggregate functions are not allowed in JOIN conditions

[Description]

aggregate functions are not allowed in JOIN conditions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.17 17416

grouping operations are not allowed in JOIN conditions

[Description]

grouping operations are not allowed in JOIN conditions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.18 17417

aggregate functions are not allowed in FROM clause of their own query level

[Description]

aggregate functions are not allowed in FROM clause of their own query level

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.19 17418

grouping operations are not allowed in FROM clause of their own query level

[Description]

grouping operations are not allowed in FROM clause of their own query level

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.20 17419

aggregate functions are not allowed in functions in FROM

[Description]

aggregate functions are not allowed in functions in FROM

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.21 17420

grouping operations are not allowed in functions in FROM

[Description]

grouping operations are not allowed in functions in FROM

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.22 17421

aggregate functions are not allowed in policy expressions

[Description]

aggregate functions are not allowed in policy expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.23 17422

grouping operations are not allowed in policy expressions

[Description]

grouping operations are not allowed in policy expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.24 17423

aggregate functions are not allowed in window RANGE

[Description]

aggregate functions are not allowed in window RANGE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.25 17424

grouping operations are not allowed in window RANGE

[Description]

grouping operations are not allowed in window RANGE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.26 17425

aggregate functions are not allowed in window ROWS

[Description]

aggregate functions are not allowed in window ROWS

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.27 17426

grouping operations are not allowed in window ROWS

[Description]

grouping operations are not allowed in window ROWS

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.28 17427

grouping operations are not allowed in check constraints

[Description]

grouping operations are not allowed in check constraints

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.29 17428

grouping operations are not allowed in DEFAULT expressions

[Description]

grouping operations are not allowed in DEFAULT expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.30 17429

grouping operations are not allowed in index expressions

[Description]

grouping operations are not allowed in index expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.31 17430

grouping operations are not allowed in index predicates

[Description]

grouping operations are not allowed in index predicates

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.32 17431

grouping operations are not allowed in transform expressions

[Description]

grouping operations are not allowed in transform expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.33 17432

grouping operations are not allowed in EXECUTE parameters

[Description]

grouping operations are not allowed in EXECUTE parameters

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.34 17433

grouping operations are not allowed in trigger WHEN conditions

[Description]

grouping operations are not allowed in trigger WHEN conditions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.35 17434

grouping operations are not allowed in @1@

[Description]

grouping operations are not allowed in the SQL constructs like GROUP BY

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.36 17435

outer-level aggregate cannot contain a lower-level variable in its direct arguments

[Description]

outer-level aggregate cannot contain a lower-level variable in its direct arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.37 17436

window functions are not allowed in functions in FROM

[Description]

window functions are not allowed in functions in FROM

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.38 17437

window functions are not allowed in policy expressions

[Description]

window functions are not allowed in policy expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.39 17438

window functions are not allowed in window definitions

[Description]

window functions are not allowed in window definitions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.40 17439

window functions are not allowed in DEFAULT expressions

[Description]

window functions are not allowed in DEFAULT expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.41 17440

window functions are not allowed in index expressions

[Description]

window functions are not allowed in index expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.42 17441

window functions are not allowed in index predicates

[Description]

window functions are not allowed in index predicates

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.43 17442

window functions are not allowed in transform expressions

[Description]

window functions are not allowed in transform expressions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.44 17443

window functions are not allowed in @1@

[Description]

window functions are not allowed in the SQL constructs like GROUP BY

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.45 17444

aggregate functions are not allowed in a recursive query's recursive term

[Description]

aggregate functions are not allowed in a recursive query's recursive term

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.46 17445

Direct arguments of an ordered-set aggregate must use only grouped columns.

[Description]

Direct arguments of an ordered-set aggregate must use only grouped columns

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.47 17446

arguments to GROUPING must be grouping expressions of the associated query level

[Description]

arguments to GROUPING must be grouping expressions of the associated query level

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.48 17447

multiple column definition lists are not allowed for the same function

[Description]

multiple column definition lists are not allowed for the same function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.49 17448

ROWS FROM() with multiple functions cannot have a column definition list

[Description]

ROWS FROM() with multiple functions cannot have a column definition list. Put a separate column definition list for each function inside ROWS FROM()

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.50 17449

WITH ORDINALITY cannot be used with a column definition list

[Description]

WITH ORDINALITY cannot be used with a column definition list. Put the column definition list inside ROWS FROM().

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.51 17450

tablesample method @1@ does not exist

[Description]

tablesample method does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.52 17452

tablesample method @1@ does not support REPEATABLE

[Description]

tablesample method does not support REPEATABLE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.53 17453

TABLESAMPLE clause can only be applied to tables and materialized views

[Description]

TABLESAMPLE clause can only be applied to tables and materialized views

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.54 17454

CUBE is limited to 12 elements

[Description]

CUBE is limited to 12 elements

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.55 17455

Omit the parentheses in this OVER clause.

[Description]

Omit the parentheses in this OVER clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.56 17456

an aggregate with DISTINCT must have at least one argument

[Description]

an aggregate with DISTINCT must have at least one argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.57 17457

SELECT DISTINCT must have at least one column

[Description]

SELECT DISTINCT must have at least one column

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.58 17458

ASC/DESC is not allowed in ON CONFLICT clause

[Description]

ASC/DESC is not allowed in ON CONFLICT clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.59 17459

NULLS FIRST/LAST is not allowed in ON CONFLICT clause

[Description]

NULLS FIRST/LAST is not allowed in ON CONFLICT clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.60 17460

ON CONFLICT DO UPDATE requires inference specification or constraint name

[Description]

ON CONFLICT DO UPDATE requires inference specification or constraint name

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.61 17461

ON CONFLICT is not supported with system catalog tables

[Description]

ON CONFLICT is not supported with system catalog tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.62 17462

ON CONFLICT is not supported on table "@1@" used as a catalog table

[Description]

ON CONFLICT is not supported on table used as a catalog table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.63 17463

argument of @1@ must be type @2@, not type @3@

[Description]

argument of the SQL construct must be of acceptable type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.64 17464

argument declared @1@ is not a range type but type @2@

[Description]

argument declared \"anyrange\" is not a range type but type %s

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.65 17465

column @1@.@2@ does not exist

[Description]

column does not exist.Re-check the column name referenced.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.66 17466

syntax error at or near "(+)"

[Description]

syntax error at or near "(+)"

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.67 17467

could not find element type for data type @1@

[Description]

could not find element type for data type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.68 17468

WITHIN GROUP specified, but @1@ is not an aggregate function

[Description]

WITHIN GROUP specified, but the function is not an aggregate function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.69 17469

FILTER specified, but @1@ is not an aggregate function

[Description]

FILTER specified, but the function is not an aggregate function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.70 17470

WITHIN GROUP is required for ordered-set aggregate @1@

[Description]

WITHIN GROUP is required for ordered-set aggregate

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.71 17471

OVER is not supported for ordered-set aggregate @1@

[Description]

OVER is not supported for ordered-set aggregate

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.72 17472

@1@ is not an ordered-set aggregate, so it cannot have WITHIN GROUP

[Description]

The function is not an ordered-set aggregate, so it cannot have WITHIN GROUP

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.73 17476

VARIADIC argument must be an array

[Description]

VARIADIC argument must be an array

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.74 17479

system column "@1@" reference in check constraint is invalid

[Description]

system column reference in check constraint is invalid

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.75 17480

primary key constraints are not supported on foreign tables

[Description]

primary key constraints are not supported on foreign tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.76 17481

unique constraints are not supported on foreign tables

[Description]

unique constraints are not supported on foreign tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.77 17482

foreign key constraints are not supported on foreign tables

[Description]

foreign key constraints are not supported on foreign tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.78 17483

exclusion constraints are not supported on foreign tables

[Description]

exclusion constraints are not supported on foreign tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.79 17484

LIKE is not supported for creating foreign tables

[Description]

LIKE is not supported for creating foreign tables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.80 17485

rules on materialized views are not supported

[Description]

rules on materialized views are not supported

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.81 17486

@1@ failed: @2@

[Description]

function call for poll() failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.82 17488

could not map anonymous shared memory: @1@

[Description]

could not map anonymous shared memory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.83 17489

huge pages not supported on this platform

[Description]

huge pages not supported on this platform

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.84 17490

could not create shared memory segment: error code @1@

[Description]

could not create shared memory segment

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.85 17491

@1@: invalid argument: "@2@"

[Description]

invalid argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.86 17492

WAL archival cannot be enabled when wal_level is "minimal"

[Description]

WAL archival cannot be enabled when wal_level is "minimal"

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.87 17493

postmaster became multithreaded during startup

[Description]

postmaster became multithreaded during startup

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.88 17494

data directory "@1@" does not exist

[Description]

data directory does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.89 17495

performing immediate shutdown because data directory lock file is invalid

[Description]

performing immediate shutdown because data directory lock file is invalid

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.90 17497

invalid processing mode in background worker

[Description]

invalid processing mode in background worker

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.91 17498

could not create inherited socket: error code @1@

[Description]

could not create inherited socket

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.71.92 17499

could not open backend variables file "@1@": @2@

[Description]

could not open backend variables file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72 Message Numbers Beginning with 17500

2.72.1 17500

could not read from backend variables file "@1@": @2@

[Description]

could not read from backend variables file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.2 17501

could not map view of backend variables: error code @1@

[Description]

could not map view of backend variables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.3 17502

could not unmap view of backend variables: error code @1@

[Description]

could not unmap view of backend variables

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.4 17503

could not open file "@1@" : @2@

[Description]

could not open WAL file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.5 17504

could not write to log segment @1@ at offset @2@, length @3@: @4@

[Description]

could not write to log segment

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.6 17507

invalid timeline @1@

[Description]

invalid timeline

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.7 17508

could not stat file "@1@": @2@

[Description]

could not stat control file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.8 17509

could not find WAL file "@1@"

[Description]

could not find WAL file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.9 17510

could not stat file or directory "@1@": @2@

[Description]

could not stat file or directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.10 17511

file name too long for tar format: "@1@"

[Description]

file name too long for tar format

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.11 17512

could not send end-of-streaming message to primary: @1@

[Description]

could not send end-of-streaming message to primary

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.12 17513

error reading result of streaming command: @1@

[Description]

error reading result of streaming command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.13 17514

unexpected result after CommandComplete: @1@

[Description]

unexpected result after CommandComplete

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.14 17515

could not receive timeline history file from the primary server: @1@

[Description]

could not receive timeline history file from the primary server

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.15 17516

logical decoding requires wal_level >= logical

[Description]

logical decoding requires wal_level >= logical

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.16 17517

logical decoding requires a database connection

[Description]

logical decoding requires a database connection

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.17 17518

logical decoding cannot be used while in recovery

[Description]

logical decoding cannot be used while in recovery

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.18 17519

cannot use physical replication slot for logical decoding

[Description]

cannot use physical replication slot for logical decoding

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.19 17520

replication slot "@1@" was not created in this database

[Description]

replication slot was not created in this database

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.20 17521

cannot create logical replication slot in transaction that has performed writes

[Description]

cannot create logical replication slot in transaction that has performed writes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.21 17522

must be superuser or replication role to use replication slots

[Description]

must be superuser or replication role to use replication slots

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.22 17523

array must be one-dimensional

[Description]

The provided input array must be one-dimensional

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.23 17524

array must not contain nulls

[Description]

The provided input array must not contain nulls

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.24 17525

array must have even number of elements

[Description]

The provided input array must have even number of elements

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.25 17526

logical decoding output plugin "@1@" produces binary output, but function "@2@" expects textual data

[Description]

logical decoding output plugin produces binary output, but function expects textual data

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.26 17527

only superusers can query or manipulate replication origins

[Description]

only superusers can query or manipulate replication origins

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.27 17528

cannot query or manipulate replication origin when max_replication_slots = 0

[Description]

cannot query or manipulate replication origin when max_replication_slots = 0

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.28 17529

cannot manipulate replication origins during recovery

[Description]

cannot manipulate replication origins during recovery

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.29 17530

could not find free replication origin OID

[Description]

could not find free replication origin OID

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.30 17531

could not drop replication origin with OID @1@, in use by PID @2@

[Description]

could not drop replication origin with OID as it is in use by a process

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.31 17532

replication checkpoint has wrong magic @1@ instead of @2@

[Description]

replication checkpoint has wrong magic number instead of a correct magic number provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.32 17533

could not read file "@1@": read @2@ of @3@

[Description]

could not read file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.33 17534

could not find free replication state, increase max_replication_slots

[Description]

could not find free replication state, increase max_replication_slots

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.34 17535

replication slot checkpoint has wrong checksum @1@, expected @2@

[Description]

replication slot checkpoint has wrong checksum value, expected value is shown

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.35 17536

replication origin with OID @1@ is already active for PID @2@

[Description]

replication origin with OID is already active for process with PID

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.36 17537

could not find free replication state slot for replication origin with OID @1@

[Description]

could not find free replication state slot for replication origin with OID %u

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.37 17539

no replication origin is configured

[Description]

no replication origin is configured

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.38 17540

could not write to data file for XID @1@: @2@

[Description]

could not write to data file for XID

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.39 17541

could not read from reorderbuffer spill file: @1@

[Description]

could not read from reorderbuffer spill file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.40 17542

could not read from reorderbuffer spill file: read @1@ instead of @2@ bytes

[Description]

could not read from reorderbuffer spill file: read instead of bytes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.41 17543

could not read from file "@1@": read @2@ instead of @3@ bytes

[Description]

could not read from file : read some bytes instead of actual bytes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.42 17545

snapbuild state file "@1@" has wrong magic number: @2@ instead of @3@

[Description]

snapbuild state file has wrong magic number: instead of actual magic number

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.43 17546

snapbuild state file "@1@" has unsupported version: @2@ instead of @3@

[Description]

snapbuild state file has unsupported version: instead of actual version number

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.44 17547

checksum mismatch for snapbuild state file "@1@": is @2@, should be @3@

[Description]

checksum mismatch for snapbuild state file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.45 17548

replication slot name "@1@" is too short

[Description]

replication slot name is too short

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.46 17549

replication slot name "@1@" is too long

[Description]

replication slot name \"%s\" is too long

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.47 17550

replication slot name "@1@" contains invalid character

[Description]

replication slot name \"%s\" contains invalid character

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.48 17551

replication slot "@1@" already exists

[Description]

replication slot already exists invalid character

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.49 17552

all replication slots are in use

[Description]

all replication slots are in use character

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.50 17553

replication slot "@1@" does not exist

[Description]

replication slot does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.51 17554

replication slot "@1@" is active for PID @2@

[Description]

replication slot \"%s\" is already active for PID

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.52 17555

could not remove directory "@1@"

[Description]

could not remove directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.53 17556

replication slots can only be used if max_replication_slots > 0

[Description]

replication slots can only be used if max_replication_slots > 0

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.54 17557

replication slots can only be used if wal_level >= replica

[Description]

replication slots can only be used if wal_level >= archive

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.55 17559

replication slot file "@1@" has wrong magic number: @2@ instead of @3@

[Description]

replication slot file has wrong magic number

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.56 17560

replication slot file "@1@" has unsupported version @2@

[Description]

replication slot file has unsupported version

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.57 17561

replication slot file "@1@" has corrupted length @2@

[Description]

replication slot file has corrupted length

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.58 17562

checksum mismatch for replication slot file "@1@": is @2@, should be @3@

[Description]

checksum mismatch for replication slot file \"%s\": is %u, should be %u

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.59 17563

too many replication slots active before shutdown

[Description]

too many replication slots active before shutdown

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.60 17564

terminating walreceiver due to timeout

[Description]

terminating walreceiver due to timeout

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.61 17566

could not seek to beginning of file "@1@": @2@

[Description]

could not seek to beginning of file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.62 17567

cannot use a logical replication slot for physical replication

[Description]

cannot use a logical replication slot for physical replication

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.63 17568

requested starting point @1@/@2@ on timeline @3@ is not in this server's history

[Description]

While streaming WALs during standby recovery. Requested starting point on timeline is not in this server's history

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.64 17570

could not convert table "@1@" to a view because it has row security enabled

[Description]

could not convert table to a view because it has row security enabled

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.65 17571

could not convert table "@1@" to a view because it has row security policies

[Description]

could not convert table to a view because it has row security policies

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.66 17573

renaming an ON SELECT rule is not allowed

[Description]

renaming an ON SELECT rule is not allowed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.67 17574

infinite recursion detected in policy for relation "@1@"

[Description]

infinite recursion detected in policy for relation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.68 17575

cannot insert into column "@1@" of view "@2@"

[Description]

cannot insert into column of view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.69 17576

cannot update column "@1@" of view "@2@"

[Description]

cannot update column of view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.70 17577

INSERT with ON CONFLICT clause cannot be used with table that has INSERT or UPDATE rules

[Description]

INSERT with ON CONFLICT clause cannot be used with table that has INSERT or UPDATE rules

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.71 17578

NEW variables in ON UPDATE rules cannot reference columns that are part of a multiple assignment in the subject UPDATE command

[Description]

NEW variables in ON UPDATE rules cannot reference columns that are part of a multiple assignment in the subject UPDATE command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.72 17579

exceeded maxAllocatedDescs (@1@) while trying to execute command "@2@"

[Description]

exceeded maxAllocatedDescs while trying to execute command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.73 17580

could not duplicate handle for "@1@" : @2@

[Description]

could not duplicate handle for the segment

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.74 17581

invalid flags for opening a large object: @1@

[Description]

invalid flags for opening a large object

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.75 17582

invalid whence setting: @1@

[Description]

invalid whence setting

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.76 17583

invalid large object write request size: @1@

[Description]

invalid large object write request size

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.77 17584

canceling statement due to lock timeout

[Description]

canceling statement due to lock timeout. Check the process holding the lock.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.78 17585

@1@: invalid command-line argument: @2@

[Description]

invalid command-line argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.79 17586

fastpath function calls not supported in a replication connection

[Description]

fastpath function calls not supported in a replication connection

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.80 17587

extended query protocol not supported in a replication connection

[Description]

extended query protocol not supported in a replication connection

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.81 17588

cannot execute @1@ during a parallel operation

[Description]

cannot execute SQL commands such as CREATE during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.82 17589

too many lexemes in thesaurus entry

[Description]

too many lexemes in thesaurus entry

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.83 17590

input data type is not an array

[Description]

input data type is not an array

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.84 17591

searching for elements in multidimensional arrays is not supported

[Description]

searching for elements in multidimensional arrays is not supported

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.85 17593

data type @1@ is not an array type

[Description]

data type is not an array type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.86 17594

cannot accumulate null arrays

[Description]

cannot accumulate null arrays

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.87 17595

cannot accumulate empty arrays

[Description]

cannot accumulate empty arrays

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.88 17596

cannot accumulate arrays of different dimensionality

[Description]

cannot accumulate arrays of different dimensionality

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.89 17597

removing elements from multidimensional arrays is not supported

[Description]

removing elements from multidimensional arrays is not supported

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.90 17598

thresholds must be one-dimensional array

[Description]

thresholds must be one-dimensional array

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.72.91 17599

thresholds array must not contain NULLs

[Description]

thresholds array must not contain NULLs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73 Message Numbers Beginning with 17600

2.73.1 17600

date field value out of range: @1 @-@2@-@3@

[Description]

date field value out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.2 17601

date out of range: @1 @-@2@-@3@

[Description]

date out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.3 17602

time field value out of range: @1 @: @2@: @3@

[Description]

time field value out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.4 17608

localized string format value too long

[Description]

localized string format value too long

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.5 17610

invalid line specification: A and B cannot both be zero

[Description]

invalid line specification: A and B cannot both be zero

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.6 17611

function "close_sl" not implemented

[Description]

function \"close_sl\" not implemented

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.7 17612

invalid input syntax for type @1@

[Description]

invalid input syntax for type json

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.8 17613

"\u" must be followed by four hexadecimal digits.

[Description]

must be followed by four hexadecimal digits. Check the syntax

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.9 17614

unsupported Unicode escape sequence

[Description]

unsupported Unicode escape sequence

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.10 17615

key value must be scalar, not array, composite, or json

[Description]

key value must be scalar, not array, composite, or json

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.11 17616

could not determine data type for argument @1@

[Description]

could not determine data type for argument 1

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.12 17617

could not determine data type for argument @1@

[Description]

could not determine data type for argument 2

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.13 17618

field name must not be null

[Description]

field name must not be null

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.14 17619

argument list must have even number of elements

[Description]

argument list must have even number of elements

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.15 17620

could not determine data type for argument @1@

[Description]

could not determine data type for argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.16 17621

argument @1 @ cannot be null

[Description]

argument cannot be null

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.17 17622

array must have two columns

[Description]

array must have two columns

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.18 17623

null value not allowed for object key

[Description]

null value not allowed for object key

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.19 17624

mismatched array dimensions

[Description]

mismatched array dimensions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.20 17625

string too long to represent as jsonb string

[Description]

string too long to represent as jsonb string

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.21 17626

argument list must have even number of elements

[Description]

invalid number or arguments: object must be matched key value pairs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.22 17629

object keys must be strings

[Description]

object keys must be strings

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.23 17630

number of jsonb object pairs exceeds the maximum allowed (@1@)

[Description]

number of jsonb object pairs exceeds the maximum allowed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.24 17631

number of jsonb array elements exceeds the maximum allowed (@1@)

[Description]

number of jsonb array elements exceeds the maximum allowed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.25 17632

total size of jsonb array elements exceeds the maximum of @1@ bytes

[Description]

total size of jsonb array elements exceeds the maximum number of bytes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.26 17633

total size of jsonb object elements exceeds the maximum of @1@ bytes

[Description]

total size of jsonb object elements exceeds the maximum number of bytes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.27 17634

cannot call @1@ on a scalar

[Description]

cannot call this function on a scalar input

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.28 17635

cannot call @1@ on an array

[Description]

cannot call this function on an array input

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.29 17636

cannot get array length of a scalar

[Description]

cannot get array length of a scalar

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.30 17637

cannot get array length of a non-array

[Description]

cannot get array length of a non-array

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.31 17639

function returning record called in context that cannot accept type record

[Description]

function returning record called in context that cannot accept type record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.32 17640

cannot deconstruct an array as an object

[Description]

cannot deconstruct an array as an object

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.33 17641

cannot deconstruct a scalar

[Description]

cannot deconstruct a scalar

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.34 17642

cannot extract elements from a scalar

[Description]

cannot extract elements from a scalar

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.35 17643

cannot extract elements from an object

[Description]

cannot extract elements from an object

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.36 17644

cannot call @1@ on a non-array

[Description]

cannot call this function on a non-array input

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.37 17645

first argument of @1@ must be a row type

[Description]

first argument of this function must be a row type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.38 17646

argument of @1@ must be an array of objects

[Description]

argument of must be an array of objects

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.39 17647

cannot call @1@ on an object

[Description]

cannot call this function on an object input

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.40 17648

cannot delete from scalar

[Description]

cannot delete from scalar

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.41 17649

cannot delete from object using integer index

[Description]

cannot delete from object using integer subscript

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.42 17650

cannot set path in scalar

[Description]

cannot set path in scalar

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.43 17651

cannot delete path in scalar

[Description]

cannot delete path in scalar

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.44 17652

invalid concatenation of jsonb objects

[Description]

invalid concatenation of jsonb objects

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.45 17659

cannot merge addresses from different families

[Description]

cannot merge addresses from different families

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.46 17660

invalid scale in external "numeric" value

[Description]

invalid scale in external \"numeric\" value

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.47 17661

start value cannot be NaN

[Description]

While generating a numeric series - start value cannot be NaN

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.48 17662

stop value cannot be NaN

[Description]

stop value cannot be NaN

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.49 17663

step size cannot be NaN

[Description]

step size cannot be NaN

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.50 17664

percentile value @1@ is not between 0 and 1

[Description]

percentile value %g is not between 0 and 1

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.51 17665

invalid input syntax for type @1@: "@2@"

[Description]

invalid input syntax for type pg_lsn

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.52 17666

function can only be called when server is in binary upgrade mode

[Description]

function can only be called when server is in binary upgrade mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.53 17672

cannot output a value of type @1@

[Description]

cannot output a value of type pg_ddl_command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.54 17673

malformed range literal: "@1@"

[Description]

malformed range literal. Check the input string format

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.55 17674

invalid input syntax for type @1@: "@2@"

[Description]

invalid input syntax for numeric time zone

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.56 17675

numeric time zone "@1@" out of range

[Description]

numeric time zone out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.57 17676

timestamp out of range: @1@-@2@-@3@ @4@:@5@:@6@

[Description]

timestamp out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.58 17677

interval units "@1@" not supported because months usually have fractional weeks

[Description]

interval units \"%s\" not supported because months usually have fractional weeks

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.59 17678

invalid external txid_snapshot data

[Description]

invalid external txid_snapshot data

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.60 17679

unterminated format() type specifier

[Description]

unterminated format specifier

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.61 17680

number is out of range

[Description]

number is out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.62 17681

width argument position must be ended by "\$"

[Description]

width argument position must be ended by \"\$\"

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.63 17682

type @1@ is not composite

[Description]

type is not composite

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.64 17683

keystore location "@1@" is too long

[Description]

While configuring a keystore, the error is "keystore location mentioned is too long".

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.65 17684

keystore does not exist

[Description]

keystore does not exist. Make sure keystore_location points to the correct location. If the setting is correct, set the master encryption key to create the keystore.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.66 17685

must be superuser to manipulate keystore

[Description]

must be superuser to manipulate keystore

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.67 17686

function "@1@" is not supported by this build

[Description]

function \"%s\" is not supported by this build

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.68 17687

file "@1@" is not a keystore

[Description]

file \"%s\" is not a keystore

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.69 17688

lock file "@1@" is empty

[Description]

lock file is empty. Check if the lockfile is corrupt.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.70 17689

could not access directory "@1@": @2@

[Description]

could not access directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.71 17690

bind_textdomain_codeset failed

[Description]

bind_textdomain_codeset failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.72 17691

invalid value for parameter "@1@": "@2@"

[Description]

parameter \"%s\" requires a numeric value

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.73 17692

cannot set parameters during a parallel operation

[Description]

cannot set parameters during a parallel operation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.74 17693

permission denied to set parameter "@1@"

[Description]

permission denied to set parameter

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.75 17694

must be superuser to execute ALTER SYSTEM command

[Description]

must be superuser to execute ALTER SYSTEM command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.76 17696

parameter "@1@" could not be set

[Description]

parameter could not be set

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.77 17698

could not seek in tuplestore temporary file: @1@

[Description]

could not seek in tuplestore temporary file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.73.78 17699

could not read from tuplestore temporary file: @1@

[Description]

could not read from tuplestore temporary file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74 Message Numbers Beginning with 17700

2.74.1 17700

could not write to tuplestore temporary file: @1@

[Description]

could not write to tuplestore temporary file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.2 17703

user does not exist

[Description]

user does not exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.3 17704

could not open directory "@1@": @2@

[Description]

could not open directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.4 17705

could not read directory "@1@": @2@

[Description]

could not read directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.5 17706

could not stat file "@1@": @2@

[Description]

could not stat file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.6 17707

could not open file "@1@": @2@

[Description]

could not open file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.7 17708

directory name too long

[Description]

directory name too long

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.8 17709

multiple "=" signs in tablespace mapping

[Description]

multiple signs in tablespace mapping

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.9 17710

invalid tablespace mapping format "@1@", must be "OLDDIR=NEWDIR"

[Description]

invalid tablespace mapping format must be OLDDIR=NEWDIR

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.10 17711

old directory is not an absolute path in tablespace mapping: @1@

[Description]

old directory is not an absolute path in tablespace mapping

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.11 17712

new directory is not an absolute path in tablespace mapping: @1@

[Description]

new directory is not an absolute path in tablespace mapping

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.12 17713

transfer rate "@1@" is not a valid value

[Description]

backup transfer rate is not a valid value

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.13 17714

invalid transfer rate "@1@": @2@

[Description]

invalid transfer rate

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.14 17715

transfer rate must be greater than zero

[Description]

transfer rate must be greater than zero

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.15 17716

invalid --max-rate unit: "@1@"

[Description]

invalid --max-rate unit

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.16 17717

transfer rate "@1@" exceeds integer range

[Description]

Transfer rate exceeds integer range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.17 17718

transfer rate "@1@" is out of range

[Description]

Transfer rate is out of range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.18 17719

incompatible server version @1@

[Description]

incompatible server version

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.19 17720

server returned unexpected response to BASE_BACKUP command; got @1@ rows and @2@ fields, expected @3@ rows and @4@ fields

[Description]

server returned unexpected response to BASE_BACKUP command; got rows and fields, expected rows and fields

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.20 17721

invalid wal-method option "@1@", must be "fetch", "stream", or "none"

[Description]

invalid xlog-method option : must be fetch or stream

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.21 17722

WAL directory location can only be specified in plain mode

[Description]

transaction log directory location can only be specified in plain mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.22 17723

could not create symbolic link "@1@": @2@

[Description]

could not create symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.23 17724

symlinks are not supported on this platform

[Description]

symlinks are not supported on this platform

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.24 17725

cannot use --create-slot together with --drop-slot

[Description]

cannot use --create-slot together with --drop-slot

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.25 17726

@1@ needs a slot to be specified using --slot

[Description]

needs a slot to be specified using --slot

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.26 17728

could not open log file "@1@": @2@

[Description]

could not open log file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.27 17729

invalid fsync interval "@1@"

[Description]

invalid fsync interval

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.28 17730

could not parse start position "@1@"

[Description]

could not parse start position

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.29 17731

no slot specified

[Description]

no slot specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.30 17732

no target file specified

[Description]

no target file specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.31 17733

no database specified

[Description]

no database specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.32 17734

at least one action needs to be specified

[Description]

at least one action needs to be specified

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.33 17735

cannot use --create-slot or --start together with --drop-slot

[Description]

cannot use --create-slot or --start together with --drop-slot

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.34 17736

cannot use --create-slot or --drop-slot together with --startpos

[Description]

cannot use --create-slot or --drop-slot together with --startpos

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.35 17737

could not establish database-specific replication connection

[Description]

could not establish database-specific replication connection

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.36 17738

could not create archive status file "@1@": @2@

[Description]

could not create archive status file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.37 17740

server reported unexpected history file name for timeline @1@: @2@

[Description]

server reported unexpected history file name for timeline

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.38 17741

could not create timeline history file "@1@": @2@

[Description]

could not create timeline history file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.39 17742

could not write timeline history file "@1@": @2@

[Description]

could not write timeline history file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.40 17743

could not rename file "@1@" to "@2@": @3@

[Description]

could not rename file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.41 17744

incompatible server version @1@; client does not support streaming from server versions older than @2@

[Description]

incompatible server version; client does not support streaming from server versions older than

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.42 17745

incompatible server version @1@; client does not support streaming from server versions newer than @2@

[Description]

incompatible server version; client does not support streaming from server versions newer than

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.43 17746

starting timeline @1@ is not present in the server

[Description]

starting timeline is not present in the server

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.44 17747

server reported unexpected next timeline @1@, following timeline @2@

[Description]

server reported unexpected next timeline, following timeline

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.45 17748

server stopped streaming timeline @1@ at @2@/@3@, but reported next timeline @4@ to begin at @5@/@6@

[Description]

server stopped streaming a timeline, but reported next timeline

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.46 17749

unexpected result set after end-of-timeline: got @1@ rows and @2@ fields, expected @3@ rows and @4@ fields

[Description]

unexpected result set after end-of-timeline: got unexpected rows and fields

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.47 17750

could not parse next timeline's starting point "@1@"

[Description]

could not parse next timeline's starting point

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.48 17751

invalid socket: @1@

[Description]

socket not open

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.49 17752

could not send copy-end packet: @1@

[Description]

could not send copy-end packet

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.50 17753

could not connect to server: @1@

[Description]

could not connect to server

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.51 17754

could not create replication slot "@1@": got @2@ rows and @3@ fields, expected @4@ rows and @5@ fields

[Description]

could not create replication slot : got unexpected rows and fields

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.52 17755

could not drop replication slot "@1@": got @2@ rows and @3@ fields, expected @4@ rows and @5@ fields

[Description]

could not drop replication slot : got rows and fields mismatch with, expected rows and fields

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.53 17758

WSAStartup failed: @1@

[Description]

WSAStartup failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.54 17759

could not create communication channels: @1@

[Description]

could not create communication channels

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.55 17761

unrecognized command received from master: "@1@"

[Description]

unrecognized command on communication channel

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.56 17762

invalid message received from worker: "@1@"

[Description]

invalid message received from worker

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.57 17764

could not write to the communication channel: @1@

[Description]

could not write to the communication channel

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.58 17765

select() failed: @1@

[Description]

error in ListenToWorkers()

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.59 17766

pgpipe: could not create socket: error code @1@

[Description]

pgpipe: could not create socket

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.60 17767

pgpipe: could not bind: error code @1@

[Description]

pgpipe: could not bind

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.61 17768

pgpipe: could not listen: error code @1@

[Description]

pgpipe: could not listen

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.62 17769

pgpipe: getsockname() failed: error code @1@

[Description]

pgpipe: getsockname() failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.63 17770

pgpipe: could not create second socket: error code @1@

[Description]

pgpipe: could not create second socket

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.64 17771

pgpipe: could not connect socket: error code @1@

[Description]

pgpipe: could not connect socket

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.65 17773

unexpected COPY statement syntax: "@1@"

[Description]

unexpected COPY statement syntax

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.66 17774

options -s/--schema-only and -a/--data-only cannot be used together

[Description]

options `-s/--schema-only` and `-a/--data-only` cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.67 17775

options `-c/--clean` and `-a/--data-only` cannot be used together

[Description]

options `-c/--clean` and `-a/--data-only` cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.68 17776

option `--if-exists` requires option `-c/--clean`

[Description]

option `--if-exists` requires option `-c/--clean`

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.69 17777

invalid number of parallel jobs

[Description]

%s: invalid number of parallel jobs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.70 17778

parallel backup only supported by the directory format

[Description]

parallel backup only supported by the directory format

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.71 17779

Exported snapshots are not supported by this server version.

[Description]

Exported snapshots are not supported by this server version

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.72 17780

unexpected policy command type: @1@

[Description]

unexpected policy command type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.73 17781

options -g/--globals-only and -r/--roles-only cannot be used together

[Description]

options -g/--globals-only and -r/--roles-only cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.74 17782

options -g/--globals-only and -t/--tablespaces-only cannot be used together

[Description]

options -g/--globals-only and -t/--tablespaces-only cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.75 17783

option --if-exists requires option -c/--clean

[Description]

option --if-exists requires option -c/--clean

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.76 17784

options -r/--roles-only and -t/--tablespaces-only cannot be used together

[Description]

options -r/--roles-only and -t/--tablespaces-only cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.77 17785

options -d/--dbname and -f/--file cannot be used together

[Description]

options -d/--dbname and -f/--file cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.78 17786

options -c/--clean and -a/--data-only cannot be used together

[Description]

options -c/--clean and -a/--data-only cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.79 17787

cannot specify both --single-transaction and multiple jobs

[Description]

cannot specify both --single-transaction and multiple jobs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.80 17788

@1@: could not start server: @2@

[Description]

could not start server

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.81 17789

@1@: could not start server: error code @2@

[Description]

could not start server: error code

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.82 17790

encoding conversion error on line @1@

[Description]

encoding conversion error on line

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.83 17791

invalid value for numeric type "@1@" on line @2@

[Description]

invalid value for numeric type on line

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.84 17793

@1@: could not locate my own executable path

[Description]

could not locate my own executable path

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.85 17794

lookup failed for type @1@

[Description]

lookup failed for type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.86 17795

didn't get a return item from function

[Description]

didn't get a return item from function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.87 17796

couldn't fetch \$_TD

[Description]

couldn't fetch \$_TD

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.88 17797

didn't get a return item from trigger function

[Description]

didn't get a return item from trigger function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.89 17798

event trigger functions cannot have declared arguments

[Description]

event trigger functions cannot have declared arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.74.90 17799

GET STACKED DIAGNOSTICS cannot be used outside an exception handler

[Description]

GET STACKED DIAGNOSTICS cannot be used outside an exception handler

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75 Message Numbers Beginning with 17800

2.75.1 17800

cannot return non-composite value from function returning composite type

[Description]

cannot return non-composite value from function returning composite type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.2 17804

[@1@ cannot be used as a role name here](#)

[Description]

Reserved name cannot be used as a role name here

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.3 17805

[@1@ is not allowed with UNION/INTERSECT/EXCEPT](#)

[Description]

Locking clause is not allowed with UNION/INTERSECT/EXCEPT

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.4 17806

[@1@: could not access directory "@2@": @3@](#)

[Description]

Failure in accessing directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.5 17807

[could not allocate SIDs: error code @1@](#)

[Description]

Failure in allocating SIDs

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.6 17808

could not change permissions of "@1@": @2@

[Description]

Failure in changing the permissions of a file/directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.7 17809

@1@: could not close directory "@2@": @3@

[Description]

Failure in closing directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.8 17810

could not close directory "@1@": @2@

[Description]

Failure in closing a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.9 17811

could not create restricted token: error code @1@

[Description]

Failure in creating restricted token

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.10 17812

could not fsync file "@1@": @2@

[Description]

Failure in syncing the file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.11 17813

could not get exit code from subprocess: error code @1@

[Description]

Failure in getting the exit code of a child process

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.12 17816

could not open process token: error code @1@

[Description]

Failure in opening process token

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.13 17818

could not read directory "@1@": @2@

[Description]

Failure in reading from a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.14 17821

could not re-execute with restricted token: error code @1@

[Description]

re-executing with a restricted token is not allowed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.15 17822

@1@: could not remove promote signal file "@2@": @3@

[Description]

Failure in removing promote signal file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.16 17823

could not start process for command "@1@": error code @2@

[Description]

Process start failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.17 17824

could not write @1@ bytes to log file "@2@": @3@

[Description]

Failure in writing to a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.18 17825

@1@: directory "@2@" does not exist

[Description]

directory doesn't exist

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.19 17826

@1@: directory "@2@" is not a database cluster directory

[Description]

directory is not a database cluster directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.20 17827

@1@: invalid argument for option -f: "@2@"

[Description]

Invalid argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.21 17828

@1@: invalid argument for option -t: "@2@"

[Description]

Invalid argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.22 17829

keystore location "@1@" is too long

[Description]

keystore location is more than 1024 characters

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.23 17830

@1@: oldest multitransaction ID (-m) must not be 0

[Description]

The provided oldest multitransaction ID (-m) must not be 0

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.24 17832

out of memory

[Description]

out of memory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.25 17833

replication connection using slot "@1@" is unexpectedly database specific

[Description]

replication connection using slot specified is unexpectedly database specific

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.26 17834

@1@: the PID file "@2@" is empty

[Description]

Wrong PID file is found, it is empty

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.27 17835

@1@: too many command-line arguments (first is "@2@")

[Description]

too many command-line arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.28 17836

@1@: transaction ID (-c) must be either 0 or greater than or equal to 2

[Description]

Provided transaction ID (-c) must be either 0 or greater than or equal to 2

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.29 17837

unexpected response to TIMELINE_HISTORY command: got @1@ rows and @2@ fields, expected @3@ rows and @4@ fields

[Description]

Response from server to TIMELINE_HISTORY command is wrong from the expected

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.30 17838

"@1@" is a symbolic link, but symbolic links are not supported on this platform

[Description]

Symbolic links are not supported in this platform

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.31 17839

"@1@" is not a BRIN index

[Description]

The provided index is not a BRIN index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.32 17840

"@1@" is not a directory or symbolic link

[Description]

Specified path is not a directory or symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.33 17841

"@1@" is not a directory

[Description]

The specified path is not a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.34 17842

"@1@" is not a regular file

[Description]

The specified file is not a regular file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.35 17843

"@1@" is not a symbolic link

[Description]

The specified path/file is not a symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.36 17844

"@1@" is not a table, view, materialized view, sequence, or foreign table

[Description]

Object is not a table, view, materialized view, sequence, or foreign table to do the alter relation

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.37 17845

"@1@" : stopping truncate due to conflicting lock request

[Description]

Truncating table is stopped due to conflicting lock request by vacuum

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.38 17846

\\watch cannot be used with an empty query

[Description]

\\watch comamnd cannot be used with an empty query

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.39 17847

\\watch cannot be used with COPY

[Description]

\\watch command cannot be used along with COPY command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.40 17848

aggregate cannot accept shell type @1@

[Description]

Shell type is not allowed in aggregate functions

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.41 17849

aggregates cannot have output arguments

[Description]

Defining aggregates with output arguments is not supported

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.42 17850

an ordered-set aggregate with a VARIADIC direct argument must have one VARIADIC aggregated argument of the same data type

[Description]

an ordered-set aggregate with a VARIADIC direct argument must have one VARIADIC aggregated argument of the same data type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.43 17852

argument @1@: key must not be null

[Description]

Invalid key value

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.44 17853

argument of lo_read exceeds integer range

[Description]

The length argument of lo_read exceeds integer range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.45 17854

argument of lo_truncate exceeds integer range

[Description]

The length argument of lo_truncate exceeds integer range

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.46 17855

argument of lo_write exceeds integer range

[Description]

The provided index is not a BRIN index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.47 17856

background worker "@1@": only dynamic background workers can request notification**[Description]**

only dynamic background workers can request notification

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.48 17857

BKPBLOCK_HAS_DATA not set, but data length is @1@ at @2@/@3@**[Description]**

BKPBLOCK_HAS_DATA not set, but data length is present in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.49 17858

BKPBLOCK_HAS_DATA set, but no data included at @1@/@2@**[Description]**

BKPBLOCK_HAS_DATA set, but no data in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.50 17859

BKPBLOCK_SAME_REL set but no previous rel at @1@/@2@**[Description]**

BKPBLOCK_SAME_REL set but no previous rel is provided in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.51 17860

BKPIMAGE_HAS_HOLE not set, but hole offset @1@ length @2@ at @3@/@4@

[Description]

BKPIMAGE_HAS_HOLE not set, but hole offset is provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.52 17861

BKPIMAGE_HAS_HOLE set, but hole offset @1@ length @2@ block image length @3@ at @4@/@5@

[Description]

BKPIMAGE_HAS_HOLE set, but hole offset is not provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.53 17862

BKPIMAGE_IS_COMPRESSED set, but block image length @1@ at @2@/@3@

[Description]

BKPIMAGE_IS_COMPRESSED set, but block image length is not provided.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.54 17863

cannot allocate multiple Perl interpreters on this platform

[Description]

cannot allocate multiple Perl interpreters on this platform

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.55 17864

cannot alter type of a column used in a policy definition

[Description]

cannot alter type of a column used in a policy definition

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.56 17865

cannot call @1@ on a non-object

[Description]

The parameter is not a Json Object

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.57 17866

cannot change logged status of table "@1@" because it is temporary

[Description]

Temporary table logged status cannot be changed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.58 17867

cannot copy from materialized view "@1@"

[Description]

Copy command cannot be executed on a materialized view

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.59 17868

cannot delete tuples during a parallel operation

[Description]

Delete operation is not allowed in parallel mode

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.60 17869

cannot determine OID of function lo_lseek64

[Description]

lo_lseek64 function is not defined

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.61 17870

cannot determine OID of function lo_tell64

[Description]

lo_tell64 function is not defined

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.62 17871

cannot determine OID of function lo_truncate64

[Description]

lo_truncate64 function is not defined

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.63 17872

cannot display a value of a shell type

[Description]

Shell type cannot be displayed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.64 17873

cannot duplicate null pointer (internal error)

[Description]

The given input is a null pointer

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.65 17874

cannot refresh materialized view "@1@" concurrently

[Description]

Cannot refresh materialized view concurrently

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.66 17875

cannot set system attribute "@1@"

[Description]

Cannot set system attributes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.67 17876

cannot setup replication origin when one is already setup

[Description]

replication origin is already setup

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.68 17877

cannot use DISTINCT with WITHIN GROUP

[Description]

cannot use DISTINCT with WITHIN GROUP

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.69 17878

cannot use multiple ORDER BY clauses with WITHIN GROUP

[Description]

cannot use multiple ORDER BY clauses with WITHIN GROUP sql query

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.70 17879

cannot use special role specifier in DROP ROLE

[Description]

cannot use special role specifier in DROP ROLE

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.71 17880

cannot use VARIADIC with WITHIN GROUP

[Description]

cannot use VARIADIC with WITHIN GROUP

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.72 17881

constraint "@1@" of relation "@2@" is not a foreign key constraint

[Description]

constraint is not a foreign key constraint

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.73 17882

conversion from numeric to Decimal failed

[Description]

conversion from numeric to Decimal failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.74 17883

COPY data transfer failed: @1 @

[Description]

Failed in data transfer of COPY command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.75 17884

corrupted line pointer: offset = @1 @, size = @2 @

[Description]

item pointer of a page is corrupted

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.76 17885

could not change table "@1 @" to logged because it references unlogged table "@2@"

[Description]

could not change table logged status because it references unlogged table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.77 17886

could not change table "@1@" to unlogged because it references logged table "@2@"

[Description]

could not change table logged status because it references logged table

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.78 17887

could not close directory "@1@": @2@

[Description]

Failure in closing a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.79 17888

could not close directory "@1@": @2@

[Description]

Failure in closing a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.80 17889

could not close file "@1@": @2@

[Description]

Failure in file close

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.81 17890

could not close pipe to external command: @1@

[Description]

Failure in closing the pipe command to external command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.82 17891

could not close target file "@1@": @2@

[Description]

Failure in closing target file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.83 17892

could not convert Python Unicode object to bytes

[Description]

could not convert Python Unicode object to bytes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.84 17893

could not create any Unix-domain sockets

[Description]

Failure in creating Unix-domain sockets

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.85 17894

could not create directory "@1@": @2@

[Description]

Failure in creating a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.86 17895

could not create internal procedure "@1@": @2@

[Description]

could not create internal procedure

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.87 17896

could not create symbolic link at "@1@": @2@

[Description]

Failure in creating a symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.88 17897

could not execute command "@1@": @2@

[Description]

could not execute command if it is not copy stream

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.89 17898

could not import a module for Decimal constructor

[Description]

Non decimal data found

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.75.90 17899

could not initialize globals

[Description]

could not initialize globals in pl/python function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76 Message Numbers Beginning with 17900

2.76.1 17901

could not look up effective user ID @1@: @2@

[Description]

Getting the current user details failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.2 17902

could not look up local user ID @1@: @2@

[Description]

Lookup user name failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.3 17903

could not map dynamic shared memory segment

[Description]

Attaching to a dynamci shared memory segment failed.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.4 17904

could not open directory "@1@": @2@

[Description]

Failure in opening the directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.5 17905

could not open file "@1@" for reading: @2@

[Description]

Failure in opening a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.6 17906

could not open file "@1@" for truncation: @2@

[Description]

Faliure in opening a file for truncating it's size

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.7 17907

could not open file "@1@": @2@

[Description]

Failure in opening the file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.8 17908

could not open parent table of index @1@

[Description]

Failure in opening the parent relation of an index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.9 17909

could not open source file "@1@": @2@

[Description]

Failure in opening a source file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.10 17910

could not open target file "@1@": @2@

[Description]

Failure in opening target file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.11 17911

could not read directory "@1@": @2@

[Description]

Failure in reading from a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.12 17912

could not read directory "@1@": @2@

[Description]

Failure in reading from a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.13 17913

could not read file "@1@": @2@

[Description]

Failure in reading a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.14 17914

could not read symbolic link "@1@": @2@

[Description]

Failure in reading a symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.15 17915

could not read time zone file "@1@": @2@

[Description]

Failure in reading timezone file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.16 17916

could not remove directory "@1@": @2@

[Description]

Failure in removing a directory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.17 17917

could not remove file "@1@": @2@

[Description]

Failure in removing a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.18 17918

could not remove symbolic link "@1@": @2@

[Description]

Failure in removing a symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.19 17920

could not seek in source file: @1@

[Description]

Failure in executing seek system call in source file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.20 17921

could not seek in target file "@1@": @2@

[Description]

Failure in executing seek system call in target file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.21 17923

could not split return value from trigger: @1@

[Description]

Trigger return value couldn't be splitted

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.22 17924

could not stat file "@1@": @2@

[Description]

stat system call failed on a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.23 17925

could not stat file "@1@": @2@

[Description]

Failure in stat system call

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.24 17926

could not truncate file "@1@" to @2@: @3@

[Description]

Failure in truncating a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.25 17927

could not write file "@1@": @2@

[Description]

Failure in writing to a file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.26 17928

could not write to file "@1@", wrote @2@ of @3@: @4@

[Description]

Failure in writing to a file.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.27 17929

data file "@1@" in source is not a regular file

[Description]

The data file is not a regular file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.28 17930

database connection requirement not indicated during registration

[Description]

database connection requirement not indicated during background worker registration

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.29 17931

declared name @1@ is already defined

[Description]

declared name has been defined already

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.30 17934

EVP error code @1@

[Description]

Non zero error message. The error number returned by ERR_get_error

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.31 17935

EVP error code @1@

[Description]

EVP error code

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.32 17936

FOR value should be positive integer

[Description]

FOR loop value should be positive integer

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.33 17937

foreign key referenced-columns list must not contain duplicates

[Description]

The provided foreign key referenced-columns list contain duplicates

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.34 17938

foreign-data wrapper "@1@" does not support IMPORT FOREIGN SCHEMA

[Description]

IMPORT FOREIGN SCHEMA doesn't supported by the foerign data wrapper

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.35 17939

improper use of "*"

[Description]

improper use of "\"*" in the indirection reference

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.36 17941

initial position must not be null

[Description]

First member of the array must not be nul

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.37 17942

invalid action (CREATE) for regular file

[Description]

Regular files are created with open_target_file function, not with this

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.38 17943

invalid block_id @1@ at @2@/@3@

[Description]

invalid block_id in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.39 17944

Invalid character value.

[Description]

Invalid XML character value.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.40 17945

invalid compressed image at @1@/@2@, block @3@

[Description]

The provided index is not a BRIN index

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.41 17947

invalid input syntax for type @1@: "@2@"

[Description]

invalid input syntax for type txid_snapshot

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.42 17948

invalid line number: @1@

[Description]

Provided line number is wrong in the sql query

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.43 17949

invalid magic number in dynamic shared memory segment

[Description]

Invalid dynamic shared memory segment

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.44 17950

invalid MultiXactId: @1@

[Description]

Invalid multixactid parameter

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.45 17951

invalid value "@1@" for "@2@"

[Description]

Invalid argument

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.46 17953

invalid value in ECOBPG_NCHAR on line @1@. The valid value is UTF16LE/ UTF16BE/ UTF32LE/ UTF32BE/ SJIS/ COBOL_EUC.

[Description]

Invalid ECOBPG_NCHAR environment variable value

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.47 17954

Junk view columns are not updatable.

[Description]

Write operation Junk view columns are not updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.48 17955

length of nvarchar type is not assigned

[Description]

length of nvarchar type is not assigned

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.49 17956

local user with ID @1@ does not exist

[Description]

Lookup user name failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.50 17957

lost connection to parallel worker

[Description]

Error while reading message queue may caused the worker to be shutdown

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.51 17958

Malformed declaration: missing version.

[Description]

Version number missing in xml document/content

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.52 17959

Missing encoding in text declaration.

[Description]

missing encoding in xml document/content

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.53 17960

more than one row returned for \gset

[Description]

more than one row returned for \gset command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.54 17961

must be owner of event trigger @1@

[Description]

must be owner of the even trigger

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.55 17962

national characters is not supported on non-utf8 databases.

[Description]

national characters is not supported on non-utf8 databases.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.56 17963

neither BKPIMAGE_HAS_HOLE nor BKPIMAGE_IS_COMPRESSED set, but block image length is @1@ at @2@/ @3@

[Description]

neither BKPIMAGE_HAS_HOLE nor BKPIMAGE_IS_COMPRESSED set, but block impage length is provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.57 17964

nested service specifications not supported in service file "@1@", line @2@

[Description]

nested service specifications not supported in service file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.58 17965

no Decimal attribute in module

[Description]

no Decimal attribute in module

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.59 17966

no EVP error reported

[Description]

The errorcode returned by ERR_get_error() function is zero.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.60 17967

no rows returned for \gset

[Description]

no rows returned for \gset command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.61 17968

no SSL error reported

[Description]

no SSL error reported

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.62 17969

not enough arguments for cursor "@1@"

[Description]

syntax error

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.63 17970

number of parameters must be between 0 and 65535

[Description]

number of parameters must be between 0 and 65535

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.64 17972

operator not allowed in variable definition

[Description]

Only sizeof operation is allowed in variable definition

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.65 17973

operator too long

[Description]

The length of the operator is more than or equal to 64 characters

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.66 17974

out of memory

[Description]

out of memory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.67 17975

out of memory

[Description]

out of memory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.68 17976

out-of-order block_id @1@ at @2@/@3@

[Description]

Out-of-order blocks in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.69 17977

Parsing XML declaration: '?>' expected.

[Description]

Provided XML declaration is unfinished

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.70 17978

pclose failed: @1@

[Description]

pclose system call failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.71 17979

permission denied to reassign objects

[Description]

Insufficient privileges on the object

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.72 17980

pgpipe: could not accept connection: error code @1@

[Description]

Failure in reading a symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.73 17981

record with invalid length at @1@/@2@

[Description]

record with invalid length in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.74 17982

requested character not valid for encoding: @1@

[Description]

Invalid character for the encoding

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.75 17984

source file list is empty

[Description]

Source file list is empty

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.76 17985

Space required.

[Description]

Space required in the specified location of XML content.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.77 17986

SPI_execute failed: @1@

[Description]

Failure in SPI_execute function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.78 17987

SPI_execute_plan failed: @1@

[Description]

Failure in SPI_execute_plan function

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.79 17988

SSL error code @1@

[Description]

SSL has reported some error

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.80 17989

standalone accepts only 'yes' or 'no'.

[Description]

XML standalone accepts only 'yes' or 'no'.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.81 17990

STDIN/STDOUT not allowed with PROGRAM

[Description]

STDIN/STDOUT not allowed with PROGRAM in copy command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.82 17991

symbolic link "@1@" target is too long

[Description]

Symbolic link target length is more than the specified length

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.83 17992

symbolic link target too long for tar format: file name "@1@", target "@2@"

[Description]

provided symbolic link target name is too long for tar format

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.84 17993

tablesample method @1@ requires @2@ argument, not @3@

[Description]

Invalid number of tablespample arguments

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.85 17995

The server (version @1@) does not support editing function source.

[Description]

The server does not support editing function source.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.86 17996

time zone "@1@" appears to use leap seconds

[Description]

The provided timezone appears to have leap seconds

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.87 17997

too many arguments for cursor "@1@"

[Description]

syntax error

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.76.88 17999

type modifier cannot have ORDER BY

[Description]

type modifier cannot have ORDER BY clause

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77 Message Numbers Beginning with 18000

2.77.1 18000

unexpected EOF while reading file "@1@"

[Description]

unexpected EOF reach while reading file

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.2 18001

unexpected page modification for directory or symbolic link "@1@"

[Description]

unexpected page modification for directory or symbolic link

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.3 18002

unexpected result set after end-of-streaming

[Description]

unexpected data after end-of-streaming

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.4 18003

unexpected result status for \\watch

[Description]

unexpected result status for \\watch command

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.5 18004

unexpected standby message type "@1@", after receiving CopyDone

[Description]

unexpected standby message type after copyDone

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.6 18005

Unix-domain socket path "@1@" is too long (maximum @2@ bytes)

[Description]

unix-domain socket path has crossed more than 100 bytes

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.7 18006

UNNEST() with multiple arguments cannot have a column definition list

[Description]

UNNEST() with multiple arguments cannot have a column definition list

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.8 18008

Unrecognized libxml error code: @1@.

[Description]

Unknown code error - the default error

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.9 18009

unrecognized object type in default privileges: @1@

[Description]

Unrecognized object type

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.10 18010

unterminated /* comment

[Description]

unterminated /* comment in the sql query

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.11 18011

User "@1@" has an expired password.**[Description]**

user's password has been expired

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.12 18012

User "@1@" has no password assigned.**[Description]**

no password has assigned to user

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.13 18013

user name lookup failure: error code @1@**[Description]**

Lookup user name failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.14 18014

View columns that are not columns of their base relation are not updatable.**[Description]**

Write operation View columns that are not columns of their base relation are not updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.15 18015

View columns that refer to system columns are not updatable.

[Description]

Write operation View columns that refer to system columns are not updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.16 18016

View columns that return whole-row references are not updatable.

[Description]

Write operation View columns that return whole-row references are not updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.17 18017

Views containing DISTINCT are not automatically updatable.

[Description]

Write operation Views containing DISTINCT clause are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.18 18018

Views containing GROUP BY are not automatically updatable.

[Description]

Write operation Views containing GROUP BY clause are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.19 18019

Views containing HAVING are not automatically updatable.

[Description]

Write operation Views containing HAVING clause are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.20 18020

Views containing LIMIT or OFFSET are not automatically updatable.

[Description]

write operation Views containing LIMIT or OFFSET are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.21 18021

Views containing TABLESAMPLE are not automatically updatable.

[Description]

Write operation Views containing TABLESAMPLE are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.22 18022

Views containing UNION, INTERSECT, or EXCEPT are not automatically updatable.

[Description]

Write operation Views containing UNION, INTERSECT, or EXCEPT are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.23 18023

Views containing WITH are not automatically updatable.

[Description]

Write operation Views containing WITH are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.24 18024

Views that do not select from a single table or view are not automatically updatable.

[Description]

Write operation Views that do not select from a single table or view are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.25 18025

Views that have no updatable columns are not automatically updatable.

[Description]

Write operation Views that have no updatable columns are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.26 18026

Views that return aggregate functions are not automatically updatable.

[Description]

Write operation Views that return aggregate functions are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.27 18027

Views that return set-returning functions are not automatically updatable.

[Description]

Write operation Views that return set-returning functions are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.28 18028

Views that return window functions are not automatically updatable.

[Description]

Write operation Views that return window functions are not automatically updatable.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.29 18029

WAL file is from different database system: incorrect XLOG_BLCKSZ in page header

[Description]

WAL file is from a different database not generated by these binaries because of mismatch in WAL block size

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.30 18030

WAL file is from different database system: incorrect XLOG_SEG_SIZE in page header

[Description]

WAL file is from a different database not generated by these binaries because of mismatch in WAL segment size

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.31 18034

window function @1@ cannot have WITHIN GROUP

[Description]

window function cannot have WITHIN GROUP

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.32 18035

window function @1@ requires an OVER clause

[Description]

True window functions must be called with a window definition

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.33 18036

WITH CHECK OPTION not supported on recursive views

[Description]

WITH CHECK OPTION not supported on recursive views

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.34 18038

"@1@" must be registered in shared_preload_libraries and session_preload_libraries

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.35 18039

"@1@" must be registered in shared_preload_libraries

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.36 18044

duplicate lock detected

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.37 18049

internal error. memory not allocated.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.38 18050

internal error. unknown code.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.39 18058

ROS has not been formatted yet.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.40 18061

could not read from SMC evacuating temporary file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.41 18066

vci_index_size requires 1 argument

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.42 18067

cannot alter table because the table is indexed by VCI

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.43 18068

ALTER INDEX SET TABLESPACE is not supported for VCI

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.44 18069

REINDEX is not supported for VCI

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.45 18072

access method "@1@" does not support EXCLUDE clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.46 18073

access method "@1@" does not support index on temporary table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.47 18074

access method "@1@" does not support to CREATE INDEX on the expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.48 18075

access method "@1@" does not support concurrent index drop

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.49 18076

access method "@1@" does not support concurrent index build

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.50 18077

access method "@1@" does not support partial-index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.51 18078

access method "@1@" does not support index on materialized view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.77.52 18079

compression buffer is full

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.77.53 18091

could not start background process : postmaster died

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.54 18092

could not stop background process

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.55 18093

could not register background process

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.56 18097

could not open file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.77.57 18099

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.78 Message Numbers Beginning with 18100

2.78.1 18103

could not identify a comparison function for type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.2 18104

aggregate @1@ needs to have compatible input type and transition type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.3 18105

aggregate function calls cannot be nested

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.4 18106

cannot pass more than @1@ argument to a function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.5 18108

value out of range: underflow

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.6 18109

value out of range: overflow

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.7 18112

access method "@1@" does not work under full_page_writes=off

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.8 18113

slot name must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.9 18114

options array must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.10 18115

cannot create a RETURNING list for a relation containing dropped columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.11 18116

path element at position @1@ is null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.12 18117

path element at position @1@ is not an integer: "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.13 18118

role with OID @1@ does not exist

[Description]

An error occurred during DB Server processing in the database.

[System Processing]

Processing will be aborted.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.78.14 18119

BKPBLOCK_HAS_DATA not set, but data length is @1@ at @2@/@3@

[Description]

BKPBLOCK_HAS_DATA not set, but data length is present in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.15 18120

BKPBLOCK_HAS_DATA set, but no data included at @1@/@2@

[Description]

BKPBLOCK_HAS_DATA set, but no data in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.16 18121

BKPBLOCK_SAME_REL set but no previous rel at @1@/@2@

[Description]

BKPBLOCK_SAME_REL set but no previous rel is provided in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.17 18122

BKPIMAGE_HAS_HOLE not set, but hole offset @1@ length @2@ at @3@/@4@

[Description]

BKPIMAGE_HAS_HOLE not set, but hole offset is provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.18 18123

BKPIMAGE_HAS_HOLE set, but hole offset @1@ length @2@ block image length @3@ at @4@/@5@

[Description]

BKPIMAGE_HAS_HOLE set, but hole offset is not provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.19 18124

BKPIMAGE_IS_COMPRESSED set, but block image length @1@ at @2@/@3@

[Description]

BKPIMAGE_IS_COMPRESSED set, but block image length is not provided.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.20 18126

invalid block_id @1@ at @2@/@3@

[Description]

invalid block_id in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.21 18127

neither BKPIMAGE_HAS_HOLE nor BKPIMAGE_IS_COMPRESSED set, but block image length is @1 @ at @2@/@3@

[Description]

neither BKPIMAGE_HAS_HOLE nor BKPIMAGE_IS_COMPRESSED set, but block image length is provided

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.22 18128

out-of-order block_id @1 @ at @2@/@3@

[Description]

Out-of-order blocks in WAL record

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.23 18129

could not look up effective user ID @1 @: @2@

[Description]

Getting the current user details failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.24 18130

could not look up effective user ID @1 @: @2@

[Description]

Getting the current user details failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.25 18131

pclose failed: @1 @

[Description]

pclose system call failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.26 18132

pclose failed: @1 @

[Description]

pclose system call failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.27 18133

pclose failed: @1 @

[Description]

pclose system call failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.28 18134

pclose failed: @1 @

[Description]

pclose system call failed

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.29 18135

Valid values are "none", "AES128" and "AES256".

[Description]

Wrong tablespace encryption algorithm is passed during CREATE TABLESPACE command.

[System Processing]

Processing will be aborted

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.30 18136

parameter "parallel" must be SAFE, RESTRICTED, or UNSAFE

[Description]

Invalid parallel option is passed for the function to be created with CREATE FUNCTION command.

[System Processing]

Processing will be aborted

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.31 18137

Sets the maximum number of parallel processes per executor node.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.78.32 18139

Sets the planner's estimate of the cost of passing each tuple (row) from worker to master backend.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.78.33 18140

Sets the planner's estimate of the cost of starting up worker processes for parallel query.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.78.34 18144

no EVP error reported

[Description]

The errorcode returned by ERR_get_error() function is zero.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.35 18145

WARNING: password file "@1@" has group or world access; permissions should be u=rw (0600) or less

[Description]

Password file has group or world access.

[System Processing]

WARNING is issued

[Action]

To investigate the cause of the occurrence from the message, and remove cause for the WARNING.

2.78.36 18146

WARNING: password file "@1@" is not a plain file

[Description]

Password file is not a plain file.

[System Processing]

WARNING is issued

[Action]

To investigate the cause of the occurrence from the message, and remove cause for the WARNING.

2.78.37 18147

nested /* ... */ comments

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.38 18148

Please log in (using, e.g., "su") as the (unprivileged) user that willown the server process.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.39 18149

could not change permissions of directory "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.40 18150

Check your installation or specify the correct path using the option -L.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.41 18151

invalid locale settings; check LANG and LC_* environment variables

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.42 18152

You must identify the directory where the data for this database system will reside. Do this with either the invocation option `-D` or the environment variable `PGDATA`.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.78.43 18153

Data page checksums are disabled.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.78.44 18154

Data page checksums are enabled.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.78.45 18155

index "@1@" cannot be used as replica identity because column @2@ is a system column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.46 18157

parameter value for ALTER SYSTEM must not contain a newline

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.47 18162

multiple Python libraries are present in session

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.48 18163

Only one Python major version can be used in one session.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.49 18164

syncing target data directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.50 18168

reading user-defined tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.51 18169

requested compression not available in this installation -- archive will be uncompressed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.52 18170

WARNING: unexpected extra results during COPY of table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.53 18171

Synchronized snapshots on standby servers are not supported by this server version. Run with --no-synchronized-snapshots instead if you do not need synchronized snapshots.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.54 18172

TCP user timeout

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.55 18173

Cancel queries that conflict with recovery during hot standby promotion.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.56 18174

could not load library "vci.so": @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.57 18175

debug_helper must be loaded via shared_preload_libraries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.58 18176

[debug_helper injects error](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.59 18177

[More details may be available in the server log.](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.60 18178

[Kill all remaining database processes and restart the database.](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.61 18179

[deadlock detected](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.62 18180

VCI parallel execution is blocked by other operation.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.63 18181

not enough maximum share memory for parallel query (@1@ bytes requested)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.64 18182

You possibly need to raise the configuration parameter "vci.shared_work_mem" value to be at least @1@kB.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.65 18183

You may need to increase max_worker_processes.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.66 18184

unable to map dynamic shared memory segment

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.67 18185

too many workers already @1@/@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.68 18186

Failed while creating memory context "@1@".

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.69 18187

Failed on request of size @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.70 18188

failed to shm_open()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.71 18189

could not open file "@1@": @2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.72 18190

could not get process AffinityMask: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.73 18191

Failed system call was DuplicateHandle.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.74 18192

could not create semaphore: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.75 18193

Failed system call was GetModuleHandle("ntdll.dll").

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.76 18194

could not get address of "NtQuerySystemInformation": error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.77 18195

Failed system call was GetModuleHandle("NtQuerySystemInformation").

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.78 18196

could not get system processor performance information : error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.79 18197

Failed system call was NtQuerySystemInformation.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.80 18198

cannot find vci.smc_directory: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.78.81 18199

could not create shared memory segment: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79 Message Numbers Beginning with 18200

2.79.1 18200

Failed system call was OpenFileMapping(name=@1@).

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.2 18201

Failed system call was MapViewOfFileEx.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.3 18202

could not map shared memory segment

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.4 18203

could not initialize security descriptor: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.5 18204

Failed system call was InitializeSecurityDescriptor.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.6 18205

could not set security descriptor DACL: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.7 18206

Failed system call was SetSecurityDescriptorDacl.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.8 18207

Failed system call was CreateFileMapping(size=@1@, name=@2@).

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.9 18208

could not get priority class: error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.10 18209

Failed system call was GetPriorityClass.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.11 18210

could not set priority class=@1 @: error code @2 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.12 18211

Failed system call was SetPriorityClass.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.13 18212

pgx_prewarm_vci requires one argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.14 18213

relation cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.15 18214

@1@(VCI index regclass)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.16 18215

@1@ is not VCI index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.17 18216

extension '@1@' does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.18 18217

function '@1@.@2@('

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.19 18218

Disable VCI by 'SELECT vci_disable();'

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.20 18219

internal error. unsupported compression format.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.21 18220

column missed in VCI index creation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.22 18221

This must never happen. Give up to use VCI index.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.23 18222

internal error: unsupported compression type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.24 18223

relation full

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.25 18224

internal error. unsupported compression type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.26 18225

Use DROP INDEX "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.27 18226

unexpected index access method call : "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.28 18227

duplicated columns in vci index creation: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.29 18228

duplicated columns are specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.30 18229

data type @1@ is not supported for access method "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.31 18230

unexpected attribute length

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.32 18231

You must drop index "@1@" before using this command.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.33 18232

DROP INDEX and CREATE INDEX instead

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.34 18233

only VCI index is supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.35 18234

extension "@1@" cannot specify a schema name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.36 18235

cannot cluster tables including @1 @ index(es)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.37 18236

Use DROP INDEX @1 @ first

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.38 18237

Use DROP INDEX to remove an vci index and try again without CONCURRENTLY option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.39 18238

Try again without CONCURRENTLY option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.40 18239

extension "@1@" prohibits this operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.41 18240

extension "@1@" prohibits this operation on access method "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.42 18241

extension "@1@" prohibits this operation on operation class "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.43 18242

extension "@1@" prohibits this operation on operation family "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.44 18243

extension "@1@" prohibits this operation on view "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.45 18244

database @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.46 18245

undefined lock state

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.47 18246

This might happen when CREATE INDEX fails. "DROP INDEX @1@" and CREATE INDEX again may help.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.48 18247

incompatible VCI version: expected (@1@, @2@), stored (@3@, @4@).

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.49 18248

This can happen when accessing old database with newer VCI modules. DROP and CREATE INDEX may help.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.50 18249

internal error. unsupported parameter.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.51 18250

Normally relations of VCI index are smaller than the table relation, therefore this error must not happen. Disable VCI by 'SELECT vci_disable()'

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.52 18251

data relation full

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.53 18252

vci index "@1@" corrupted

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.54 18253

TID (@1@, @2@) has been deleted from table "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.55 18254

try to insert TID (@1@, @2@) into ROS twice: extentId=@3@, index=@4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.56 18255

try to delete TID (@1@, @2@) into local delete list

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.57 18256

try to delete TID (@1 @, @2 @) into delete vector twice

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.58 18257

too many WOS rows over estimation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.59 18258

The number of devices exceeds the upper bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.60 18259

database connection requirement not indicated during registration

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.61 18260

invalid processing mode in background worker

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.62 18261

terminating VCI worker process due to administrator command

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.63 18262

"@1@" is not directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.64 18263

could not create directory "@1@" : @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.65 18264

could not stat directory "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.66 18265

needs to set at least @1@ to "max_worker_processes"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.67 18266

You will specify more than $\text{vci.control_max_workers} + (\# \text{ of CPU cores}) * @1@ + 1$ to the configuration parameter "max_worker_processes".

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.68 18267

extension "@1@" cannot be installed under this version of PostgreSQL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.69 18268

crash_emulation must be loaded via shared_preload_libraries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.79.70 18269

standby mode is not supported by single-user servers

[Description]

An error occurred during DB Server processing in the database.

[System Processing]

Processing will be aborted.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.79.71 18270

constraint "@1@" conflicts with inherited constraint on relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.72 18271

constraint "@1@" conflicts with NOT VALID constraint on relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.73 18272

constraint "@1@" conflicts with NOT VALID constraint on child table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.74 18274

only one of --source-pgdata or --source-server can be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.75 18275

internal error. failed to split

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.76 18276

invalid attribute number @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.77 18277

duplicated columns in vci index creation: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.78 18278

duplicated columns are specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.79 18279

cannot use "ctid" column with other columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.80 18280

The "vci_column_ids" option is required when "ctid" column is specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.81 18281

The "vci_column_ids" option cannot be used without "ctid" column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.82 18282

index name cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.83 18283

table oid cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.84 18284

array of column names cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.85 18285

storage option cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.86 18286

column name cannot be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.87 18287

column "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.88 18288

SPI_connect failed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.89 18289

SPI_prepare failed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.90 18290

cannot execute multi-query in vci_create()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.91 18291

You might fold the index name with double quotation marks.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.92 18292

SPI_excep failed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.93 18293

SPI_finish failed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.94 18294

unterminated quoted string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.95 18295

failed to parse vci_create() options.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.96 18296

failed to parse a vci_create() options: an invalid pair

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.97 18297

unrecognized options: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.98 18298

WARNING: could not find where to insert IF EXISTS in statement "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.79.99 18299

could not find function definition for function with OID @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.80 Message Numbers Beginning with 18300

2.80.1 18300

could not create the spiexceptions module

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.80.2 18301

could not create exception "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.80.3 18302

exclusive backup not in progress

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.80.4 18303

USING expression contains a whole-row table reference.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.80.5 18304

cannot COPY to/from client in a SQL function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.80.6 18305

calculated CRC checksum does not match value stored in file

[Description]

An error occurred reading the pg_control file.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.7 18306

byte ordering mismatch

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.8 18307

operator family "@1@" of access method @2@ contains function @3@ with invalid support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.9 18308

operator family "@1@" of access method @2@ contains function @3@ with wrong signature for support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.10 18310

operator family "@1@" of access method @2@ contains invalid ORDER BY specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.11 18311

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.12 18312

operator family "@1@" of access method @2@ is missing operator(s) for types @3@ and @4@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.13 18313

operator family "@1@" of access method @2@ is missing support function(s) for types @3@ and @4@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.14 18314

operator class "@1@" of access method @2@ is missing operator(s)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.15 18315

operator class "@1@" of access method @2@ is missing operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.16 18316

posting list is too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Reduce the value of maintenance_work_mem.

2.80.17 18317

Reduce maintenance_work_mem.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.18 18318

GIN pending list cannot be cleaned up during recovery.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.19 18319

"@1@" is not a GIN index

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.20 18320

cannot access temporary indexes of other sessions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.21 18321

operator family "@1@" of access method @2@ contains support procedure @3@ with different left and right input types

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.22 18322

operator family "@1@" of access method @2@ contains function @3@ with invalid support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.23 18323

operator family "@1@" of access method @2@ contains function @3@ with wrong signature for support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.24 18324

operator family "@1@" of access method @2@ contains operator @3@ with invalid strategy number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.25 18325

operator family "@1@" of access method @2@ contains invalid ORDER BY specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.26 18326

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.27 18327

operator class "@1@" of access method @2@ is missing support function @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.28 18328

operator class "@1@" of access method @2@ is missing support function @3@ or @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.29 18329

Valid values are "on", "off", and "auto".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.30 18330

operator family "@1@" of access method @2@ contains support procedure @3@ with different left and right input types

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.31 18331

operator family "@1@" of access method @2@ contains function @3@ with invalid support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.32 18332

operator family "@1@" of access method @2@ contains function @3@ with wrong signature for support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.33 18333

operator family "@1@" of access method @2@ contains operator @3@ with invalid strategy number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.34 18334

operator family "@1@" of access method @2@ contains unsupported ORDER BY specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.35 18335

operator family "@1@" of access method @2@ contains incorrect ORDER BY of family specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.36 18336

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.37 18337

operator class "@1@" of access method @2@ is missing support function @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.38 18338

operator family "@1@" of access method @2@ contains support procedure @3@ with different left and right input types

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.39 18339

operator family "@1@" of access method @2@ contains function @3@ with wrong signature for support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.40 18340

operator family "@1@" of access method @2@ contains function @3@ with invalid support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.41 18341

operator family "@1@" of access method @2@ contains operator @3@ with invalid strategy number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.42 18342

operator family "@1@" of access method @2@ contains invalid ORDER BY specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.43 18343

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.44 18344

operator family "@1@" of access method @2@ lacks support function for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.45 18345

operator family "@1@" of access method @2@ is missing operator(s) for types @3@ and @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.46 18346

operator class "@1@" of access method @2@ is missing operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.47 18347

operator family "@1@" of access method @2@ is missing cross-type operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.48 18348

access method "@1@" is not of type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.49 18349

index access method "@1@" does not have a handler

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.50 18350

This can be caused by an interrupted VACUUM in version 9.3 or older, before upgrade. Please REINDEX it.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.51 18351

operator family "@1@" of access method @2@ contains function @3@ with invalid support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.52 18352

operator family "@1@" of access method @2@ contains function @3@ with wrong signature for support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.53 18353

operator family "@1@" of access method @2@ contains operator @3@ with invalid strategy number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.54 18354

operator family "@1@" of access method @2@ contains invalid ORDER BY specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.55 18355

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.56 18356

operator family "@1@" of access method @2@ is missing operator(s) for types @3@ and @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.57 18357

operator family "@1@" of access method @2@ is missing support function for types @3@ and @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.58 18358

operator class "@1@" of access method @2@ is missing operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.59 18359

operator family "@1@" of access method @2@ is missing cross-type operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.60 18360

operator family "@1@" of access method @2@ contains support procedure @3@ with different left and right input types

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.61 18361

operator family "@1@" of access method @2@ contains function @3@ with invalid support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.62 18362

operator family "@1@" of access method @2@ contains function @3@ with wrong signature for support number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.63 18363

operator family "@1@" of access method @2@ contains operator @3@ with invalid strategy number @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.64 18364

operator family "@1@" of access method @2@ contains invalid ORDER BY specification for operator @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.65 18365

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.66 18366

operator family "@1@" of access method @2@ is missing operator(s) for types @3@ and @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.67 18367

operator family "@1@" of access method @2@ is missing support function @3@ for type @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.68 18368

operator class "@1@" of access method @2@ is missing operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.69 18369

Make sure the configuration parameter "@1@" is set on the master server.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.70 18370

Make sure the configuration parameter "@1@" is set.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.71 18371

Execute a database-wide VACUUM in that database. You might also need to commit or roll back old prepared transactions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.72 18372

database "@1@" must be vacuumed before @2@ more MultiXactId is used

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.80.73 18373

database with OID @1@ must be vacuumed before @2@ more MultiXactId is used

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.80.74 18374

This command would create a multixact with @1@ members, but the remaining space is only enough for @2@ member.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.75 18375

Execute a database-wide VACUUM in database with OID @1@ with reduced vacuum_multixact_freeze_min_age and vacuum_multixact_freeze_table_age settings.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.76 18376

database with OID @1@ must be vacuumed before @2@ more multixact member is used

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.77 18377

Execute a database-wide VACUUM in that database with reduced vacuum_multixact_freeze_min_age and vacuum_multixact_freeze_table_age settings.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.78 18378

Expected a write-ahead log switchpoint location.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.79 18379

requested timeline @1@ is not in this server's history

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.80 18380

Failed while allocating a WAL reading processor.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.81 18381

could not read two-phase state from WAL at @1@/@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.82 18382

expected two-phase state data is not present in WAL at @1@/@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.83 18383

Stop the postmaster and vacuum that database in single-user mode. You might also need to commit or roll back old prepared transactions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.84 18384

The database cluster was initialized with LOBLKSIZE @1 @, but the server was compiled with LOBLKSIZE @2 @.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.80.85 18387

@1 @ "@2 @": @3 @

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.86 18388

aborting backup due to backend exiting before pg_stop_backup was called

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.87 18389

a backup is already in progress in this session

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.88 18390

non-exclusive backup in progress

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

Try using `pg_stop_backup('f')` to stop a non-exclusive backup.

2.80.89 18391

non-exclusive backup is not in progress

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

Try using `pg_stop_backup('t')` to stop an exclusive backup.

2.80.90 18392

pg_class heap OID value not set when in binary upgrade mode

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.80.91 18393

return type of inverse transition function @1@ is not @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.92 18394

return type of combine function @1@ is not @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.93 18395

combine function with transition type @1@ must not be declared STRICT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.94 18396

return type of serialization function @1@ is not @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.95 18397

return type of deserialization function @1@ is not @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.96 18398

aggregate mfinalfunc must not be specified without mstype

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.80.97 18399

serialization functions may be specified only when the aggregate transition data type is @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81 Message Numbers Beginning with 18400

2.81.1 18400

must specify both or neither of serialization and deserialization functions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.2 18401

permission denied to create access method "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.3 18402

must be superuser to drop access methods

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.4 18403

handler function is not specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.5 18404

DO INSTEAD NOTHING rules are not supported for COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.6 18405

conditional DO INSTEAD rules are not supported for COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.7 18406

DO ALSO rules are not supported for the COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.8 18407

multi-statement DO INSTEAD rules are not supported for COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.9 18408

COPY query must have a RETURNING clause

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.10 18409

FORCE_NULL column "@1@" not referenced by COPY

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.11 18410

There is @1@ active slot

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.12 18411

There is @1@ other session using the database.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.13 18412

There is @1@ prepared transaction using the database.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.14 18413

access method "@1@" does not exist, skipping

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.81.15 18414

Must be superuser to create an event trigger.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.16 18415

filter value "@1@" not recognized for filter variable "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.17 18416

The owner of an event trigger must be a superuser.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.18 18417

Use CREATE EXTENSION ... CASCADE to install required extensions too.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.19 18418

file "@1@" is too large

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.20 18420

index creation on system columns is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.21 18421

Create a unique index with no WHERE clause on one or more columns of the materialized view.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.22 18422

join estimator function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.23 18423

operator attribute "@1@" cannot be changed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.24 18424

All roles are members of the PUBLIC role.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.25 18425

role "@1@" could not be removed from policy "@2@" on "@3@"

[Description]

A warning has occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.26 18426

You might need to add an explicit cast.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.27 18427

You might need to specify "USING @1@::@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.28 18428

@1@ depends on column "@2@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.29 18429

tablespace location should not be inside the data directory

[Description]

A warning has occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.30 18430

Open the existing keystore, or set the master encryption key to create and open a new keystore

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.31 18431

Tablespace "@1@" does not exist.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.32 18432

Foreign tables cannot have TRUNCATE triggers.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.33 18433

Foreign tables cannot have constraint triggers.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.34 18434

Consider using an AFTER trigger instead of a BEFORE trigger to propagate changes to other rows.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.35 18435

type input function @1@ should not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that functions are not marked as volatile.

2.81.36 18436

type output function @1@ should not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that functions are not marked as volatile.

2.81.37 18437

type receive function @1 @ should not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that functions are not marked as volatile.

2.81.38 18438

type send function @1 @ should not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that functions are not marked as volatile.

2.81.39 18439

type modifier input function @1 @ should not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that functions are not marked as volatile.

2.81.40 18440

type modifier output function @1 @ should not be volatile

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that functions are not marked as volatile.

2.81.41 18441

You must specify an operator class for the range type or define a default operator class for the subtype.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.42 18442

Use ALTER TABLE instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.43 18443

VACUUM option DISABLE_PAGE_SKIPPING cannot be used with FULL

[Description]

The DISABLE_PAGE_SKIPPING option cannot be used with VACUUM FULL or ANALYZE commands.

[System Processing]

Processing is aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.44 18444

oldest multixact is far in the past

[Description]

Terminated normally but a warning was output.

[System Processing]

Continues processing.

[Action]

Close open transactions with multixacts soon to avoid wraparound problems.

2.81.45 18445

Close open transactions with multixacts soon to avoid wraparound problems.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.46 18446

Unrecognized key word: "@1@".

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.47 18447

Conflicting "datestyle" specifications.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.48 18448

Cannot specify months in time zone interval.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.49 18449

Cannot specify days in time zone interval.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.50 18450

PostgreSQL does not support leap seconds.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.51 18451

UTC timezone offset is out of range.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.52 18452

You can use REPEATABLE READ instead.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.53 18453

Conversion between @1@ and @2@ is not supported.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.54 18454

Cannot change "client_encoding" now.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.55 18455

cannot change client_encoding during a parallel operation

[Description]

This error occurs if a function wants to set client_encoding and is invoked by the parallel query.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that client_encoding is not set by the parallel query operation.

2.81.56 18456

Valid values are "local" and "cascaded".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.57 18457

Key conflicts exist.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.58 18458

Key conflicts with existing key.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.59 18459

Failing row contains @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.60 18460

Use the REFRESH MATERIALIZED VIEW command.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.61 18461

combine function for aggregate @1@ must be declared as STRICT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.62 18462

Ensure that no rows proposed for insertion within the same command have duplicate constrained values.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.63 18463

could not send tuple to shared-memory queue

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.81.64 18464

BSD authentication failed for user "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.65 18465

Connection matched pg_hba.conf line @1@: "@2@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.66 18466

could not translate name

[Description]

An error occurred while translating domain name to Kerberos realm name in SSL.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the domain name is written correctly.

2.81.67 18467

realm name too long

[Description]

An error occurred while translating domain name to Kerberos realm name in SSL.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the domain name is written correctly.

2.81.68 18468

translated account name too long

[Description]

An error occurred while translating account name to Kerberos user name in SSL.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the account name is written correctly.

2.81.69 18469

pam_set_item(PAM_RHOST) failed: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.70 18470

LDAP search for filter "@1@" on server "@2@" returned @3@ entry.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.71 18471

RADIUS response from @1@ has corrupt length: @2@ (actual length @3@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.72 18472

private key file "@1@" is not a regular file

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.73 18473

private key file "@1@" must be owned by the database user or root

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.74 18474

terminating connection due to unexpected postmaster exit

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the server is still running.

2.81.75 18475

Role "@1@" does not exist.

[Description]

The user does not exist.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.76 18476

User "@1@" has an expired password.

[Description]

The password is blank.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.77 18477

Password does not match for user "@1@".

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.78 18478

Specify exactly one connection type per line.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.79 18479

Specify one address range per line.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.80 18480

Specify an address range in CIDR notation, or provide a separate netmask.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.81 18481

Specify exactly one authentication type per line.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.82 18482

extensible node type "@1@" already exists

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.83 18483

ExtensibleNodeMethods "@1@" was not registered

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.84 18484

whole row unique index inference specifications are not supported

[Description]

The whole row unique index inference specifications are not supported.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.81.85 18485

It is SQL to which the outer joined operator is not supported. Please change to SQL that is using the joined table.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.86 18486

too many grouping sets present (maximum 4096)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the items in the GROUPING SET are less than the maximum allowable value.

2.81.87 18487

Put a separate column definition list for each function inside ROWS FROM().

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.88 18488

Use separate UNNEST() calls inside ROWS FROM(), and attach a column definition list to each one.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.89 18489

Put the column definition list inside ROWS FROM().

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.90 18490

For example, ON CONFLICT (column_name).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.91 18491

operator precedence change: @1@ is now lower precedence than @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.92 18492

There is an ordered-set aggregate @1@, but it requires @2@ direct arguments, not @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.93 18493

To use the hypothetical-set aggregate @1@, the number of hypothetical direct arguments (here @2@) must match the number of ordering columns (here @3@).

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.94 18494

There is an ordered-set aggregate @1@, but it requires at least @2@ direct arguments.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.95 18495

Could not choose a best candidate function. You might need to add explicit type casts.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.96 18496

FILTER is not implemented for non-aggregate window functions

[Description]

FILTER is not yet supported with true window functions.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.81.97 18497

The combining JOIN type must be INNER or LEFT for a LATERAL reference.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.98 18498

Perhaps you meant to reference the column "@1@.@2@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.81.99 18499

There is a column named "@1@" in table "@2@", but it cannot be referenced from this part of the query.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82 Message Numbers Beginning with 18500

2.82.1 18500

Perhaps you meant to reference the column "@1@.@2@" or the column "@3@.@4@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.2 18501

This error usually means that PostgreSQL's request for a shared memory segment exceeded your kernel's SHMMAX parameter, or possibly that it is less than your kernel's SHMMIN parameter. The PostgreSQL documentation contains more information about shared memory configuration.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.3 18502

This error usually means that PostgreSQL's request for a shared memory segment exceeded your kernel's SHMALL parameter. You might need to reconfigure the kernel with larger SHMALL. The PostgreSQL documentation contains more information about shared memory configuration.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.4 18503

This error does **not mean that you have run out of disk space. It occurs either if all available shared memory IDs have been taken, in which case you need to raise the SHMMNI parameter in your kernel, or because the system's overall limit for shared memory has been reached. The PostgreSQL documentation contains more information about shared memory configuration.**

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.5 18504

This error usually means that PostgreSQL's request for a shared memory segment exceeded available memory, swap space, or huge pages. To reduce the request size (currently @1@ bytes), reduce PostgreSQL's shared memory usage, perhaps by reducing shared_buffers or max_connections.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.6 18505

wrote crash dump to file "@1@"

[Description]

An error occurred.

[System Processing]

None

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.7 18506

background worker "@1@" : must be registered in shared_preload_libraries

[Description]

The background worker must be registered in shared_preload_libraries.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.8 18507

too many background workers

[Description]

Up to max_worker_processes background worker can be registered with the current settings.

[System Processing]

Processing will be aborted.

[Action]

Consider increasing the value of configuration parameter max_worker_processes.

2.82.9 18508

Up to @1@ background worker can be registered with the current settings.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.10 18509

Consider increasing the configuration parameter "max_worker_processes".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.11 18510

checkpoints are occurring too frequently (@1@ second apart)

[Description]

Checkpoints are occurring too frequently.

[System Processing]

Continues processing.

[Action]

Consider increasing the value of configuration parameter max_wal_size.

2.82.12 18511

using stale statistics instead of current ones because stats collector is not responding

[Description]

Using stale statistics instead of current ones because the statistics collector is not responding.

[System Processing]

Continues processing.

[Action]

Contact Fujitsu technical support.

2.82.13 18512

ending log output to stderr

[Description]

Ending log output to stderr.

[System Processing]

Continues processing.

[Action]

Future log output will be output to the log destination.

2.82.14 18513

Future log output will go to log destination "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.15 18514

Set the LC_ALL environment variable to a valid locale.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.16 18515

@1@: could not find the database systemExpected to find it in the directory "@2@",but could not open file "@3@": @4@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.17 18516

Valid values are: "false", 0, "true", 1, "database".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.18 18517

@1@ was not reloaded

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.82.19 18518

shutdown at recovery target

[Description]

Terminated normally, but a log message was output.

[System Processing]

None

[Action]

No action required.

2.82.20 18519

Failed process was running: @1@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.21 18520

could not fork checkpointer process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.22 18521

could not fork worker process: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.23 18522

could not parse connection string: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.82.24 18523

Could not identify system: got @1@ rows and @2@ fields, expected @3@ rows and @4@ or more fields.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.25 18524

Increase max_replication_slots and try again.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.26 18525

logical decoding found consistent point at @1@/@2@

[Description]

Transaction ID has finished. There are no more running transactions.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.27 18527

There are no running transactions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.28 18528

logical decoding found initial starting point at @1@/@2@

[Description]

The transaction needs to finish before building a snapshot.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.29 18530

Logical decoding will begin using saved snapshot.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.30 18531

could not parse file name "@1@"

[Description]

Could not parse file name in pg_logical/snapshots.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.31 18532

Replication slot names may only contain lower case letters, numbers, and the underscore character.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.32 18533

Free one or increase max_replication_slots.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.33 18534

standby "@1@" is now a synchronous standby with priority @2@

[Description]

Inform the user that the standby server is now a synchronous standby with priority number.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.34 18535

synchronous_standby_names parser failed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the value of synchronous_standby_names, which may come from postgresql.conf or the SQL command line.

2.82.35 18536

End of WAL reached on timeline @1@ at @2@/@3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.36 18537

primary server contains no more WAL on requested timeline @1@

[Description]

The primary server contains no more WALs on the requested timeline.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.37 18538

could not close log segment @1@: @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.38 18539

This server's history forked from timeline @1@ at @2@/@3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.39 18540

requested starting point @1@/@2@ is ahead of the WAL flush position of this server @3@/@4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.40 18541

terminating walsender process after promotion

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.41 18542

invalid page in block @1@ of relation @2@; zeroing out page

[Description]

In invalid page was found in the relation.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.42 18543

snapshot too old

[Description]

The snapshot is too old.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.43 18544

could not flush dirty data: @1@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.44 18545

could not determine dirty data size: @1@

[Description]

Could not determine dirty data size when flushing data.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.45 18546

could not munmap() while flushing data: @1@**[Description]**

An error is returned from the munmap function.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.82.46 18547

dynamic shared memory control segment is corrupt**[Description]**

Dynamic shared memory control segment is corrupt.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.47 18548

Set dynamic_shared_memory_type to a value other than "none".**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.48 18549

@1@ failed: @2@**[Description]**

An error occurred for epoll_ctl.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.49 18550

@1@ failed: @2@

[Description]

An error occurred for epoll_wait.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.50 18551

while updating tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.51 18552

while deleting tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.52 18553

while locking tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.53 18554

while locking updated version (@1@, @2@) of tuple in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.54 18555

while inserting index tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.55 18556

while checking uniqueness of tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.56 18557

while rechecking updated tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.57 18558

while checking exclusion constraint on tuple (@1@, @2@) in relation "@3@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.58 18559

The source process with PID @1@ is not running anymore.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.59 18560

Process @1@ waits for @2@ on @3@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.60 18561

page verification failed, calculated checksum @1@ but expected @2@

[Description]

The calculated checksum is different from the checksum in the page head.

[System Processing]

Continues processing.

[Action]

No action required.

2.82.61 18562

could not open file "@1@" (target block @2@): previous segment is only @3@ blocks

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.82.62 18563

terminating connection because of crash of another server process

[Description]

The postmaster has commanded this server process to roll back the current transaction and exit, because another server process exited abnormally and possibly corrupted shared memory.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.82.63 18564

The postmaster has commanded this server process to roll back the current transaction and exit, because another server process exited abnormally and possibly corrupted shared memory.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.64 18565

terminating connection due to idle-in-transaction timeout

[Description]

Processing was canceled.

[System Processing]

Processing will be aborted.

[Action]

Check the message text.

2.82.65 18566

"max_stack_depth" must not exceed @1@kB.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.66 18567

increase the platform's stack depth limit via "ulimit -s" or local equivalent.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.67 18568

invalid affix flag "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.68 18569

affix flag "@1@" is out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.69 18570

invalid character in affix flag "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.70 18571

invalid affix flag "@1@" with "long" flag value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.71 18572

invalid affix alias "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.72 18573

invalid number of flag vector aliases

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.73 18574

Missing array dimension value.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.74 18575

Missing "@1@" after array dimensions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.75 18576

Array contents must start with "{".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.76 18577

Unexpected "@1@" character.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.77 18578

Unexpected array element.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.78 18579

Unmatched "@1@" character.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.79 18580

Multidimensional arrays must have sub-arrays with matching dimensions.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.80 18581

Junk after closing right brace.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.81 18582

array slice subscript must provide both boundaries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

When assigning to a slice of an empty array value, slice boundaries must be fully specified.

2.82.82 18583

When assigning to a slice of an empty array value, slice boundaries must be fully specified.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.83 18585

This time zone name appears in the configuration file for time zone abbreviation "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.84 18586

invalid size: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.82.85 18587

Invalid size unit: "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.86 18588

Valid units are "bytes", "kB", "MB", "GB", and "TB".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.87 18589

Input data is missing padding, is truncated, or is otherwise corrupted.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.88 18590

Character with value 0x@1@ must be escaped.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.89 18591

Unicode high surrogate must not follow a high surrogate.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.90 18592

Unicode low surrogate must follow a high surrogate.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.91 18593

\\u0000 cannot be converted to text.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.92 18594

Unicode escape values cannot be used for code point values above 007F when the server encoding is not UTF8.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.93 18595

Escape sequence "\\@1@" is invalid.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.94 18596

The input string ended unexpectedly.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.95 18597

Expected end of input, but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.96 18598

Expected JSON value, but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.82.97 18599

Expected string, but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83 Message Numbers Beginning with 18600

2.83.1 18600

Expected array element or "]", but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.2 18601

Expected ",", or "]", but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.3 18602

Expected string or "}", but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.4 18603

Expected ":", but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.5 18604

Expected ", " or "}", but found "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.6 18605

Token "@1@" is invalid.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.7 18606

JSON data, line @1@: @2@@3@@4@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.8 18607

The arguments of json_build_object() must consist of alternating keys and values.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.9 18608

Object keys should be text.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.10 18609

Due to an implementation restriction, jsonb strings cannot exceed @1@ bytes.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.11 18610

Try calling the function in the FROM clause using a column definition list.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.12 18611

cannot replace existing key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Try using the function `jsonb_set` to replace the key value.

2.83.13 18612

Try using the function `jsonb_set` to replace key value.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.14 18613

levenshtein argument exceeds maximum length of @1@ characters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.15 18614

cannot use advisory locks during a parallel operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.16 18615

string is not a valid identifier: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

The string may have unclosed double quotation marks.

2.83.17 18616

String has unclosed double quotes.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.18 18617

Quoted identifier must not be empty.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.19 18618

No valid identifier before ".".**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.20 18619

No valid identifier after ".".**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.21 18620

Apply system library package updates.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.22 18621

invalid command name: "@1@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.23 18624

Valid values are "[]", "[]", "[]", and "()".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.24 18625

Junk after "empty" key word.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.25 18626

Missing left parenthesis or bracket.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.26 18627

Missing comma after lower bound.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.27 18628

Too many commas.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.28 18629

Junk after right parenthesis or bracket.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.29 18630

Key is not present in table "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.30 18631

Key is still referenced from table "@1@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.31 18632

Numeric time zones must have "-" or "+" as first character.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.32 18633

timestamp out of range: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.33 18634

distance in phrase operator should not be greater than @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.34 18635

distance in phrase operator should be non-negative and less than @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.35 18636

lexeme array may not contain nulls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.36 18637

weight array may not contain nulls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.37 18638

unrecognized weight: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.38 18639

For a single "@1@" use "@2@@3@".

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.39 18640

This probably indicates that the version of libxml2 being used is not compatible with the libxml2 header files that PostgreSQL was built with.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.40 18641

Make sure keystore_location points to the correct location. If the setting is correct, set the master encryption key to create the keystore.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.41 18642

keystore has been opened

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.83.42 18643

auto-open keystore has been opened

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.83.43 18644

Compile with --with-openssl to use transparent data encryption.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.44 18645

Specify keystore_location parameter in postgresql.conf.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.45 18646

The length of the passphrase must be between @1@ and @2@ bytes.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.46 18647

Check if keystore_location parameter points to a correct directory.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.47 18648

TRAP: ExceptionalCondition: bad arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.83.48 18649

TRAP: @1@(" @2@", File: " @3@", Line: @4@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.83.49 18650

Server has FUNC_MAX_ARGS = @1@, library has @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.50 18651

Server has INDEX_MAX_KEYS = @1@, library has @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.51 18652

Server has NAMEDATALEN = @1@, library has @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.52 18653

Server has FLOAT4PASSBYVAL = @1@, library has @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.53 18654

Server has FLOAT8PASSBYVAL = @1@, library has @2@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.54 18655

Magic block has unexpected length or padding difference.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.55 18656

Either another server is starting, or the lock file is the remnant of a previous server startup crash.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.56 18657

could not open file "@1@": @2@; continuing anyway

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Continues processing.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.57 18658

lock file "@1@" contains wrong PID: @2@ instead of @3@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.58 18659

Specify a path outside the data directory.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.59 18660

Specify a path outside the transaction log directory.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.60 18661

replication connection authorized: user=@1@ SSL enabled (protocol=@2@, cipher=@3@, compression=@4@)

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.83.61 18662

connection authorized: user=@1@ database=@2@ SSL enabled (protocol=@3@, cipher=@4@, compression=@5@)

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.83.62 18663

must be superuser or replication role to start walsender

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.63 18665

@1@: could not access directory "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.64 18666

Run initdb or pg_basebackup to initialize a PostgreSQL data directory.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.65 18667

@1@ does not know where to find the server configuration file. You must specify the --config-file or -D invocation option or set the PGDATA environment variable.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.66 18668

@1@ does not know where to find the database system data. This can be specified as "data_directory" in "@2@", or by the -D invocation option, or by the PGDATA environment variable.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.67 18669

@1@ does not know where to find the "hba" configuration file. This can be specified as "hba_file" in "@2@", or by the -D invocation option, or by the PGDATA environment variable.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.68 18670

@1@ does not know where to find the "ident" configuration file. This can be specified as "ident_file" in "@2@", or by the -D invocation option, or by the PGDATA environment variable.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.69 18671

Value exceeds integer range.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.70 18672

"temp_buffers" cannot be changed after any temporary tables have been accessed in the session.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.71 18673

Cannot enable parameter when "log_statement_stats" is true.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.72 18674

Cannot enable "log_statement_stats" when "log_parser_stats", "log_planner_stats", or "log_executor_stats" is true.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.73 18675

query-specified return tuple and function return type are not compatible

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.83.74 18676

query would be affected by row-level security policy for table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

To disable the policy for the table owner, use ALTER TABLE NO FORCE ROW LEVEL SECURITY.

2.83.75 18677

To disable the policy for the table's owner, use ALTER TABLE NO FORCE ROW LEVEL SECURITY.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.76 18678

Entry in time zone file "@1@", line @2@, conflicts with entry in file "@3@", line @4@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.77 18679

cannot have more than @1@ runs for an external sort

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.78 18680

Duplicate keys exist.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.79 18681

The source transaction is not running anymore.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.83.80 18682

@1@: WARNING: cannot create restricted tokens on this platform

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.81 18683

@1@: could not open process token: error code @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.82 18684

@1@: could not allocate SIDs: error code @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.83 18685

@1@: could not create restricted token: error code @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.84 18686

@1@: could not start process for command "@2@": error code @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.85 18687

@1@: could not re-execute with restricted token: error code @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.86 18688

@1@: could not get exit code from subprocess: error code @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.87 18689

You must run @1@ as the PostgreSQL superuser.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.88 18690

@1@: lock file "@2@" existsIs a server running? If not, delete the lock file and try again.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.89 18691

The database server was not shut down cleanly. Resetting the transaction log might cause data to be lost. If you want to proceed anyway, use -f to force reset.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.90 18692

If you are sure the data directory path is correct, execute touch @1@ and try again.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.83.91 18693

user does not exist

[Description]

user does not exist.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.92 18694

command not executable

[Description]

The command cannot be executed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.93 18695

command not found

[Description]

The command cannot be found.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.94 18696

The server (version @1@) does not support editing view definitions.

[Description]

The server does not support editing the view function.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.95 18697

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.83.96 18698

There is no previous error.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.83.97 18699

Query buffer is empty.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84 Message Numbers Beginning with 18700

2.84.1 18700

The server (version @1@) does not support showing view definitions.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.2 18701

view name is required

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.3 18702

\pset: allowed Unicode column line styles are single, double

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.4 18703

\\pset: allowed Unicode header line styles are single, double

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.5 18704

Pager won't be used for less than @1@ line.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.6 18705

could not parse reloptions array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.7 18706

The connection to the server was lost. Attempting reset:

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.8 18707

canceled by user

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.9 18708

trying to exit copy mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.10 18709

\\crosstabview: statement did not return a result set

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.11 18710

\\crosstabview: query must return at least three columns

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.12 18711

\\crosstabview: vertical and horizontal headers must be different columns

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.13 18712

\\crosstabview: data column must be specified when query returns more than three columns

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.14 18713

\\crosstabview: maximum number of columns (@1 @) exceeded

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.15 18714

\\crosstabview: query result contains multiple data values for row "@1@", column "@2@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.16 18715

\\crosstabview: column number @1@ is out of range 1..@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.17 18716

\\crosstabview: ambiguous column name: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.18 18717

\\crosstabview: column name not found: "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.19 18718

The server (version @1@) does not support access methods.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.20 18719

Did not find any text search parser named "@1@".

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.21 18720

could not find own program executable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.22 18721

buffer size is wrong

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.23 18722

source or destination file is not specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.24 18723

too many command-line arguments (first is "@1@")

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.25 18724

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.84.26 18725

could not create file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.27 18726

could not read file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.28 18727

could not write to file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.29 18728

could not fsync file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.30 18729

could not close file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.31 18730

user does not exist

[Description]

user does not exist.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.32 18731

user name lookup failure: error code @1@

[Description]

User name lookup failed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.33 18732

Cannot add header to table content: column count of @1@ exceeded.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.34 18733

Cannot add cell to table content: total cell count of @1@ exceeded.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.35 18734

invalid output format (internal error): @1@**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.36 18735

could not connect to database @1@: out of memory**[Description]**

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.84.37 18736

cannot reindex specific schema(s) in all databases

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.38 18737

cannot reindex specific schema(s) and system catalogs at the same time

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.39 18738

reindexing of schema "@1@" in database "@2@" failed: @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.40 18739

number of parallel jobs must be at least 1

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.41 18741

out of memory

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.84.42 18742

could not obtain lock on relation "@1@"This usually means that someone requested an ACCESS EXCLUSIVE lock on the table after the pg_dump parent process had gotten the initial ACCESS SHARE lock on the table.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.43 18743

schema "@1@" not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.44 18744

table "@1@" not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.45 18745

index "@1@" not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.46 18746

function "@1@" not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.47 18747

trigger "@1@" not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.48 18748

WARNING: don't know how to set owner for object type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.49 18749

archive was made on a machine with larger integers, some operations might fail

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.50 18750

archive is compressed, but this installation does not support compression -- no data will be available

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.51 18751

invalid creation date in header

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.52 18753

Synchronized snapshots are not supported by this server version. Run with --no-synchronized-snapshots instead if you do not need synchronized snapshots.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.53 18754

no matching tables were found for pattern "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.54 18755

Error message from server: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.55 18756

WARNING: owner of schema "@1@" appears to be invalid

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.56 18757

WARNING: owner of data type "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.57 18758

WARNING: owner of operator "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.58 18759

WARNING: owner of operator class "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.59 18760

WARNING: owner of operator family "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.60 18761

WARNING: owner of aggregate function "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.61 18762

WARNING: owner of function "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.62 18763

WARNING: owner of table "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.63 18764

WARNING: datatype of data type "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.64 18765

bogus value in proargmodes array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.65 18766

could not parse proallargtypes array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.66 18767

could not parse proargmodes array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.67 18768

could not parse proargnames array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.68 18769

could not parse proconfig array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.69 18770

unrecognized proparallel value for function "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.70 18771

bogus value in pg_cast.castfunc or pg_cast.castmethod field

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.71 18772

bogus value in pg_cast.castmethod field

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.72 18773

bogus transform definition, at least one of trffromsql and trftosql should be nonzero

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.73 18774

bogus value in pg_transform.trffromsql field

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.74 18775

bogus value in pg_transform.trftosql field

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.75 18777

WARNING: invalid type "@1@" of access method "@2@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.76 18778

aggregate function @1@ could not be dumped correctly for this database version; ignored

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.77 18779

could not parse initial GRANT ACL list (@1@) or initial REVOKE ACL list (@2@) for object "@3@" (@4@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.84.78 18780

could not parse reloptions array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.84.79 18781

could not connect to server: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.80 18782

source server must not be in recovery mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.81 18783

full_page_writes must be enabled in the source server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.82 18784

error running query (@1@) in source server: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.83 18785

unexpected result set from query

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.84 18786

unrecognized result "@1@" for current WAL insert location

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.85 18787

could not fetch file list: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.86 18788

unexpected result set while fetching file list

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.87 18789

could not send query: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.88 18790

could not set libpq connection to single row mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.89 18791

unexpected result while fetching remote files: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.90 18792

unexpected result set size while fetching remote files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.91 18793

unexpected data types in result set while fetching remote files: @1@ @2@ @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.92 18794

unexpected result format while fetching remote files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.93 18795

unexpected null values in result while fetching remote files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.94 18796

unexpected result length while fetching remote files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.95 18797

could not fetch remote file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.96 18798

unexpected result set while fetching remote file "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.84.97 18799

could not send COPY data: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85 Message Numbers Beginning with 18800

2.85.1 18801

could not send file list: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.2 18802

could not send end-of-COPY: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.3 18803

unexpected result while sending file list: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.4 18804

could not read WAL record at @1@/@2@: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.5 18805

could not read WAL record at @1@/@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.6 18806

could not find previous WAL record at @1@/@2@: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.7 18807

could not find previous WAL record at @1 @/@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.8 18808

WAL record modifies a relation, but record type is not recognized: lsn: @1 @/@2@, rmgr: @3@, info: @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.9 18809

cannot be executed by "root"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.10 18810

You must run @1 @ as the PostgreSQL superuser.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.11 18811

source and target clusters are from different systems

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.12 18812

clusters are not compatible with this version of pg_rewind

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.13 18813

target server needs to use either data checksums or "wal_log_hints = on"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.14 18814

target server must be shut down cleanly

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.15 18815

source data directory must be shut down cleanly

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.16 18816

invalid control file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.17 18817

could not find common ancestor of the source and target cluster's timelines

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.18 18818

backup label buffer too small

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.19 18819

unexpected control file CRC

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.20 18820

unexpected control file size @1@, expected @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.21 18822

syntax error in history file: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.22 18823

Expected a numeric timeline ID.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.23 18824

Expected a write-ahead log switchpoint location.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.24 18825

invalid data in history file: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.25 18826

Timeline IDs must be in increasing sequence.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.26 18827

invalid data in history file

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.27 18828

Timeline IDs must be less than child timeline's ID.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.28 18829

invalid record offset at @1 @/@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.29 18830

contrecord is requested by @1 @/@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.30 18831

record length @1 @ at @2 @/@3 @ too long

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.31 18832

there is no contrecord flag at @1 @/@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.32 18833

invalid contrecord length @1@ at @2@/@3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.33 18834

invalid resource manager ID @1@ at @2@/@3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.34 18835

record with incorrect prev-link @1@/@2@ at @3@/@4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.35 18836

incorrect resource manager data checksum in record at @1@/@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.36 18837

invalid magic number @1@ in log segment @2@, offset @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.37 18838

invalid info bits @1@ in log segment @2@, offset @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.38 18839

WAL file is from different database system: WAL file database system identifier is @1@, pg_control database system identifier is @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.39 18840

WAL file is from different database system: incorrect XLOG_SEG_SIZE in page header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.40 18841

WAL file is from different database system: incorrect XLOG_BLCKSZ in page header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.41 18842

unexpected pageaddr @1@/@2@ in log segment @3@, offset @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.42 18843

out-of-sequence timeline ID @1@ (after @2@) in log segment @3@, offset @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.43 18844

record with invalid length at @1@/@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.44 18845

invalid compressed image at @1 @/@2@, block @3@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.45 18847

WARNING: Calculated CRC checksum does not match value stored in file. Either the file is corrupt, or it has a different layout than this program is expecting. The results below are untrustworthy.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.46 18848

byte ordering mismatch**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.47 18849

possible byte ordering mismatch The byte ordering used to store the pg_control file might not match the one used by this program. In that case the results below would be incorrect, and the PostgreSQL installation would be incompatible with this data directory.**[Description]**

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.48 18850

too many command-line arguments (first is "@1@")

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.49 18851

out of memory

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.85.50 18852

cannot duplicate null pointer (internal error)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.51 18853

command not executable

[Description]

The command cannot be executed.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.52 18854

command not found

[Description]

The command cannot be found.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.53 18855

WARNING: online backup mode is activeShutdown will not complete until pg_stop_backup() is called.

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.85.54 18856

@1@: WARNING: cannot create restricted tokens on this platform

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.85.55 18857

@1@: WARNING: could not locate all job object functions in system API

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.85.56 18858

@1@: cannot be run as rootPlease log in (using, e.g., "su") as the (unprivileged) user that willown the server process.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.57 18859

out of memory

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.85.58 18860

cannot duplicate null pointer (internal error)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.59 18861

out of memory

[Description]

There was insufficient free space in the client's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- Modify the application to reduce memory usage.

2.85.60 18862

replication slots can only be used with WAL streaming

[Description]

Replication slots can only be used with WAL streaming.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.61 18863

WAL directory location must be an absolute path

[Description]

The transaction log directory location must be an absolute path.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.62 18864

Make sure the WAL archive area specified by archive_command parameter is writable and not full.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.63 18865

query result has too many rows to fit in a Perl array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.85.64 18867

query result has too many rows to fit in a Python list

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.65 18868

'@1@' is an invalid keyword argument for this function

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.66 18869

invalid SQLSTATE code

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.67 18870

PGresult is not an error result

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.85.68 18871

extraneous data in "t" message

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86 Message Numbers Beginning with 18900

2.86.1 18954

invalid operator "@1@" in @2@ section

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.2 18955

invalid format parameter "@1@" of field "@2@" in @3@ section

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.3 18956

timestamp parameter must be set with pair of the begin and end timestamp : "@1@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.4 18957

invalid timestamp parameters, the end timestamp must advance to the begin timestamp: begin = "@1@", end = "@2@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.5 18958

pgaudit must be loaded via shared_preload_libraries

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.6 18959

pgaudit must be set log_replication_commands.

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.7 18960

"pgaudit.config_file" must be specify when pgaudit is loaded

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.8 18961

error invalid token "@1@" in "@2@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.9 18962

redundant @1@ section defined in file "@2@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.10 18963

invalid parameter "@1@" in "@2@" in file "@3@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.11 18964

invalid operator "@1@" in file "@2@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.12 18965

syntax error near token "@1@" in file "@2@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.13 18966

unrecognized configuration token "@1@" in "@2@" in file "@3@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.14 18967

could not make FIFO special file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.15 18968

could not open FIFO special file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.16 18969

could not read from named pipe: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.17 18970

could not write audit log "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.18 18971

could not open audit log file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.19 18972

disabling automatic rotation

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.86.20 18973

pgaudit extension initialized

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.86.21 18974

following_async_walsenders parser failed

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.22 18975

Cannot specify "*" as standby names in "synchronous_standby_names" when "following_async_walsenders" is enabled

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.23 18976

Cannot enable "following_async_walsenders" when "*" is specify as standby names in "synchronous_standby_names"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.24 18977

Cannot specify the standby name (@1@) in "synchronous_standby_names" because it has been specified in "following_async_walsenders"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.25 18978

Cannot specify the standby name (@1@) in "following_async_walsenders" because it has been specified in "synchronous_standby_names"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.26 18979

tablespace "@1@" in the tablespaces list file does not exist

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.27 18980

no resource to backup with the copy command

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.28 18981

results of copying file does not exist

[Description]

The backup data may be corrupted.

[System Processing]

Processing will be aborted.

[Action]

Copy the backup data to the backup storage directory from backup media.

2.86.29 18982

Backup using the copy command has not been done

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.30 18983

option -Y is necessary because backup has been performed with the copy command

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.31 18984

option -Y must not be specified because backup has not been performed with the copy command

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.32 18985

could not set permissions of file "@1@": @2@ (errno=@3@)

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.33 18986

copy command "@1@" failed (mode=@2@): @3@**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.34 18987

tablespace name "@1@" has been overlapped in the tablespaces list file**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.35 18988

file "@1@" does not exist or is not a regular file**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.36 18989

tablespace "@1@" can not be specified in the tablespaces list file**[Description]**

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.37 18990

the tablespace name specified in the tablespaces list file could not be acquired: @1@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.86.38 18991

@1@: COPY FROM command must be specified

[Description]

COPY FROM command must be specified.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.86.39 18992

@1@: cannot launch more than @2@ workers

[Description]

The number of workers is too many

[System Processing]

Processing will be aborted.

[Action]

If the number of workers is high, reduce it.

2.86.40 18993

@1@: no table name specified

[Description]

No table name specified.

[System Processing]

Processing will be aborted.

[Action]

Please specify the table name you would load data.

2.86.41 18994

@1@: COPY TO command cannot be available

[Description]

COPY TO command cannot be available.

[System Processing]

Processing will be aborted.

[Action]

Please specify COPY FROM command.

2.86.42 18995

load failed

[Description]

Load failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.86.43 18996

could not start @1@ background processes

[Description]

Could not start %d background processes.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.86.44 18997

You might need to increase max_worker_processes.

[Description]

You might need to increase max_worker_processes.

[System Processing]

Processing will be aborted.

[Action]

You might need to increase max_worker_processes

2.86.45 18998

postmaster exited during a parallel loading

[Description]

postmaster exited during a parallel loading.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.86.46 18999

COPY statement cannot be null

[Description]

COPY statement cannot be null.

[System Processing]

Processing will be aborted.

[Action]

Please specify COPY FROM statement.

2.87 Message Numbers Beginning with 19000

2.87.1 19000

number of workers must not be negative

[Description]

The number of workers must not be negative.

[System Processing]

Processing will be aborted.

[Action]

Please specify more than one.

2.87.2 19001

lack of max_prepared_transactions

[Description]

Lack of max_prepared_transactions.

[System Processing]

Processing will be aborted.

[Action]

Please increase max_prepared_transactions.

2.87.3 19002

max_prepared_transactions must be set at least @1@

[Description]

Lack of max_prepared_transactions.

[System Processing]

Processing will be aborted.

[Action]

Please increase max_prepared_transactions.

2.87.4 19003

pgx_loader only available using COPY FROM

[Description]

pgx_loader can be available only COPY FROM command.

[System Processing]

Processing will be aborted.

[Action]

Please specify COPY FROM statement.

2.87.5 19004

failed to execute SPI returned @1@

[Description]

Could not execute SPI.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.6 19005

@1@ the prepared transaction with gid: "@2@"

[Description]

The prepared transaction has been completed.

[System Processing]

Continues processing.

[Action]

No action required.

2.87.7 19006

failed to delete the record with id: @1@(SPI returned: @2@)

[Description]

Could not delete the row in pgx_loader_state table.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.8 19007

could not write to the shared message queue for PID @1 @: "@2@"

[Description]

Could not write to the shared memory message queue.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.9 19008

COPY FROM instructs the PostgreSQL server process to read a file. You may want a client-side facility such as pgx_loader command.

[Description]

Failed to read the file.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.87.10 19009

failed to add new prepared transaction "@1@" by worker(@2@)

[Description]

Failed to add new prepared transaction.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.11 19010

failed to fetch id column from "@1@" by worker(@2@)

[Description]

Failed to fetch the id column.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.12 19011

cannot uniquely identify the id

[Description]

Could not uniquely identify the id.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.13 19012

record with gid: "@1@" and master_pid: @2@ might already exist

[Description]

Could not uniquely identify the id.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.14 19013

failed to update state column of record with id: @1@

[Description]

Failed to update the state column.

[System Processing]

Processing will be aborted.

[Action]

Please refer to the server log, and determine the cause of the error.

2.87.15 19014

could not get the status of file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.87.16 19015

could not open directory "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.87.17 19016

could not stat file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.87.18 19017

invalid value "@1@" for "@2@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.87.19 19018

could not open file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.87.20 19019

could not close file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.87.21 19020

[parallel worker failed to initialize](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.22 19021

[More details may be available in the server log.](#)

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.87.23 19022

[operator family "@1@" of access method @2@ contains support procedure @3@ with different left and right input types](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.24 19023

[operator family "@1@" of access method @2@ contains invalid ORDER BY specification for operator @3@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.25 19024

operator family "@1@" of access method @2@ contains operator @3@ with wrong signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.26 19025

operator family "@1@" of access method @2@ is missing cross-type operator(s)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.27 19026

could not determine data type for argument @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.28 19027

@1@: data directory is of wrong version File "@2@" contains "@3@", which is not compatible with this program's version "@4@".

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.87.29 19028

@1@: could not clear search_path: @2@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.87.30 19029

@1@: query returned @2@ row instead of one: @3@

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.87.31 19030

@1@: could not stat file "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.32 19031

@1@: could not open directory "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.33 19032

@1@: could not read directory "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.34 19033

@1@: could not open file "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.35 19034

@1@: could not fsync file "@2@" to "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.36 19035

@1@: could not rename file "@2@" to "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.37 19036

password too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.38 19037

block number out of range: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.39 19038

corrupted BRIN index: inconsistent range map

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.40 19039

invalid overflow block number @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.41 19040

removing stale two-phase state from memory for transaction @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.87.42 19041

removing future two-phase state from memory for transaction @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.87.43 19042

cannot PREPARE a transaction that has manipulated logical replication workers

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.87.44 19043

cannot PREPARE a transaction that has manipulated logical replication workers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.45 19044

could not open write-ahead log directory "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.46 19045

could not generate secret authorization token

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.47 19046

cannot use IN SCHEMA clause when using GRANT/REVOKE ON SCHEMAS

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.48 19047

permission denied for statistics object @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.49 19048

permission denied for publication @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.50 19049

permission denied for subscription @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.51 19050

must be owner of statistics object @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.52 19051

must be owner of publication @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.53 19052

must be owner of subscription @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.54 19053

publication with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.55 19054

subscription with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.56 19055

statistics object with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.57 19056

cannot add NO INHERIT constraint to partitioned table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.58 19057

statistics object "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.59 19058

must specify relation and object name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.60 19059

publication relation "@1@" in publication "@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.61 19060

empty range bound specified for partition "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.62 19061

partition "@1@" would overlap partition "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.63 19062

"@1@" is a partitioned table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.64 19063

"@1@" is a system table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.65 19064

table "@1@" cannot be replicated

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.66 19065

relation "@1@" is already member of publication "@2@"**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.67 19066

publication "@1@" does not exist**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.68 19067

subscription "@1@" does not exist**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.69 19068

publication "@1@" already exists**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.70 19069

subscription "@1@" already exists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.71 19070

statistics object "@1@" already exists in schema "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.72 19071

column "@1@" of relation "@2@" appears more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.73 19072

collation "default" cannot be copied

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.74 19073

unrecognized collation provider: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.75 19074

could not convert locale name "@1@" to language tag: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.76 19075

must be superuser to import system collations

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.77 19076

no usable system locales were found

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.87.78 19077

cannot copy from partitioned table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.79 19078

cannot route inserted tuples to a foreign table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.80 19079

database "@1@" is being used by logical replication subscription

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.81 19080

statistics object "@1@" does not exist, skipping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.82 19081

publication "@1@" does not exist, skipping

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.87.83 19082

extension "@1@" has no installation script nor update path for version "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.84 19083

user mapping for "@1@" already exists for server "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.85 19084

third argument of cast function must be type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.86 19085

cannot create unique index on partitioned table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.87 19086

invalid list syntax for "publish" option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.88 19087

unrecognized "publish" value: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.89 19088

unrecognized publication parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.90 19089

must be superuser to create FOR ALL TABLES publication

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.91 19090

publication "@1@" is defined as FOR ALL TABLES

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.92 19091

relation "@1@" is not part of the publication

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.93 19092

permission denied to change owner of publication "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.94 19093

invalid sequence option SEQUENCE NAME

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.95 19094

identity column type must be smallint, integer, or bigint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.96 19095

MAXVALUE (@1@) is out of range for sequence data type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.97 19096

MINVALUE (@1@) is out of range for sequence data type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.98 19097

cannot change ownership of identity sequence

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.99 19098

only a single relation is allowed in CREATE STATISTICS

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.87.100 19099

relation "@1@" is not a table, foreign table, or materialized view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88 Message Numbers Beginning with 19100

2.88.1 19100

only simple column references are allowed in CREATE STATISTICS

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.2 19101

statistics creation on system columns is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.3 19102

column "@1@" cannot be used in statistics because its type @2@ has no default btree

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.4 19103

cannot have more than @1@ columns in statistics

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.5 19104

extended statistics require at least 2 columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.6 19105

duplicate column name in statistics definition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.7 19106

unrecognized statistics kind "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.8 19107

unrecognized subscription parameter: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.9 19115

publication name "@1@" used more than once

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.10 19116

must be superuser to create subscriptions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.11 19117

could not connect to the publisher: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.12 19118

tables were not subscribed, you will have to run @1@ to subscribe the tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.13 19119

cannot set @1@ for enabled subscription

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.14 19120

cannot enable subscription that does not have a slot name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.15 19121

ALTER SUBSCRIPTION with refresh is not allowed for disabled subscriptions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.16 19122

ALTER SUBSCRIPTION ... REFRESH is not allowed for disabled subscriptions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.17 19123

could not drop the replication slot "@1@" on publisher

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.18 19124

permission denied to change owner of subscription "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.19 19125

could not receive list of replicated tables from the publisher: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.20 19127

"@1@" is not partitioned

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.21 19128

cannot partition using more than @1@ columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.22 19129

cannot truncate only a partitioned table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.23 19130

cannot inherit from partitioned table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.24 19131

cannot inherit from partition "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.25 19132

partition constraint is violated by some row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.26 19133

cannot add column to a partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.27 19134

cannot recursively add identity column to table that has child tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.28 19135

cannot remove constraint from only the partitioned table when partitions exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.29 19136

column "@1@" of relation "@2@" is an identity column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.30 19137

column "@1@" is marked NOT NULL in parent table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.31 19139

column "@1@" of relation "@2@" must be declared NOT NULL before identity can be added

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.32 19140

column "@1@" of relation "@2@" is already an identity column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.33 19141

column "@1@" of relation "@2@" already has a default value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.34 19142

column "@1@" of relation "@2@" is not an identity column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.35 19144

cannot drop column "@1@" because it is part of the partition key of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.36 19145

cannot drop column from only the partitioned table when partitions exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.37 19148

cannot alter column "@1@" because it is part of the partition key of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.38 19149

cannot change inheritance of a partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.39 19150

cannot change inheritance of partitioned table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.40 19151

cannot inherit from a partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.41 19152

trigger "@1@" prevents table "@2@" from becoming an inheritance child

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.42 19153

relation "@1@" is not a partition of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.43 19154

cannot change table "@1@" to unlogged because it is part of a publication

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.44 19155

unrecognized partitioning strategy "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.45 19156

cannot use "list" partition strategy with more than one column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.46 19157

column "@1@" appears more than once in partition key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.47 19158

column "@1@" named in partition key does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.48 19159

cannot use system column "@1@" in partition key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.49 19160

functions in partition key expression must be marked IMMUTABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.50 19161

partition key expressions cannot contain whole-row references

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.51 19162

partition key expressions cannot contain system column references

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.52 19163

cannot use constant expression as partition key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.53 19164

could not determine which collation to use for partition expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.54 19166

"@1@" is already a partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.55 19167

cannot attach a typed table as partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.56 19168

cannot attach inheritance child as partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.57 19169

cannot attach inheritance parent as partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.58 19170

cannot attach a permanent relation as partition of temporary relation "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.59 19171

cannot attach as partition of temporary relation of another session

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.60 19172

cannot attach temporary relation of another session as partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.61 19173

table "@1@" contains column "@2@" not found in parent "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.62 19174

trigger "@1@" prevents table "@2@" from becoming a partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.63 19175

ROW triggers with transition tables are not supported on partitions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.64 19176

ROW variable naming in the REFERENCING clause is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.65 19177

ROW triggers with transition tables are not supported on inheritance children

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.66 19178

transition table name can only be specified for an AFTER trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.67 19179

TRUNCATE triggers with transition tables are not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.68 19180

transition tables cannot be specified for triggers with more than one event

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.69 19181

transition tables cannot be specified for triggers with column lists

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.70 19182

NEW TABLE can only be specified for an INSERT or UPDATE trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.71 19183

NEW TABLE cannot be specified multiple times

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.72 19184

OLD TABLE can only be specified for a DELETE or UPDATE trigger

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.73 19185

OLD TABLE cannot be specified multiple times

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.74 19186

OLD TABLE name and NEW TABLE name cannot be the same

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.75 19187

attribute @1@ of type @2@ has been dropped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.76 19188

attribute @1@ of type @2@ has wrong type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.77 19189

new row for relation "@1@" violates partition constraint

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.78 19190

no partition of relation "@1@" found for row

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.79 19191

cannot update table "@1@" because it does not have a replica identity and publishes updates**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.80 19192

cannot delete from table "@1@" because it does not have a replica identity and publishes deletes**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.81 19193

cannot use relation "@1@.@2@" as logical replication target**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.82 19194

namespace URI must not be null**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.83 19195

row filter expression must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.84 19196

column filter expression must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.85 19197

null is not allowed in column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.86 19198

UNENCRYPTED PASSWORD is no longer supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.88.87 19199

sequence option "@1@" not supported here

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89 Message Numbers Beginning with 19200

2.89.1 19200

unrecognized row security option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.2 19201

only one DEFAULT value is allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.3 19202

only one PATH value per column is allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.4 19203

conflicting or redundant NULL / NOT NULL declarations for column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.5 19204

unrecognized column option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.6 19205

malformed SCRAM message

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.7 19206

invalid SCRAM response

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.8 19207

could not generate random salt

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.9 19208

client requires SCRAM channel binding, but it is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.10 19209

client uses authorization identity, but it is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.11 19210

client requires an unsupported SCRAM extension

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.12 19211

non-printable characters in SCRAM nonce

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.13 19212

could not generate random nonce

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.14 19213

unexpected SCRAM channel-binding attribute in client-final-message

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.15 19214

SASL authentication is not supported in protocol version 2

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.16 19215

expected SASL response, got message type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.17 19216

client selected an invalid SASL authentication mechanism

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.18 19217

private key file "@1@" cannot be reloaded because it requires a passphrase

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.19 19218

could not set the cipher list (no valid ciphers available)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.20 19219

could not initialize SSL connection: SSL context not set up

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.21 19220

could not open DH parameters file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.22 19221

could not load DH parameters file: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.23 19222

invalid DH parameters: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.24 19223

invalid DH parameters: p is not prime

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.25 19224

invalid DH parameters: neither suitable generator or safe prime

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.26 19225

DH: could not load DH parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.27 19226

DH: could not set DH parameters: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.28 19227

could not parse RADIUS server list "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.29 19228

could not parse RADIUS port list "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.30 19229

could not parse RADIUS secret list "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.31 19230

could not parse RADIUS identifiers list "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.32 19231

ON CONFLICT clause is not supported with partitioned tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.33 19232

@1@ cannot be applied to a table function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.34 19233

@1@ cannot be applied to a named tuplestore

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.35 19234

aggregate functions are not allowed in partition key expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.36 19235

grouping operations are not allowed in partition key expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.37 19236

aggregate function calls cannot contain set-returning function calls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.38 19237

window functions are not allowed in partition key expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.39 19238

relation "@1@" cannot be the target of a modifying statement

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.40 19239

set-returning functions must appear at top level of FROM

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.41 19240

only one FOR ORDINALITY column is allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.42 19241

column name "@1@" is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.43 19242

namespace name "@1@" is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.44 19243

only one default namespace is allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.45 19244

could not determine polymorphic type because input has type @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.46 19245

DEFAULT is not allowed in this context

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.47 19246

@1@ must not return a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.48 19247

source for a multiple-column UPDATE item must be a sub-SELECT or ROW() expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.49 19248

set-returning functions are not allowed in @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.50 19249

cannot use subquery in partition key expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.51 19250

window function calls cannot contain set-returning function calls

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.52 19251

function name "@1@" is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.53 19252

could not find a function named "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.54 19253

set-returning functions are not allowed in JOIN conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.55 19254

set-returning functions are not allowed in policy expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.56 19255

set-returning functions are not allowed in window definitions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.57 19256

set-returning functions are not allowed in check constraints

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.58 19257

set-returning functions are not allowed in DEFAULT expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.59 19258

set-returning functions are not allowed in index expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.60 19259

set-returning functions are not allowed in index predicates

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.61 19260

set-returning functions are not allowed in transform expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.62 19261

set-returning functions are not allowed in EXECUTE parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.63 19262

set-returning functions are not allowed in trigger WHEN conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.64 19263

set-returning functions are not allowed in partition key expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.65 19264

cannot create partitioned table as inheritance child

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.66 19265

multiple identity specifications for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.67 19266

primary key constraints are not supported on partitioned tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.68 19267

unique constraints are not supported on partitioned tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.69 19268

foreign key constraints are not supported on partitioned tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.70 19269

both default and identity specified for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.71 19270

exclusion constraints are not supported on partitioned tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.72 19271

invalid bound specification for a list partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.73 19272

invalid bound specification for a range partition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.74 19273

FROM must specify exactly one value per partitioning column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.75 19274

TO must specify exactly one value per partitioning column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.76 19275

cannot specify NULL in range bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.77 19276

every bound following MAXVALUE must also be MAXVALUE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.78 19277

every bound following MINVALUE must also be MINVALUE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.79 19278

specified value cannot be cast to type @1@ for column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.80 19279

invalid connection string syntax: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.81 19280

error while shutting down streaming COPY: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.82 19281

could not create replication slot "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.83 19282

invalid query response

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.84 19283

the query interface requires a database connection

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.85 19284

cannot start logical replication workers when max_replication_slots = 0

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.86 19285

out of logical replication worker slots

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.89.87 19286

out of background worker slots

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.89.88 19287

logical replication worker slot @1@ is empty, cannot attach

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.89 19288

replication origin "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.90 19289

replication origin with OID @1@ does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.91 19290

logical replication target relation "@1@.@2@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.92 19291

built-in type @1@ not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.93 19292

data type "@1@.@2@" required for logical replication does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.94 19293

initial slot snapshot too large

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.95 19294

could not fetch table info for table "@1@.@2@" from publisher: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.96 19295

table "@1@.@2@" not found on publisher

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.97 19296

could not fetch table info for table "@1@.@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.98 19297

could not start initial contents copy for table "@1@.@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.99 19298

table copy could not start transaction on publisher

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.89.100 19299

table copy could not finish transaction on publisher

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90 Message Numbers Beginning with 19300

2.90.1 19300

ORIGIN message sent out of order

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.2 19301

invalid logical replication message type "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.3 19302

terminating logical replication worker due to timeout

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.4 19303

subscription has no replication slot set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.5 19304

invalid proto_version

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.6 19305

proto_version "@1@" out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.7 19306

invalid publication_names syntax

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.8 19307

client sent proto_version=@1@ but we only support protocol @2@ or lower

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.9 19308

client sent proto_version=@1@ but we only support protocol @2@ or higher

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.10 19309

publication_names parameter missing

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.11 19310

number of synchronous standbys (@1@) must be greater than zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.12 19311

IDENTIFY_SYSTEM has not been run before START_REPLICATION

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.13 19312

cannot execute new commands while WAL sender is in stopping mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.14 19313

cannot execute SQL commands in WAL sender for physical replication

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.15 19314

cannot convert partitioned table "@1@" to a view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.16 19315

cannot convert partition "@1@" to a view

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.17 19316

cannot insert into column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.18 19317

column "@1@" can only be updated to DEFAULT

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.19 19319

statistics object "@1@.@2@" could not be computed for relation "@3@.@4@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.90.20 19324

out of shared memory (@1@ bytes requested)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.21 19325

terminating logical replication worker due to administrator command

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.22 19326

case conversion failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.23 19327

formatting field "@1@" is only supported in to_char

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.24 19328

expected json array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.25 19329

malformed json array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.26 19330

macaddr8 data out of range to convert to macaddr

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.27 19331

log format "@1@" is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.28 19332

cannot convert infinity to numeric

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.29 19333

collation provider LIBC is not supported on this platform

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.30 19334

collations with different collate and ctype values are not supported by ICU

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.31 19335

could not open collator for locale "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.32 19336

collation "@1@" has no actual version, but a version was specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.33 19337

collation "@1@" has version mismatch

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.34 19338

could not open ICU converter for encoding "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.35 19339

@1@ failed: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.36 19340

@1@ failed: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.37 19341

@1@ does not support the "global" option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.38 19342

@1@ does not support the "global" option

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.39 19343

transaction ID @1@ is in the future

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.40 19344

collation failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.41 19345

sort key generation failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.42 19346

DEFAULT namespace is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.43 19347

row path filter must not be empty string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.44 19348

column path filter must not be empty string

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.45 19349

more than one value returned by column XPath expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.46 19350

could not find function information for function "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.47 19351

encoding "@1@" not supported by ICU

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.48 19352

could not attach to dynamic shared area

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.49 19353

\\@1@ command ignored; use \\endif or Ctrl-C to exit current \\if block

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.50 19354

\\elif: cannot occur after \\else

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.51 19355

\\elif: no matching \\if

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.52 19356

\\else: cannot occur after \\else

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.53 19357

\\else: no matching \\if

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.54 19358

\\endif: no matching \\if

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.55 19359

shell command argument contains a newline or carriage return: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.56 19360

Did not find any settings for role "@1@" and database "@2@".

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.57 19361

Did not find any text search parsers.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.58 19362

Did not find any text search configurations.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.59 19363

The server (version @1@) does not support publications.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.60 19364

Did not find any publication named "@1@".

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.61 19365

Did not find any publications.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.62 19366

The server (version @1@) does not support subscriptions.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.63 19367

\\if: escaped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.64 19368

query ignored; use `\endif` or `Ctrl-C` to exit current `\if` block

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.65 19369

reached EOF without finding closing `\endif(s)`

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.66 19370

unrecognized collation provider: `@1@`

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.67 19371

unrecognized value "`@1@`" for "`@2@`": Boolean expected

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.68 19372

invalid value "@1@" for "@2@": integer

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.69 19373

invalid variable name: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.70 19374

could not write to output file: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.71 19375

no matching schemas were found for pattern "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.72 19376

WARNING: owner of publication "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.90.73 19377

subscriptions not dumped because current user is not a superuser

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.90.74 19378

WARNING: owner of subscription "@1@" appears to be invalid

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.90.75 19379

could not parse subpublications array

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.90.76 19380

failed sanity check, parent table with OID @1@ of pg_rewrite entry with OID @2@ not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.77 19381

invalid number of parents @1@ for table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.78 19382

could not rename file "@1@" to "@2@" : @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.79 19383

failed to remove WAL directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.80 19384

failed to remove contents of WAL directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.81 19385

could not open file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.82 19386

failed to remove data directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.83 19387

failed to remove contents of data directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.84 19388

failed to remove WAL directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.85 19389

failed to remove contents of WAL directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.86 19390

data directory "@1@" not removed at user's request

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.87 19391

WAL directory "@1@" not removed at user's request

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.88 19392

changes to tablespace directories will not be undone

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.89 19393

could not finish writing WAL files: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.90 19394

cannot stream write-ahead logs in tar mode to stdout

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.91 19395

--no-slot cannot be used with slot name

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.92 19396

could not open compressed file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.93 19397

could not seek in compressed file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.94 19398

could not read compressed file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.90.95 19399

compressed segment file "@1@" has incorrect uncompressed size @2@, skipping

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91 Message Numbers Beginning with 19400

2.91.1 19400

could not parse end position "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.2 19401

--endpos may only be specified with --start

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.3 19402

could not get size of write-ahead log file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.4 19403

could not fsync existing write-ahead log file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.5 19404

could not open write-ahead log file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.6 19405

@1@: could not create temporary replication slot "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.7 19406

could not compress data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.8 19407

could not reset compression stream

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.9 19408

could not initialize compression library

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.10 19409

implementation error: tar files can't have more than one open file

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.11 19410

could not create tar header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.12 19411

could not change compression parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.13 19412

unlink not supported with compression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.14 19413

could not close compression stream

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.15 19414

archive location "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.16 19416

could not remove file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.17 19417

could not read archive location "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.18 19418

could not close archive location "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.19 19419

could not open archive location "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.20 19420

invalid file name argument

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.21 19421

failed to get system locale name for "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.22 19422

must specify archive location

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.23 19423

must specify oldest kept WAL file

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.24 19424

too many command-line arguments

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.25 19425

This utility can only upgrade from PostgreSQL version 8.4 and later.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.26 19426

This utility can only upgrade to PostgreSQL version @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.27 19427

This utility cannot be used to downgrade to older major PostgreSQL versions.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.28 19428

Old cluster data and binary directories are from different major versions.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.29 19429

New cluster data and binary directories are from different major versions.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.30 19430

encodings for database "@1@" do not match: old "@2@", new "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.31 19431

lc_collate values for database "@1@" do not match: old "@2@", new "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.32 19432

lc_ctype values for database "@1@" do not match: old "@2@", new "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.33 19433

New cluster database "@1@" is not empty: found relation "@2@.@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.34 19434

could not open file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.35 19435

could not add execute permission to file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.36 19436

database user "@1@" is not the install user

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.37 19437

could not determine the number of users

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.38 19438

Only the install user can be defined in the new cluster.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.39 19439

The source cluster contains prepared transactions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.40 19440

The target cluster contains prepared transactions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.41 19441

The source cluster contains roles starting with "pg_"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.42 19442

The target cluster contains roles starting with "pg_"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.43 19443

failed to get the current locale

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.44 19444

failed to restore old locale "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.45 19445

could not get control data using @1@: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.46 19446

@1@: pg_resetwal problem

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.47 19447

@1@: controldata retrieval problem

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.48 19448

The source cluster lacks some required control information:**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.49 19449

The target cluster lacks some required control information:**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.50 19450

Cannot continue without required control information, terminating**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.51 19451

old and new pg_controldata alignments are invalid or do not matchLikely one cluster is a 32-bit install, the other 64-bit**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.52 19452

old and new pg_controldata block sizes are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.53 19453

old and new pg_controldata maximum relation segment sizes are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.54 19454

old and new pg_controldata WAL block sizes are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.55 19455

old and new pg_controldata WAL segment sizes are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.56 19456

old and new pg_controldata maximum identifier lengths are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.57 19457

old and new pg_controldata maximum indexed columns are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.58 19458

old and new pg_controldata maximum TOAST chunk sizes are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.59 19459

old and new pg_controldata large-object chunk sizes are invalid or do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.60 19460

old and new pg_controldata date/time storage types do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.61 19461

old cluster does not use data checksums but the new one does

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.62 19462

old cluster uses data checksums but the new one does not

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.63 19463

old and new cluster pg_controldata checksum versions do not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.64 19464

Unable to rename @1@ to @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.65 19465

could not get pg_ctl version data using @1@: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.66 19466

could not get pg_ctl version output from @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.67 19467

command too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.68 19468

could not write to log file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.69 19469

There were problems executing "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.70 19470

could not open file "@1@" for reading: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.71 19471

You must have read and write access in the current directory.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.72 19472

check for "@1@" failed: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.73 19473

"@1@" is not a directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.74 19474

check for "@1@" failed: not a regular file

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.75 19475

check for "@1@" failed: cannot read file (permission denied)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.76 19476

check for "@1@" failed: cannot execute (permission denied)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.77 19477

error while copying relation "@1@.@2@" : could not open file "@3@" : @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.78 19478

error while copying relation "@1@.@2@": could not create file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.79 19479

error while copying relation "@1@.@2@": could not read file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.80 19480

error while copying relation "@1@.@2@": could not write file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.81 19481

error while copying relation "@1@.@2@" ("@3@" to "@4@"): @5@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.82 19482

error while creating link for relation "@1@.@2@" ("@3@" to "@4@"): @5@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.83 19483

error while copying file ("@1@" to "@2@"): could not open file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.84 19484

error while copying file ("@1@" to "@2@"): could not create file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.85 19485

error while copying file ("@1@" to "@2@"): could not read file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.86 19486

error while copying file ("@1@" to "@2@"): could not write file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.87 19487

error while copying file ("@1@" to "@2@"): @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.88 19488

error while linking file ("@1@" to "@2@"): @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.89 19489

error while copying relation "@1@.@2@": could not stat file "@3@": @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.90 19490

error while copying relation "@1@.@2@": partial page found in file "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.91 19491

@1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.92 19492

Remove the problem functions from the old cluster to continue.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.93 19493

Checking for presence of required libraries

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.94 19494

could not load library "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.95 19495

Failed to match up old and new tables in database "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.96 19496

which is an index on "@1@.@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.97 19497

which is an index on OID @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.98 19498

which is the TOAST table for "@1@.@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.91.99 19499

[which is the TOAST table for OID @1@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92 Message Numbers Beginning with 19500

2.92.1 19500

[No match found in old cluster for new relation with OID @1@ in database "@2@": @3@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.2 19501

[No match found in new cluster for old relation with OID @1@ in database "@2@": @3@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.3 19502

[mappings for database "@1@":](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.4 19503

[@1@.@2@: @3@ to @4@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.5 19505

[source databases:](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.6 19506

[target databases:](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.7 19507

[Database: @1@](#)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.8 19508

relname: @1 @. @2@: relolid: @3@ reltblspace: @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.9 19509

@1@: cannot be run as root

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.10 19510

invalid old port number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.11 19511

invalid new port number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.12 19512

Running in verbose mode

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.13 19513

Try "[@1@ --help](#)" for more information.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.14 19514

old cluster binaries reside

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.15 19515

new cluster binaries reside

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.16 19516

old cluster data resides

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.17 19517

new cluster data resides

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.18 19518

could not determine current directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.19 19519

cannot run pg_upgrade from inside the new cluster data directory on Windows

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.20 19520

pg_upgrade upgrades a PostgreSQL cluster to a different major version.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.21 19521

Usage:

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.22 19522

pg_upgrade [OPTION]...

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.23 19523

Options:

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.24 19524

-b, --old-bindir=BINDIR old cluster executable directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.25 19525

-B, --new-bindir=BINDIR new cluster executable directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.26 19526

-c, --check check clusters only, don't change any data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.27 19527

-d, --old-datadir=DATADIR old cluster data directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.28 19528

-D, --new-datadir=DATADIR new cluster data directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.29 19529

-j, --jobs number of simultaneous processes or threads to use

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.30 19530

-k, --link link instead of copying files to new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.31 19531

-o, --old-options=OPTIONS old cluster options to pass to the server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.32 19532

-O, --new-options=OPTIONS new cluster options to pass to the server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.33 19533

-p, --old-port=PORT old cluster port number (default @1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.34 19534

-P, --new-port=PORT new cluster port number (default @1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.35 19535

-r, --retain retain SQL and log files after success

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.36 19536

-U, --username=NAME cluster superuser (default "@1@")

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.37 19537

-v, --verbose enable verbose internal logging**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.38 19538

-V, --version display version information, then exit**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.39 19539

-, --help show this help, then exit**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.40 19540

Report bugs to <pgsql-bugs@postgresql.org>.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.41 19541

Finding the real data directory for the source cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.42 19542

Finding the real data directory for the target cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.43 19543

could not get data directory using @1@: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.44 19544

could not read line @1@ from file "@2@": @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.45 19545

user-supplied old port number @1@ corrected to @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.46 19546

could not create worker process: @1 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.47 19547

could not create worker thread: @1 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.48 19548

child worker exited abnormally: @1 @

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.49 19549

Setting next OID for new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.50 19550

Sync data directory to disk

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.51 19551

@1@: could not find own program executable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.52 19552

Analyzing all rows in the new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.53 19553

Freezing all rows in the new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.54 19554

Restoring global objects in the new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.55 19555

Restoring database schemas in the new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.56 19556

Deleting files from new @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.57 19557

could not delete directory "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.58 19558

Copying old @1@ to new server

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.59 19559

Setting next transaction ID and epoch for new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.60 19560

Setting next multixact ID and offset for new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.61 19561

Setting oldest multixact ID in new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.62 19562

Resetting WAL archives

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.63 19563

Setting frozenxid and minmxid counters in new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.64 19564

Setting minmxid counter in new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.65 19565

error while checking for existence of keystore file @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.66 19566

Linking user relation files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.67 19567

Copying user relation files

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.68 19568

copying "@1@" to "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.69 19569

linking "@1@" to "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.70 19570

old database "@1@" not found in the new cluster

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.71 19571

error while checking for file existence "@1@.@2@" ("@3@" to "@4@"): @5@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.72 19572

rewriting "@1@" to "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.73 19573

connection to database failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.74 19574

Failure, exiting

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.75 19575

executing: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.76 19576

SQL command failed @1@@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.77 19577

could not open version file: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.78 19578

could not parse PG_VERSION file from @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.79 19579

connection to database failed: @1@**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.80 19580

pg_ctl failed to start the source server, or connection failed**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.81 19581

pg_ctl failed to start the target server, or connection failed**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.82 19582

out of memory**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.83 19583

libpq environment variable @1@ has a non-local server value: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.84 19584

tablespace directory "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.85 19585

could not stat tablespace directory "@1@" : @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.86 19586

tablespace path "@1@" is not a directory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.87 19587

%-*s

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.88 19588

ok

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.89 19589

Checking for large objects

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.90 19590

warning

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.91 19591

Checking for incompatible "line" data type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.92 19592

Checking for invalid "unknown" user columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.93 19593

Checking for hash indexes

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.94 19594

@1@: unexpected empty file "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.95 19595

@1@: pg_control exists but is broken or wrong version; ignoring it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.96 19596

could not find file "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.97 19597

could not seek in log file @1@ to offset @2@: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.98 19598

could not read from log file @1@, offset @2@, length @3@: @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.92.99 19599

no arguments specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93 Message Numbers Beginning with 19600

2.93.1 19600

could not parse end WAL location "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.2 19601

could not parse limit "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.3 19602

resource manager "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.4 19603

could not parse start WAL location "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.5 19604

could not parse timeline "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.6 19605

could not parse "@1@" as a transaction ID

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.7 19606

unrecognized argument to --stats: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.8 19607

too many command-line arguments (first is "@1@")

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.9 19608

path "@1@" could not be opened: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.10 19609

could not open directory "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.11 19610

could not open file "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.12 19611

start WAL location @1@/@2@ is not inside file "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.13 19612

ENDSEG @1@ is before STARTSEG @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.14 19613

end WAL location @1 @/@2@ is not inside file "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.15 19614

no start WAL location given

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.16 19615

out of memory

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.17 19616

could not find a valid record after @1 @/@2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.18 19617

error in WAL record at @1 @/@2@: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.19 19618

cannot set system attribute "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.20 19619

function "@1@" is in the wrong language

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.21 19620

function "@1@" must not be SECURITY DEFINER

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.22 19621

set-valued function called in context that cannot accept a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.23 19622

column name/value list must have even number of elements

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.24 19623

column name/value list contains nonexistent column name "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.25 19624

cannot set system attribute "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.26 19625

malformed record literal: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.27 19626

number of array dimensions exceeds the maximum allowed (@1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.28 19627

could not determine sequence length for function return value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.29 19628

array size exceeds the maximum allowed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.30 19629

wrong length of inner sequence: has length @1@, but @2@ was expected

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.31 19630

malformed SCRAM message (empty message)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.32 19631

malformed SCRAM message (length mismatch)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.33 19632

incorrect server signature

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.34 19633

invalid SCRAM exchange state

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.35 19634

malformed SCRAM message (attribute "@1@" expected)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.36 19635

malformed SCRAM message (expected character "=" for attribute "@1@")

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.37 19636

could not generate nonce

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.38 19637

invalid SCRAM response (nonce mismatch)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.39 19638

malformed SCRAM message (invalid iteration count)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.40 19639

malformed SCRAM message (garbage at end of server-first-message)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.41 19640

error received from server in SCRAM exchange: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.42 19641

malformed SCRAM message (garbage at end of server-final-message)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.43 19642

malformed SCRAM message (invalid server signature)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.44 19643

out of memory allocating SSPI buffer (@1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.45 19644

duplicate SSPI authentication request

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.46 19645

duplicate SASL authentication request

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.47 19646

none of the server's SASL authentication mechanisms are supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.48 19647

out of memory allocating SASL buffer (@1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.49 19648

AuthenticationSASLFinal received from server, but SASL authentication was not completed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.50 19649

unexpected shape of result set returned for SHOW

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.51 19650

password_encryption value too long

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.52 19651

unrecognized password encryption algorithm "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.53 19652

could not match @1@ host names to @2@ hostaddrs

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.54 19653

could not match @1@ port numbers to @2@ hosts

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.55 19654

invalid target_session_attrs value: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.56 19655

invalid target_server value: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.57 19656

could not parse network address "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.58 19657

PGresult cannot support more than INT_MAX tuples

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.59 19658

size_t overflow

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.60 19659

cannot pass more than @1@ arguments to a function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.61 19660

set-valued function called in context that cannot accept a set

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.62 19661

More details may be available in the server log.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.63 19662

Kill all remaining database processes and restart the database.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.64 19663

deadlock detected

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.65 19664

VCI parallel execution is blocked by other operation.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.66 19665

not enough maximum share memory for parallel query (@1@ bytes requested)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.67 19666

You possibly need to raise the configuration parameter "vci.shared_work_mem" value to be at least @1@kB.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.68 19667

You may need to increase max_worker_processes.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.69 19669

Failed on request of size @1@.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.93.70 19670

failed to shm_open()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.71 19671

could not open file "@1@": @2@

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.93.72 19672

could not get handle of the kernel module : error code @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.73 19673

the relation is not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.74 19674

access method "@1@" does not work with partitioned tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.75 19675

The "vci_column_ids" option cannot be used without "ctid" column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.76 19676

VCI failed to catch up with dropped columns in table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.77 19677

Automatically recreated "CREATE INDEX" is corrupt. Please recreate VCI by "vci_create()" function.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.78 19688

compress method must be defined when leaf type is different from input type

[Description]

compress method is not defined.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.79 19689

WAL segment size must be a power of two between 1 MB and 1 GB, but the control file specifies @1 @ byte

[Description]

Control file specifies WAL segment size is wrong, may be the control file is corrupted?

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.80 19690

"min_wal_size" must be at least twice "wal_segment_size"

[Description]

The GUC parameter of min_wal_size must be at least twice the size of the wal_segment_size

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.81 19691

"max_wal_size" must be at least twice "wal_segment_size"

[Description]

The GUC parameter of max_wal_size must be at least twice the size of the wal_segment_size

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.82 19692

-X requires a power of two value between 1 MB and 1 GB

[Description]

Specified WAL segment size must be power of two and it should be between 1MB and 1GB

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.83 19693

parameter "@1@" must be READ_ONLY, SHAREABLE, or READ_WRITE

[Description]

The value of aggregate function aggfinalmodify or aggmfinalmodify values must not be other than the above listed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.84 19694

including column does not support an operator class

[Description]

Create index with including column doesn't support operator class.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.85 19695

column "@1@" cannot be used in statistics because its type @2@ has no default btree operator class

[Description]

When creating statistics, the column's type must have default btree operator class.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.86 19696

could not connect to publisher when attempting to drop the replication slot "@1@"

[Description]

When dropping a subscription that is associated with a replication slot on the remote host (the normal state), DROP SUBSCRIPTION will connect to the remote host and try to drop the replication slot as part of its operation. This is necessary so that the resources allocated for the subscription on the remote host are released. If this fails, either because the remote host is not reachable or because the remote replication slot cannot be dropped or does not exist or never existed, the DROP SUBSCRIPTION command will fail.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.87 19697

cannot refer to non-index column by number

[Description]

We allow referencing columns by numbers only for indexes, since table column numbers could contain gaps if columns are later dropped.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.93.88 19698

cannot use ONLY for foreign key on partitioned table "@1@" referencing relation "@2@"

[Description]

Using ONLY to add or drop a constraint on partitioned table is supported only when there are no partitions. Once partitions exist, using ONLY will result in an error as adding or dropping constraints only on the partitioned table, when partitions exist, is not supported.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94 Message Numbers Beginning with 19700

2.94.1 19701

unsupported SCRAM channel-binding type "@1@"

[Description]

The only channel binding type supported is tls-server-end-point.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.2 19702

SCRAM channel binding check failed

[Description]

Compare the value sent by the client with the value expected by the server, if they are different, then SCRAM channel binding check fails.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.3 19703

User "@1@" has a password that cannot be used with MD5 authentication.

[Description]

Incompatible password hash format.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.4 19704

RANGE with offset PRECEDING/FOLLOWING requires exactly one ORDER BY column

[Description]

The number of order by clause is not one.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.5 19705

RANGE with offset PRECEDING/FOLLOWING is not supported for column type @1@

[Description]

The column type can't be used in RANGE with offset PRECEDING/FOLLOWING.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.6 19706

a hash-partitioned table may not have a default partition

[Description]

Partition table may not be a default partition if the partitioned table have hash type partition.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.7 19707

every hash partition modulus must be a factor of the next larger modulus

[Description]

Check the rule that every modulus must be a factor of the next larger modulus. For example, if you have a bunch of partitions that all have modulus 5, you can add a new partition with modulus 10 or a new partition with modulus 15, but you cannot add both a partition with modulus 10 and a partition with modulus 15, because 10 is not a factor of 15.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.8 19708

remainder for hash partition must be a non-negative integer

[Description]

Sanity check remainder.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.9 19709

column @1@ of the partition key has type "@2@", but supplied value is of type "@3@"

[Description]

Partition key column type and given value type should match

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.10 19710

@1@ total checksum verification failures

[Description]

By default, checksums are verified and checksum failures are reported for any possible page corruptions

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.94.11 19711

checksum verification failure during base backup

[Description]

By default, checksums are verified and checksum failures are reported for any possible page corruptions

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.94.12 19712

could not verify checksum in file "@1@", block @2@: read buffer size @3@ and page size @4@ differ**[Description]**

The checksums are verified at block level, so we iterate over the buffer in chunks of BLCKSZ, after making sure that TAR_SEND_SIZE/buf is divisible by BLCKSZ.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the event indicated in supplementary information reported by the system is a planned event.

2.94.13 19713

logical replication worker slot @1@ is already used by another worker, cannot attach**[Description]**

Another worker occupied the logical replication worker slot.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.14 19714

logical replication target relation "@1@.@2@" is missing some replicated columns**[Description]**

Local relation does not have some of the columns that are logically replicated from remote relation

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.15 19715

logical replication target relation "@1@.@2@" uses system columns in REPLICA IDENTITY index**[Description]**

Logical replication target relation uses some of the system columns to identify rows which are updated or deleted.

[System Processing]

Processing will be aborted.

[Action]

Usage of system columns for REPLICA IDENTITY should be avoided as these data vary across databases.

2.94.16 19716

publisher did not send replica identity column expected by the logical replication target relation "@1@.@2@"

[Description]

The logical replication relation is not updatable. Replica identity index and primary key are not defined.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.17 19717

logical replication target relation "@1@.@2@" has neither REPLICA IDENTITY index nor PRIMARY KEY and published relation does not have REPLICA IDENTITY FULL

[Description]

The logical replication relation is not updatable.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.18 19718

logical replication apply worker for subscription @1@ will not start because the subscription was removed during startup

[Description]

Subscription to which the logical replication apply worker is been assigned is already removed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.19 19719

cannot advance replication slot that has not previously reserved WAL

[Description]

A slot whose restart_lsn has never been reserved cannot be advanced.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.20 19720

cannot advance replication slot to @1 @/@2@, minimum is @3 @/@4@

[Description]

Data older than minimum is not available anymore. Check if the slot is not moving backwards.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.21 19721

@1@ must not be called inside a transaction

[Description]

When creating a new replication slot, it is not allowed to put CREATE_REPLICATION_SLOT and EXPORT_SNAPSHOT in a transAction.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.22 19722

@1@ must be called inside a transaction

[Description]

When creating a new replication slot, we must put CREATE_REPLICATION_SLOT and USE_SNAPSHOT in a transAction.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.23 19723

@1@ must be called in REPEATABLE READ isolation mode transaction

[Description]

When creating a new replication slot, we must put CREATE_REPLICATION_SLOT and USE_SNAPSHOT in REPEATABLE READ isolation mode transAction.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.24 19724

CREATE_REPLICATION_SLOT ... USE_SNAPSHOT must be called before any query

[Description]

When creating a new replication slot, we must call CREATE_REPLICATION_SLOT ... USE_SNAPSHOT before any query.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.25 19725

@1@ must not be called in a subtransaction

[Description]

When creating a new replication slot, we must not put CREATE_REPLICATION_SLOT and USE_SNAPSHOT in a subtransAction.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.26 19726

wrong flag type, only arrays and scalars are allowed

[Description]

Jasbonb flag type support arrays and scalars only.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.27 19727

not prepared for charset_conv_convert

[Description]

conversions are not open, so it is not ready for charset_conv_convert.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.28 19728

cannot perform transaction commands inside a cursor loop that is not read-only

[Description]

Doing transAction control, especially abort, inside a cursor loop that is not read-only, for example using UPDATE RETURNING, has weird semantics issues.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.29 19729

@1@: argument of --wal-segsize must be a power of 2 between 1 and 1024

[Description]

The input parameter WAL segment size is wrong.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.30 19730

@1@: checksum error occurred

[Description]

When basebackup, checksum error occurred.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.31 19731

--create-slot and --no-slot are incompatible options

[Description]

The input parameter in invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.32 19732

WAL segment size must be a power of two between 1 MB and 1 GB, but the remote server reported a value of @1@ byte

[Description]

The WAL segment size is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.33 19733

@1@: could not open process token: error code @2@

[Description]

Most Windows targets make DWORD a 32-bit unsigned long, but in case it doesn't cast DWORD before printing.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.34 19734

@1@: could not allocate SIDs: error code @2@

[Description]

Calling AllocateAndInitializeSid failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.35 19735

@1@: could not create restricted token: error code @2@

[Description]

Calling _CreateRestrictedToken failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.36 19736

@1@: could not start process for command "@2@": error code @3@

[Description]

Calling CreateProcessAsUser failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.37 19737

@1@: could not re-execute with restricted token: error code @2@

[Description]

Calling CreateRestrictedProcess failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.38 19738

@1@: could not get exit code from subprocess: error code @2@

[Description]

Calling GetExitCodeProcess failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.39 19739

@1@: invalid argument for option @2@

[Description]

The input argument for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.40 19740

@1@: transaction ID epoch (-e) must not be -1

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.41 19741

@1@: transaction ID (-x) must not be 0

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.42 19742

@1@: transaction ID (-c) must be either 0 or greater than or equal to 2

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.43 19743

@1@: OID (-o) must not be 0

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.44 19744

@1@: multitransaction ID (-m) must not be 0

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.45 19745

@1@: oldest multitransaction ID (-m) must not be 0

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.46 19746

@1@: multitransaction offset (-O) must not be -1

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.47 19747

@1@: argument of --wal-segsize must be a power of 2 between 1 and 1024

[Description]

The input parameter for option is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.48 19748

@1@: too many command-line arguments (first is "@2@")

[Description]

The input parameters are too many.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.49 19749

@1@: no data directory specified

[Description]

Data directory must be specified.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.50 19750

@1@: cannot be executed by "root"

[Description]

Don't allow to be run by root, to avoid overwriting the ownership of files in the data directory. Check is made only for root as any other user won't have sufficient permissions to modify files in the data directory.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.51 19751

You must run @1@ as the PostgreSQL superuser.

[Description]

Don't allow to be run by root, to avoid overwriting the ownership of files in the data directory. We need only check for root any other user won't have sufficient permissions to modify files in the data directory.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.52 19752

@1@: could not change directory to "@2@": @3@

[Description]

Change directory failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.53 19753

@1@: could not open file "@2@" for reading: @3@

[Description]

Open file for reading failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.54 19754

@1@: lock file "@2@" existsIs a server running? If not, delete the lock file and try again.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.55 19755

@1@: could not read file "@2@" : @3@

[Description]

Reading file failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.56 19756

@1@: data directory is of wrong versionFile "@2@" contains "@3@", which is not compatible with this program's version "@4@".

[Description]

The version of the data directory must be same with the program's version.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.57 19757

If you are sure the data directory path is correct, execute touch @1@ and try again.

[Description]

If pg_control is not there at all, or can't be read, the odds are that wrong DataDir path is being handed. User can do "touch pg_control" to force us to proceed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.58 19758

@1@: pg_control exists but has invalid CRC; proceed with caution

[Description]

We will use the data but treat it as guessed.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.59 19759

@1@: pg_control specifies invalid WAL segment size (@2@ byte); proceed with caution

[Description]

if WAL segment size is not valid. WAL segment size must be a power of two between 1 MB and 1 GB.

[System Processing]

Processing will proceed.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.60 19760

@1@: could not create pg_control file: @2@

[Description]

Create pg_control file failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.61 19761

@1@: could not write pg_control file: @2@

[Description]

There can be not enough disk space.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.62 19762

@1@: fsync error: @2@

[Description]

The return value of fsync is not zero.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.63 19763

could not open directory "@1@": @2@

[Description]

Open directory failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.64 19764

@1@: could not read directory "@2@": @3@

[Description]

read directory failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.65 19765

@1@: could not close directory "@2@": @3@

[Description]

Close directory failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.66 19766

@1@: could not delete file "@2@": @3@

[Description]

Delete file failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.67 19767

@1@: could not open file "@2@": @3@

[Description]

Open file failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.68 19768

@1@: could not write file "@2@": @3@

[Description]

There can be not enough disk space.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.69 19769

WAL segment size must be a power of two between 1 MB and 1 GB, but the control file specifies @1@ byte

[Description]

WAL segment size is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.70 19770

Could not create thread for alarm

[Description]

Create thread for alarm failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.71 19771

could not open output file

[Description]

open output file failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.72 19772

write failed

[Description]

The return value is not same with expected value.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.73 19773

fsync failed

[Description]

The return value of fsync is not zero.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.74 19774

seek failed

[Description]

the return value of lseek is -1.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.75 19775

Detected clock going backwards in time.

[Description]

Current time is smaller than previous time.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.76 19776

Time warp: @1 @ ms

[Description]

Current time is smaller than previous time, showing the difference.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.77 19777

template0 must not allow connections, i.e. its pg_database.datallowconn must be false

[Description]

avoid restore failure when pg_dumpall tries to create template0

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.78 19778

All non-template0 databases must allow connections, i.e. their pg_database.datallowconn must be true

[Description]

avoid datallowconn == false databases from being skipped on restore

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.79 19779

The source cluster was shut down while in recovery mode. To upgrade, use "rsync" as documented or shut it down as a primary.

[Description]

we check here that the server was shut down cleanly from the controldata perspective.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.80 19780

The target cluster was shut down while in recovery mode. To upgrade, use "rsync" as documented or shut it down as a primary.

[Description]

Clean server shut down is checked from the controldata perspective.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.81 19781

Consult the last few lines of "@1@" or "@2@" for the probable cause of the failure.

[Description]

check the last few lines.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.82 19782

Consult the last few lines of "@1@" for the probable cause of the failure.

[Description]

check the last few lines.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.83 19783

could not create hard link between old and new data directories: @1@ In link mode the old and new data directories must be on the same file system.

[Description]

link file failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.84 19784

Your installation references loadable libraries that are missing from the new installation. You can add these libraries to the new installation, or remove the functions using them from the old installation. A list of problem libraries is in the file: @1@

[Description]

Some of the libraries required by the new installation is missing. Check that the new cluster contains all required libraries.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.85 19785

You must identify the directory where the @1@ . Please use the @2@ command-line option or the @3@ environment variable.

[Description]

getenv failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.86 19786

There seems to be a postmaster servicing the old cluster.Please shutdown that postmaster and try again.

[Description]

If we have a postmaster.pid file in old cluster, try to start the server. If it doesn't start, assume the server is running.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.87 19787

There seems to be a postmaster servicing the new cluster.Please shutdown that postmaster and try again.

[Description]

If we have a postmaster.pid file in new cluster, try to start the server. If it doesn't start, assume the server is running.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.88 19788

could not connect to source postmaster started with the command: @1 @

[Description]

pg_ctl failed, If connection reason is found then connection will be re-attempted.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.89 19789

could not connect to target postmaster started with the command: @1 @

[Description]

pg_ctl failed, If connection reason is found then connection will be re-attempted.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.90 19790

Cannot upgrade to/from the same system catalog version when using tablespaces.

[Description]

The directories of old cluster and new cluster should be different.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.91 19791

@1@: could not read block @2@ in file "@3@": read @4@ of @5@

[Description]

The return value of read is not BLCKSZ.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.92 19792

checksum verification failed in file "@1@", block @2@: calculated checksum @3@ but block contains @4@

[Description]

The calculated checksum is different from the checksum that was saved in the block.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.93 19793

checksums verified in file "@1@"

[Description]

List of files verified for checksum is listed.

[System Processing]

Continues processing.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.94 19794

invalid segment number @1@ in file name "@2@"

[Description]

The segment number is zero.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.95 19795

invalid filenode specification, must be numeric: @1@

[Description]

relfilenode is zero.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.96 19796

pg_control CRC value is incorrect

[Description]

CRC check failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.97 19797

cluster must be shut down

[Description]

The state of the cluster must be DB_SHUTDOWNED or DB_SHUTDOWNED_IN_RECOVERY.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.98 19798

data checksums are not enabled in cluster

[Description]

data checksum version is zero.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.94.99 19799

WAL segment size must be a power of two between 1 MB and 1 GB, but the WAL file "@1@" header specifies @2@ byte

[Description]

Specified WAL segment size is must be power of two and it should be between 1MB and 1GB

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95 Message Numbers Beginning with 19800

2.95.1 19800

invalid value "@1@" for "@2@": integer expected

[Description]

string is not recognized.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.2 19801

pointers to uvvarchar are not implemented

[Description]

The length of the uvvarchar is not positive.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.3 19802

server offered SCRAM-SHA-256-PLUS authentication over a non-SSL connection

[Description]

The server offered SCRAM-SHA-256-PLUS, but the connection is not SSL-encrypted. That's not sane.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.4 19803

procedure parameter "@1@" is an output parameter but corresponding argument is not writable

[Description]

The output parameter should be writable.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.5 19804

procedure parameter @1@ is an output parameter but corresponding argument is not writable

[Description]

The output parameter should be writable.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.6 19805

function returning record called in context that cannot accept type record

[Description]

The result type is not TYPEFUNC_COMPOSITE.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.7 19806

@1@: could not send replication command "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.8 19807

could not fetch WAL segment size: got @1@ rows and @2@ fields, expected @3@ rows and @4@ or more fields

[Description]

The result number of show wal_segment_size is not one.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.9 19808

WAL segment size could not be parsed

[Description]

The wal segment size is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.10 19809

WAL segment size must be a power of two between 1 MB and 1 GB, but the remote server reported a value of @1@ byte

[Description]

The wal segment size is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.11 19810

@1@: WAL segment size must be a power of two between 1 MB and 1 GB, but the remote server reported a value of @2@ bytes

[Description]

The wal segment size is invalid.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.12 19811

Whether to continue running after a failure to sync data files.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.13 19815

level number 77 could not be used in TYPEDEF statement

[Description]

77 level variable is used in the TYPEDEF statement.

[System Processing]

Precompiling will be aborted.

[Action]

Change the level number.

2.95.14 19816

level number 77 could not be used for group item

[Description]

A group data item contains the 77 level variable.

[System Processing]

Precompiling will be aborted.

[Action]

Remove the variable from the group data item.

2.95.15 19817

"VARYING" cannot have a level number greater than 48

[Description]

Variables that have greather than 48 level have VARYING clause.

[System Processing]

Precompiling will be aborted.

[Action]

Remove "VARYNING" clause or change the level number.

2.95.16 19818

cannot alter inherited column "@1@" of relation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.17 19819

empty configuration file name: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.18 19820

configuration file recursion in "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.19 19821

empty configuration directory name: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.20 19822

no slot available for new worker process

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.21 19823

could not read from file "@1@"

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.22 19824

while setting parameter "@1@" to "@2@"

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.95.23 19825

@1@: too many jobs for this platform -- try @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.24 19826

cannot PREPARE a transaction that has operated on temporary objects

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.25 19827

cannot perform FREEZE on a partitioned table

[Description]

(Nothing)

[System Processing]

(Nothing)

[Action]

(Nothing)

2.95.26 19836

waitpid() failed: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.27 19837

child process exited abnormally: status @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.28 19838

XMLTABLE cannot cast a namespace node to a non-XML result type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.29 19839

cannot create foreign partition of partitioned table "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.30 19840

cannot attach foreign table "@1@" as partition of partitioned table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.31 19841

could not determine row type for result of @1@

[Description]

The result row type cannot be determined.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.32 19842

selecting default time zone ...

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.95.33 19843

malformed SCRAM message (invalid salt)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.34 19844

cluster is not compatible with this version of pg_checksums

[Description]

The version of the cluster and the version of pg_verify_checksums must be the same.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.35 19845

database cluster is not compatible

[Description]

pg_verify_checksums is not compatible with the database cluster.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.36 19846

The database cluster was initialized with block size @1@, but pg_checksums was compiled with block size @2@.

[Description]

The initial BLCKSZ of the database cluster must be the same as pg_verify_checksums

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.37 19847

type @1@ is not composite

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.38 19848

tables declared WITH OIDS are not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.39 19849

could not read from log segment @1@, offset @2@, length @3@: @4@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.40 19850

could not read from log segment @1@, offset @2@: read @3@ of @4@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.41 19851

skipping redundant vacuum to prevent wraparound of table "@1@.@2@.@3@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.42 19852

index row size @1@ exceeds btree version @2@ maximum @3@ for index "@4@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.43 19853

tid (@1@, @2@) is not valid for relation "@3@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.44 19854

table access method "@1@" does not exist

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.45 19855

incorrect size of file "@1@" : @2@ byte

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.46 19856

incorrect alignment of CRC offset for file "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.47 19857

invalid magic number stored in file "@1@"

[Description]

An error occurred reading the file.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.48 19858

invalid size stored in file "@1@"

[Description]

An error occurred reading the file.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.49 19859

calculated CRC checksum does not match value stored in file "@1@"

[Description]

An error occurred reading the file.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.50 19860

using recovery command file "@1@" is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.51 19861

could not fsync write-through file "@1@": @2@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.52 19862

could not read from log segment @1@, offset @2@: read @3@ of @4@

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.53 19863

"wait_seconds" must not be negative or zero

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.54 19864

server did not promote within @1@ seconds

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.55 19865

must be superuser to call pg_nextoid()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.56 19866

pg_nextoid() can only be used on system catalogs

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.57 19867

column "@1@" is not of type oid

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.58 19868

index "@1@" is not the index for column "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.59 19869

cannot use generated column "@1@" in column generation expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.60 19870

primary key column "@1@" is not marked NOT NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.61 19871

nondeterministic collations are not supported for operator class "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.62 19872

concurrent index creation for exclusion constraints is not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.63 19873

cannot change routine kind

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.64 19874

cannot change number of direct arguments of an aggregate function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.65 19875

nondeterministic collations not supported with this provider

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.66 19876

invalid COPY file header (WITH OIDS)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.67 19877

column "@1@" is a generated column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.68 19878

support function @1@ must return type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.69 19879

must be superuser to specify a support function

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.70 19880

cannot specify default tablespace for partitioned relations

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.71 19881

table "@1@" has no indexes that can be reindexed concurrently

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.72 19882

table "@1@" has no indexes to reindex

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.73 19883

cannot reindex system catalogs concurrently

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.74 19884

cannot reindex system catalogs concurrently, skipping all

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.75 19885

cannot reindex invalid index "@1@.@2@" concurrently, skipping

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.76 19886

cannot reindex exclusion constraint index "@1@.@2@" concurrently, skipping

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.77 19887

cannot reindex this type of relation concurrently

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.95.78 19888

index "@1@.@2@" was reindexed

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.95.79 19889

@1@ and @2@ are mutually exclusive options

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.80 19890

subscription with @1@ must also set @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.81 19891

specifying a table access method is not supported on a partitioned table

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.82 19892

inherited column "@1@" has a generation conflict

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.83 19893

column "@1@" of relation "@2@" is a generated column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.84 19894

invalid @1@ action for foreign key constraint containing generated column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.85 19895

generation expression for column "@1@" cannot be cast automatically to type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.86 19896

cannot alter type of a column used by a generated column

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.87 19897

cannot use generated column in partition key

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.88 19898

BEFORE trigger's WHEN condition cannot reference NEW generated columns

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.95.89 19899

could not serialize access due to concurrent delete

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96 Message Numbers Beginning with 19900

2.96.1 19900

unrecognized ANALYZE option "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.2 19901

skipping vacuum of "@1@" --- relation no longer exists

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.96.3 19902

tuple to be deleted was already modified by an operation triggered by the current command

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.4 19903

WHERE clause not allowed with COPY TO

[Description]

WHERE clause not allowed with COPY TO in copy command.

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.96.5 19904

for a generated column, GENERATED ALWAYS must be specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.6 19905

XQuery "x" flag (expanded regular expressions) is not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.7 19906

@1@ at end of jsonpath input

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.8 19907

@1@ at or near "@2@" of jsonpath input

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.9 19908

GSSAPI encryption can only be used with gss, trust, or reject authentication methods

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.10 19909

could not extract domain name from ldapbasedn

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.11 19910

LDAP authentication could not find DNS SRV records for "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.12 19911

LDAP server not specified, and no ldapbasedn

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.13 19912

outgoing GSSAPI message would not use confidentiality

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.14 19913

server tried to send oversized GSSAPI packet (@1 @ > @2 @)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.15 19914

oversized GSSAPI packet sent by the client (@1 @ > @2 @)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.16 19915

incoming GSSAPI message did not use confidentiality

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.17 19916

oversized GSSAPI packet sent by the client (@1 @ > @2 @)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.18 19917

could not set minimum SSL protocol version

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.96.19 19918

could not set maximum SSL protocol version

[Description]

An error occurred during I/O processing in the database server.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.96.20 19919

hostgssenc record cannot match because GSSAPI is not supported by this build

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.96.21 19920

GSSAPI encryption only supports gss, trust, or reject authentication

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.22 19921

invalid value for clientcert: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.23 19922

aggregate functions are not allowed in partition bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.24 19923

grouping operations are not allowed in partition bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.25 19924

aggregate functions are not allowed in column generation expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.26 19925

grouping operations are not allowed in column generation expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.27 19926

aggregate functions are not allowed in COPY FROM WHERE conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.28 19927

grouping operations are not allowed in COPY FROM WHERE conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.29 19928

window functions are not allowed in partition bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.30 19929

window functions are not allowed in COPY FROM WHERE conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.31 19930

window functions are not allowed in column generation expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.32 19931

cannot use column reference in DEFAULT expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.33 19932

cannot use column reference in partition bound expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.34 19933

cannot use subquery in partition bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.35 19934

cannot use subquery in COPY FROM WHERE condition

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.36 19935

cannot use subquery in column generation expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.37 19936

procedures cannot have more than @1@ argument

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.96.38 19937

routine name "@1@" is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.39 19938

aggregate name "@1@" is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.40 19939

procedure name "@1@" is not unique

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.41 19940

set-returning functions are not allowed in partition bound

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.42 19941

set-returning functions are not allowed in COPY FROM WHERE conditions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.43 19942

set-returning functions are not allowed in column generation expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.44 19943

cannot use system column "@1@" in column generation expression

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.45 19944

generated columns are not supported on typed tables

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.46 19945

generated columns are not supported on partitions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.47 19946

multiple generation clauses specified for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.48 19947

both default and generation expression specified for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.49 19948

both identity and generation expression specified for column "@1@" of table "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.50 19949

collation of partition bound value for column "@1@" does not match partition key collation "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.51 19950

removed orphan archive status file "@1@"

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.96.52 19951

removal of orphan archive status file "@1@" failed too many times, will try again later

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.96.53 19952

nondeterministic collations are not supported for regular expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.54 19953

replication origin name "@1@" is reserved

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.55 19954

cannot copy physical replication slot "@1@" as a logical replication slot

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.56 19955

cannot copy logical replication slot "@1@" as a physical replication slot

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.57 19956

cannot copy a replication slot that doesn't reserve WAL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.58 19957

could not copy replication slot "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.59 19958

could not read from log segment @1@, offset @2@: read @3@ of @4@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.60 19959

could not close shared memory segment "@1@": @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.61 19960

must be superuser to rotate log files with adminpack 1.0

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.62 19961

unsafe use of new value "@1@" of enum type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.63 19962

@ is not allowed in root expressions

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.64 19963

LAST is allowed only in array subscripts

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.65 19964

single boolean result is expected

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.66 19965

"vars" argument is not an object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.67 19966

JSON object does not contain key "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.68 19967

jsonpath member accessor can only be applied to an object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.69 19968

jsonpath wildcard array accessor can only be applied to an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.70 19969

jsonpath array subscript is out of bounds

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.71 19970

jsonpath array accessor can only be applied to an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.72 19971

jsonpath wildcard member accessor can only be applied to an object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.73 19972

jsonpath item method .@1@() can only be applied to an array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.74 19973

jsonpath item method .@1@() can only be applied to a numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.75 19974

jsonpath item method .@1@() can only be applied to a string or numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.76 19975

left operand of jsonpath operator @1@ is not a single numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.77 19976

right operand of jsonpath operator @1@ is not a single numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.78 19977

operand of unary jsonpath operator @1@ is not a numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.79 19978

jsonpath item method .@1@() can only be applied to an object

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.80 19979

could not find jsonpath variable "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.81 19980

jsonpath array subscript is not a single numeric value

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.82 19981

jsonpath array subscript is out of integer range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.83 19982

nondeterministic collations are not supported for LIKE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.84 19983

nondeterministic collations are not supported for ILIKE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.85 19984

SQL regular expression may not contain more than two escape-double-quote

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.86 19985

removing partition "@1@" violates foreign key constraint "@2@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.87 19986

nondeterministic collations are not supported for substring searches

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.96.88 19987

Sets the shell command that will retrieve an archived WAL file.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.89 19988

Sets the shell command that will be executed at every restart point.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.90 19989

Sets the shell command that will be executed once at the end of recovery.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.91 19990

Specifies the timeline to recover into.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.92 19991

Set to "immediate" to end recovery as soon as a consistent state is reached.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.93 19992

Sets the transaction ID up to which recovery will proceed.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.94 19993

Sets the time stamp up to which recovery will proceed.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.95 19994

Sets the named restore point up to which recovery will proceed.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.96 19995

Sets the LSN of the write-ahead log location up to which recovery will proceed.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.97 19996

Specifies a file name whose presence ends recovery in the standby.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.98 19997

Sets the connection string to be used to connect to the sending server.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.99 19998

Sets the name of the replication slot to use on the sending server.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.96.100 19999

Sets the default table access method for new tables.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.97 Message Numbers Beginning with 20000

2.97.1 20000

[listagg_transfn called in non-aggregate context](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.2 20002

[median4_transfn called in non-aggregate context](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.3 20003

[lock request error](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.4 20004

[event registration error](#)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.5 20005

event name is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.6 20006

feature not supported

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.7 20007

not called by trigger manager

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.8 20008

not called on valid event

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.9 20009

SPI_connect failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.10 20010

not called with valid relation

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.11 20011

attribute event not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.12 20012

attribute message not found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.13 20013

SPI_prepare failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.14 20014

can't execute sql

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.15 20015

SPI execute error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.16 20016

invalid value for @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.17 20017

date out of range

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.18 20018

timestamp out of range

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.19 20019

invalid cursor number

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.20 20020

failed to execute SQL statement

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.21 20021

SQL is empty string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.22 20022

host variable name "@1@" is too long

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.23 20023

host variable name is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.24 20024

no statement parsed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.25 20025

host variable does not exist

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.26 20026

invalid length for host variable name

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.27 20027

invalid length for variable character string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.28 20028

not all variables bound

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.29 20029

no statement execute

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.30 20030

not supported data type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.31 20031

mismatch column_value data type and define_column data type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.32 20032

mismatch select data type and define_column data type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.33 20033

@1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.34 20034

invalid parameter

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.35 20035

null value not allowed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.36 20036

invalid encoding name "@1@"

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.37 20037

program limit exceeded

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.38 20038

no data found

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.39 20039

SPI_prepare_failed

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.40 20040

start_line must be positive (@1@ passed)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.41 20041

end_line must be positive (@1@ passed)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.42 20042

return type must be a row type

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.43 20043

failed to retrieve the default LC_COLLATE value

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.44 20044

failed to set the requested LC_COLLATE value [@1 @]

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.45 20045

failed to set back the default LC_COLLATE value [@1 @]

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.46 20046

unknown format

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.47 20047

function is called from invalid context

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.48 20048

argument is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.49 20049

out of memory

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.97.50 20050

insufficient privilege

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.51 20051

datatype mismatch

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.52 20052

unexpected type: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.53 20053

pipe name is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.54 20054

pipe creation error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.55 20055

message is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.56 20056

could not determine data type of input

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.57 20057

unknown equal operand for datatype

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.58 20058

cannot set range to negative number

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.59 20059

date is out of range

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.60 20060

nonbizday registration error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.61 20061

nonbizday unregistration error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.62 20062

plvlex.tokens is not available in the built

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.63 20063

too few parameters specified for template string

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.64 20064

substitution is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.65 20065

buffer overflow

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.66 20066

internal error

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.67 20067

Limit decreased to @1@ bytes.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.68 20068

Limit increased to @1@ bytes.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.69 20069

unknown option '@1@'

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.70 20070

too much large memory block request

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.71 20071

corrupted pointer

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.72 20082

SQL is NULL

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.97.73 20083

input value length is @1@; too long for type nvarchar2(@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.97.74 20084

input value too long for type nvarchar2(@1@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.97.75 20085

input value length is @1@; too long for type varchar2(@2@)

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.97.76 20086

input value length is @1@; too long for type varchar2(@2@)**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.97.77 20087

String constants with Unicode escapes cannot be used when standard_conforming_strings is off.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.97.78 20088

Unicode escapes must be \uXXXX or \UXXXXXXXX.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.97.79 20089

Use " to write quotes in strings. \' is insecure in client-only encodings.**[Description]**

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.97.80 20090

Use " to write quotes in strings, or use the escape string syntax (E'...').

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.97.81 20091

Use the escape string syntax for backslashes, e.g., E'\\'.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.97.82 20092

Use the escape string syntax for escapes, e.g., E'\\r'.

[Description]

Supplementary information was output.

[System Processing]

None.

[Action]

Refer to this message together with the message that was output immediately beforehand.

2.97.83 20093

cannot to parse timezone "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.97.84 20094

utl_file package is not supported on Microsoft Windows

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.97.85 20095

an argument is NULL

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98 Message Numbers Beginning with 20100

2.98.1 20123

Please specify an integer between 0 and 9, and retry.

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98.2 20124

could not initialize compression library: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98.3 20125

could not close compression stream: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98.4 20126

could not compress data: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98.5 20127

could not uncompress data: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98.6 20128

source file is not specified

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.98.7 20129

could not seek to end of file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99 Message Numbers Beginning with 25000

2.99.1 25000

Name of the SSL library.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.2 25001

Sets the action to perform upon reaching the recovery target.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.3 25002

Selects the shared memory implementation used for the main shared memory region.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.4 25003

Sets the minimum SSL/TLS protocol version to use.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.5 25004

Sets the maximum SSL/TLS protocol version to use.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.6 25005

multiple recovery targets specified

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.7 25006

could not determine which collation to use for string hashing

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.8 25007

WITH OIDS is no longer supported; this can only be false.

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.9 25008

could not read compressed file "@1@": read @2@ of @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.10 25009

could not close file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.11 25010

checksums enabled in file "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.12 25011

seek failed for block @1@ in file "@2@": @3@

[Description]

the return value of lseek is -1.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.13 25012

could not write block @1@ in file "@2@": @3@**[Description]**

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.99.14 25013

could not write block @1@ in file "@2@": wrote @3@ of @4@**[Description]**

There was insufficient free space in the disk of the database server during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Delete user data stored in the database server to free up space on the disk.

2.99.15 25014

data checksums are already disabled in cluster**[Description]**

data checksums are already disabled in cluster.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.99.16 25015

data checksums are already enabled in cluster**[Description]**

data checksums are already enabled in cluster.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.99.17 25016

Checksums enabled in cluster

[Description]

Checksums enabled in cluster.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.18 25017

Checksums disabled in cluster

[Description]

Checksums disabled in cluster.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.19 25018

out of memory

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.20 25019

could not close file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.21 25020

could not open file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.22 25021

could not write file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.23 25022

could not fsync file "@1@": @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.24 25023

@1@: could not start server due to setsid() failure: @2@

[Description]

could not start server

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.25 25024

@1@: cannot rotate log file; single-user server is running (PID: @2@)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.26 25025

@1@: could not create log rotation signal file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.27 25026

@1@: could not write log rotation signal file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.28 25027

@1@: could not send log rotation signal (PID: @2@): @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.29 25028

@1@: could not remove log rotation signal file "@2@": @3@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.30 25029

out of memory

[Description]

out of memory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.31 25030

out of memory

[Description]

out of memory

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.32 25031

restoring tables WITH OIDS is not supported anymore

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.33 25032

could not set default_table_access_method: @1@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.34 25033

extra_float_digits must be in range -15..3

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.35 25034

rows-per-insert must be in range @1@..@2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.36 25035

option --on-conflict-do-nothing requires option --inserts, --rows-per-insert, or --column-inserts

[Description]

option --on-conflict-do-nothing requires option --inserts, --rows-per-insert, or --column-inserts

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.37 25036

WITH OIDS is not supported anymore (table "@1@")

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.99.38 25037

no referencing object @1@ @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.99.39 25038

no referenced object @1@ @2@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.99.40 25039

option --exclude-database cannot be used together with -g/--globals-only, -r/--roles-only, or -t/--tablespaces-only

[Description]

option --exclude-database cannot be used together with -g/--globals-only, -r/--roles-only, or -t/--tablespaces-only

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.41 25040

excluding database "@1@"

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.99.42 25041

one of -d/--dbname and -f/--file must be specified

[Description]

one of -d/--dbname and -f/--file must be specified

[System Processing]

Processing will be aborted.

[Action]

Check the command-line, and re-execute the command with correct options.

2.99.43 25042

options -C/--create and -1/--single-transaction cannot be used together

[Description]

options -C/--create and -1/--single-transaction cannot be used together

[System Processing]

Processing aborts

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.99.44 25043

could not find referenced extension @1@

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.99.45 25044

number of source and target fields in assignment does not match

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.46 25045

cannot set generated column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.47 25046

cannot set generated column "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.99.48 25049

unrecognized value "@1@" for option '-i'

[Description]

Unrecognized value specified for option '-i'.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.49 25050

unrecognized stop mode "@1@"

[Description]

Unrecognized stop mode was specified.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.50 25051

invalid timeout "@1@"

[Description]

Invalid timeout specified.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.51 25052

too many command-line arguments (first is "@1@")

[Description]

Too many command-line arguments.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.52 25053

unrecognized operation mode "@1@"

[Description]

Unrecognized operation mode was specified.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.53 25054

no operation mode is specified

[Description]

No operation mode is specified.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.54 25055

no connection manager directory is specified and environment variable CMDATA is unset

[Description]

No connection manager directory is specified and environment variable CMDATA is unset.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.55 25056

could not create conmgr process: @1@

[Description]

Could not create conmgr process.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.56 25057

could not start conmgr process due to setsid() failure: @1@

[Description]

Could not start conmgr process due to setsid() failure.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.57 25058

could not start conmgr process: @1@

[Description]

Could not start conmgr process.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.58 25059

could not get a result from conmgr process: @1@

[Description]

Could not get a result from conmgr process.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.59 25060

unexpected response from conmgr process: result_status=@1 @ @2@

[Description]

Unexpected response from conmgr process.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.60 25061

unexpected response from conmgr process: attr is null

[Description]

Unexpected response from conmgr process.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.61 25062

invalid conmgr process status "@1@"

[Description]

Invalid conmgr process status.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.62 25063

invalid conmgr process status "@1@"

[Description]

Invalid conmgr process status.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.63 25064

could not open pid file "@1@" : @2@

[Description]

Could not open pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.64 25065

could not read from pid file "@1@": @2@

[Description]

Could not read from pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.65 25066

invalid data in pid file "@1@"

[Description]

Invalid data in pid file.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.66 25067

invalid pid file "@1@"

[Description]

Invalid pid file.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.67 25068

could not send signal to commgr process: @1@

[Description]

Could not send signal to commgr process

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.68 25069

could not connect to conmgr process: @1@

[Description]

Could not connect to conmgr process.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.69 25070

waiting conmgr process to connect to watchdog

[Description]

Waiting conmgr process to connect to watchdog.

[System Processing]

Continues processing.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.70 25071

could not start conmgr process in time

[Description]

Could not start conmgr process in time.

[System Processing]

Processing aborts.

[Action]

Check log of conmgr process.

2.99.71 25072

could not start conmgr process

[Description]

Could not start conmgr process.

[System Processing]

Processing aborts.

[Action]

Check log of conmgr process.

2.99.72 25073

another conmgr process is starting up

[Description]

Another conmgr process is starting up.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.73 25074

another conmgr process is running

[Description]

Another conmgr process is running.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.74 25075

another conmgr process is shutting down

[Description]

Another conmgr process is shutting down.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.75 25076

starting conmgr process

[Description]

Starting conmgr process.

[System Processing]

Continues processing.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.76 25077

conmgr process is ready

[Description]

Conmgr process is ready.

[System Processing]

Continues processing.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.77 25078

started conmgr process successfully

[Description]

Started conmgr process successfully.

[System Processing]

Continues processing.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.78 25079

could not send signal(@1@) to conmgr process(PID: @2@): @3@

[Description]

Could not send signal to conmgr process.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.79 25080

could not stop conmgr process in time

[Description]

Could not stop conmgr process in time.

[System Processing]

Processing aborts.

[Action]

Check log of conmgr process.

2.99.80 25081

pid file "@1@/conmgr.pid" does not exist

[Description]

Pid file does not exist.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.81 25082

conmgr process shutting down

[Description]

Conmgr process shutting down.

[System Processing]

Continues processing.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.82 25083

stopped conmgr process successfully

[Description]

Stopped conmgr process successfully.

[System Processing]

Continues processing.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.83 25084

connection manager directory "@1@" does not exist

[Description]

Connection manager directory does not exist.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.84 25085

could not access to connection manager directory "@1@" : @2@

[Description]

Could not access to connection manager directory.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.85 25086

"@1@" is not a directory

[Description]

Not a directory.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.86 25087

cannot be run as rootPlease log in (using

[Description]

Cannot be run as root. Please login as the (unprivileged) user that will own the conmgr process.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.87 25088

out of memory

[Description]

Out of memory.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.88 25089

too long literal in configuration file "@1@" line @2@

[Description]

Too long literal in configuration file.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.89 25090

syntax error near '@1@' in configuration file "@2@" line @3@

[Description]

Syntax error in configuration file.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.90 25091

invalid default value for parameter '@1@' of instance #@2@

[Description]

Invalid default value for parameter of instance.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.91 25092

invalid default value for parameter '@1@'

[Description]

Invalid default value for parameter.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.99.92 25093

either backend_host or backend_hostaddr is needed for instance #@1@

[Description]

Either backend_host or backend_hostaddr is needed for instance.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.93 25094

invalid value for parameter '@1@' of instance #@2@

[Description]

Invalid value for parameter of instance.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.94 25095

invalid value for parameter '@1@'

[Description]

Invalid value for parameter.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.95 25096

could not open file "@1@": @2@

[Description]

Could not open file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.99.96 25097

invalid parameter '@1@' in configuration file "@2@" line @3@

[Description]

Invalid parameter in configuration file.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.97 25098

invalid value for parameter '@1@' in configuration file "@2@" line @3@

[Description]

Invalid value for parameter in configuration file.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.99.98 25099

could not notify application: @1@

[Description]

Could not notify application.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100 Message Numbers Beginning with 25100

2.100.1 25100

unexpected heartbeat event is reported: host="@1@"

[Description]

Unexpected heartbeat event is reported.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.2 25101

could not reply all application info: @1@

[Description]

Could not reply all application info.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.3 25102

could not reply all node info: @1@

[Description]

Could not reply all node info.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.4 25103

could not reply target node info: @1@

[Description]

Could not reply target node info.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.5 25104

invalid query "@1@" is received

[Description]

Invalid query is received.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.6 25105

received invalid startup packet

[Description]

Received invalid startup packet.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.7 25106

could not complete command: @1@

[Description]

Could not complete command.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.8 25107

could not be ready for next command: @1@

[Description]

Could not be ready for next command.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.9 25108

invalid status(@1@) for connection of application internal event(@2@)

[Description]

Invalid status for connection of application internal event.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.10 25109

rejected a connection from application due to going shutdown

[Description]

Rejected a connection from application due to going shutdown.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.11 25110

could not reply for startup: @1@

[Description]

Could not reply for startup.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.12 25111

unexpected packet(@1@) is received

[Description]

Unexpected packet is received.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.13 25112

@1@ causes an error at application connection: @2@

[Description]

Causes an error at application connection.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.14 25113

application connection is closed by remote in @1@

[Description]

Application connection is closed by remote.

[System Processing]

Processing continues.

[Action]

Check log of remote system.

2.100.15 25114

unexpected heartbeat event(@1@) is received

[Description]

Unexpected heartbeat event is received.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.16 25115

could not listen for socket: @1@

[Description]

Could not listen for socket.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.17 25116

could not accept application connection: @1@

[Description]

Could not accept application connection.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.18 25117

could not get string format address: @1@

[Description]

Could not get string format address.

[System Processing]

Processing continues.

[Action]

Check log of Operating System.

2.100.19 25118

could not open pid file "@1@": @2@

[Description]

Could not open pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.20 25119

could not read from pid file "@1@": @2@

[Description]

Could not read from pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.21 25120

"@1@" is not pid file: number of line is not enough(expect 4 but @2@)

[Description]

Not pid file: number of line is not enough.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.22 25121

could not write to pid file "@1@": @2@

[Description]

Could not write to pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.23 25122

could not seek pid file "@1@": @2@

[Description]

Could not seek pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.24 25123

could not sync to pid file "@1@": @2@

[Description]

Could not sync to pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.25 25124

closing all application connections

[Description]

Closing all application connections.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.26 25125

received smart shutdown request

[Description]

Received smart shutdown request.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.27 25126

received fast shutdown request

[Description]

Received fast shutdown request.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.28 25127

received immediate shutdown request

[Description]

Received immediate shutdown request.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.29 25128

invalid packet is received: msgtype='0x@1@'

[Description]

Invalid packet is received.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.30 25129

could not change directory to "@1@": @2@

[Description]

Could not change directory.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.31 25130

could not create pid file "@1@": @2@

[Description]

Could not create pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.32 25131

invalid pid file "@1@"

[Description]

Invalid pid file.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.33 25132

another conmgr process(PID @1@) is running

[Description]

Another conmgr process is running.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.34 25133

could not write pid file "@1@": @2@

[Description]

Could not write pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.35 25134

could not remove pid file "@1@": @2@

[Description]

Could not remove pid file.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.36 25135

real and effective user IDs must match

[Description]

Real and effective user IDs must match.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.37 25136

no cmddata directory specified and environment variable CMDATA unset

[Description]

No cmddata directory specified and environment variable CMDATA unset.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.38 25137

cmdata directory "@1@" does not exist

[Description]

Cmdata directory does not exist.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.39 25138

could not access to cmdata directory "@1@" : @2@

[Description]

Could not access to cmdata directory.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.40 25139

"@1@" is not a directory

[Description]

Not a directory.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.41 25140

conmgr process is starting

[Description]

Conmgr process is starting.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.42 25141

conmgr process stopped

[Description]

Conmgr process stopped.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.43 25142

could not prepare for heartbeat: @1@

[Description]

Could not prepare for heartbeat.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.44 25143

could not connect due to the following errors

[Description]

Could not connect due to the following errors.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.45 25144

could not receive a heartbeat packet: @1@

[Description]

Could not receive a heartbeat packet.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.46 25145

error is occurred for completion of asynchronous connect for heartbeat: @1@

[Description]

Error is occurred for completion of asynchronous connect for heartbeat.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.47 25146

@1@ cause an error in heartbeat: @2@

[Description]

Cause an error in heartbeat.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.48 25147

could not accept heartbeat connection: @1@

[Description]

Could not accept heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.49 25148

could not add node: host=@1@ hostaddr=@2@ port=@3@

[Description]

Could not add node.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.50 25149

listening on @1@ port @2@

[Description]

Listening on port.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.51 25150

could not bind port @1@

[Description]

Could not bind port.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.52 25151

could not bind port @1@ with following causes

[Description]

Could not bind port with following causes.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.53 25152

could not send @1@: @2@

[Description]

Could not send.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.54 25153

could not create an additional interval event: @1@

[Description]

Could not create an additional interval event.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.55 25154

could not create bufferevent: @1@

[Description]

Could not create bufferevent.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.56 25155

could not resolve address: @1@

[Description]

Could not resolve address.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.57 25156

invalid status(@1 @) for heartbeat internal event(@2@)

[Description]

Invalid status for heartbeat internal event.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.58 25157

heartbeat connection is established

[Description]

Heartbeat connection is established.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.59 25158

heartbeat connect is refused: @1@

[Description]

Heartbeat connect is refused.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.60 25159

remote node closes heartbeat connection

[Description]

Remote node closes heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.61 25160

remote node shuts down heartbeat connection

[Description]

Remote node shuts down heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.62 25161

heartbeat connect is timed out

[Description]

Heartbeat connect is timed out.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.63 25162

heartbeat is timed out

[Description]

Heartbeat is timed out.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.64 25163

could not establish heartbeat connection

[Description]

Could not establish heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.65 25164

out of memory

[Description]

Out of memory.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.66 25165

unexpected packet(@1@) is received

[Description]

Unexpected packet is received.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.67 25166

could not listen for socket: @1@

[Description]

Could not listen for socket.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.68 25167

could not get string format address: @1@

[Description]

Could not get string format address.

[System Processing]

Processing continues.

[Action]

Check log of Operating System.

2.100.69 25168

could not prepare for heartbeat: @1@

[Description]

Could not prepare for heartbeat.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.70 25169

could not connect due to the following errors

[Description]

Could not connect due to the following errors.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.71 25170

could not receive a heartbeat packet: @1@

[Description]

Could not receive a heartbeat packet.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.72 25171

error is occurred for completion of asynchronous connect for heartbeat: @1@

[Description]

Error is occurred for completion of asynchronous connect for heartbeat.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.73 25172

@1@ cause an error in heartbeat: @2@

[Description]

Cause an error in heartbeat.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.74 25173

could not accept heartbeat connection: @1@

[Description]

Could not accept heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.75 25174

could not add node: host=@1 @ hostaddr=@2 @ port=@3 @

[Description]

Could not add node.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.76 25175

listening on @1 @ port @2 @

[Description]

Listening on port.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.77 25176

could not bind port @1 @

[Description]

Could not bind port.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.78 25177

could not bind port @1 @ with following causes

[Description]

Could not bind port with following causes.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.79 25178

could not send @1 @: @2@

[Description]

Could not send.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.80 25179

could not create an additional interval event: @1@

[Description]

Could not create an additional interval event.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.81 25180

could not create bufferevent: @1@

[Description]

Could not create bufferevent.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.82 25181

could not resolve address: @1@

[Description]

Could not resolve address.

[System Processing]

Processing aborts.

[Action]

Check log of Operating System.

2.100.83 25182

invalid status(@1@) for heartbeat internal event(@2@)

[Description]

Invalid status for heartbeat internal event.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.84 25183

heartbeat connection is established

[Description]

Heartbeat connection is established.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.85 25184

heartbeat connect is refused: @1@

[Description]

Heartbeat connect is refused.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.86 25185

remote node closes heartbeat connection

[Description]

Remote node closes heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.87 25186

remote node shuts down heartbeat connection

[Description]

Remote node shuts down heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.88 25187

heartbeat connect is timed out

[Description]

Heartbeat connect is timed out.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.89 25188

heartbeat is timed out

[Description]

Heartbeat is timed out.

[System Processing]

Processing aborts.

[Action]

Check log of remote system.

2.100.90 25189

could not establish heartbeat connection

[Description]

Could not establish heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.91 25190

terminator: could not attach to server: unexpected result(@1@)

[Description]

Could not attach to server.

[System Processing]

Processing aborts.

[Action]

Contact Fujitsu technical support.

2.100.92 25191

terminator: terminated connections: ipaddress="@1@"

[Description]

Terminated connections.

[System Processing]

Processing continues.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.93 25192

watchdog: could not send attribute

[Description]

Could not send attribute.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.94 25193

watchdog: could not accept heartbeat connection

[Description]

Could not accept heartbeat connection.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.95 25194

Increase watchdog.max_hb_connections.

[Description]

Increase watchdog.max_hb_connections.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.96 25195

terminator: could not prepare statement for "@1@"

[Description]

Could not prepare statement.

[System Processing]

Processing aborts.

[Action]

Check messages near this message.

2.100.97 25196

set-valued function called in context that cannot accept a set

[Description]

Set-valued function called in context that cannot accept a set.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.98 25197

materialize mode required, but it is not allowed in this context

[Description]

Materialize mode required, but it is not allowed in this context.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.99 25198

"root" execution of the conmgr is not permitted. The conmgr must be started under an unprivileged user ID to prevent possible system security compromise. See the documentation for more information on how to properly start the conmgr.

[Description]

"root" execution of the conmgr is not permitted. The conmgr must be started under an unprivileged user ID to prevent possible system security compromise. See the documentation for more information on how to properly start the conmgr.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.100.100 25199

Execution of conmgr by a user with administrative permissions is not permitted. The conmgr must be started under an unprivileged user ID to prevent possible system security compromises. See the documentation for more information on how to properly start the conmgr.

[Description]

Execution of conmgr by a user with administrative permissions is not permitted. The conmgr must be started under an unprivileged user ID to prevent possible system security compromises. See the documentation for more information on how to properly start the conmgr.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.101 Message Numbers Beginning with 25200

2.101.1 25200

The program "@1@" is needed by @2@ but was not found in the same directory as "@3@". Check your installation.

[Description]

A required program was not found. Check your installation.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.101.2 25201

The program "@1@" was found by "@2@" but was not the same version as @3@. Check your installation.

[Description]

The program was not the same version.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.101.3 25202

invalid value for integer parameter in configuration file "@1@" line @2@

[Description]

Invalid value for integer parameter in configuration file.

[System Processing]

Processing aborts.

[Action]

Recheck command line, configuration file, or logic of your application. Hint message may follow with this message.

2.101.4 25203

attribute of the instance(host='@1@', port=@2@) is changed from '@3@' to '@4@'

[Description]

Attribute of the instance is changed.

[System Processing]

Processing continues.

[Action]

No action required.

2.101.5 25204

Sleep until another process releases global meta cache because global meta cache cannot be swept away yet. Please increase pgx_global_metacache.

[Description]

Sleep until another process releases global meta cache because global meta cache cannot be swept away yet. Please increase pgx_global_metacache.

[System Processing]

Processing continues.

[Action]

If this message occurs frequently, increase the pgx_global_metacache parameter setting and restart the database.

2.101.6 25205

GMC is swept away

[Description]

GMC is swept away.

[System Processing]

Processing continues.

[Action]

No action required.

2.101.7 25206

pgx_global_metacache must be set to at least 10MB when enabled.

[Description]

pgx_global_metacache must be set to at least 10MB when enabled.

[System Processing]

Processing will be aborted.

[Action]

Set the pgx_global_metacache parameter to at least 10MB and restart the database.

2.101.8 25207

TDE_z: PKCS11 Slot ID is not defined

[Description]

The opencryptoki Slot ID for transparent data encryption is not defined.

[System Processing]

Processing will be aborted.

[Action]

In postgresql.conf set the GUC TDE_z.SLOT_ID to the opencryptoki Slot ID configured for transparent data encryption.

2.101.9 25208

TDE_z: PKCS11 User PIN is not available at load time

[Description]

The opencryptoki User PIN associated with the token of Slot ID was not defined at load time.

[System Processing]

This is only a warning message when TDE_z is loaded.

[Action]

The token User PIN must be known to TDE_z before secure keys can be used. Specify the User PIN at load time with --user-pin option, or by GUC TDE_z.USER_PIN in postgresql.conf. Or, specify the User PIN at run-time using SELECT pgx_open_keystore(user pin); or SELECT pgx_set_master_key(user pin);

2.101.10 25209

TDE_z: Slot @1@ token model is '@2@'

[Description]

Logs the opencryptoki Slot ID and token model that TDE_z will be using.

[System Processing]

This is an information message when TDE_z is loaded.

[Action]

No action is required. Confirm the Slot and token type are as expected.

2.101.11 25210

TDE_z: Slot @1@ token model '@2@' is not supported

[Description]

The opencryptoki token model at the specified Slot ID is not supported by TDE_z.

[System Processing]

Processing will be aborted.

[Action]

Only "EP11" and "CCA" tokens are supported.

2.101.12 25211

TDE_z: Slot @1@ C_GetMechanismInfo CKM_AES_KEY_GEN: @2@ [@3@]

[Description]

The specified Slot ID does not support a mechanism required by TDE_z.

[System Processing]

Processing will be aborted.

[Action]

Specify a different token which supports the necessary mechanism.

2.101.13 25212

TDE_z: Slot @1@ mechanism does not support CKF_GENERATE

[Description]

The specified Slot ID does not support a mechanism required by TDE_z.

[System Processing]

Processing will be aborted.

[Action]

Specify a different token which supports the necessary mechanism.

2.101.14 25213

TDE_z: Slot @1@ C_GetMechanismInfo CKM_AES_CBC: @2@ [@3@]

[Description]

The specified Slot ID does not support a mechanism required by TDE_z.

[System Processing]

Processing will be aborted.

[Action]

Specify a different token which supports the necessary mechanism.

2.101.15 25214

TDE_z: Slot @1@ mechanism does not support CKF_ENCRYPT

[Description]

The specified Slot ID does not support a mechanism required by TDE_z.

[System Processing]

Processing will be aborted.

[Action]

Specify a different token which supports the necessary mechanism.

2.101.16 25215

TDE_z: Slot @1@ mechanism does not support CKF_DECRYPT

[Description]

The specified Slot ID does not support a mechanism required by TDE_z.

[System Processing]

Processing will be aborted.

[Action]

Specify a different token which supports the necessary mechanism.

2.101.17 25216

TDE_z: Unable to initialize the opencryptoki library: 0x@1@ [@2@]

[Description]

The call to the C_Initialize function of PKCS#11 has failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and take appropriate action based on the reported PKCS#11 error code.

2.101.18 25217

TDE_z: Slot @1@ C_OpenSession: @2@ [@3@]

[Description]

The call to the C_OpenSession function of PKCS#11 has failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and take appropriate action based on the reported PKCS#11 error code.

2.101.19 25218

TDE_z extension must be loaded via shared_preload_libraries

[Description]

The TDE_z extension cannot be dynamically loaded by the user.

[System Processing]

Processing will be aborted.

[Action]

In postgresql.conf specify shared_preload_libraries = 'TDE_z'

2.101.20 25219

TDE_z: C_Login: @1@ [@2@]

[Description]

The call to the C_OpenSession function of PKCS#11 has failed.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and take appropriate action based on the reported PKCS#11 error code.

2.101.21 25220

TDE_z: Expected key not found: @1@ [@2@]

[Description]

During encryption or decryption processing TDE_z was not able to find an expected opencryptoki key.

[System Processing]

Processing will be aborted.

[Action]

The keystore and the opencryptoki token key objects are not consistent with each other. This may happen if the keystore and/or opencryptoki token directory have been incorrectly copied (or not copied at all). Check all files have been copied correctly.

2.101.22 25221

TDE_z : Operation not supported

[Description]

The TDE_z extension cannot be dynamically loaded by the user.

[System Processing]

Processing will be aborted.

[Action]

In postgresql.conf specify shared_preload_libraries = 'TDE_z'

2.101.23 25222

Keystore does not require passphrase.

[Description]

keystore-passphrase command line option and PGX_KEYSTORE_PASSPHRASE environment variable should not be set when using TDE_z extension.

[System Processing]

Processing will be aborted.

[Action]

Remove keystore-passphrase from command line option or unset PGX_KEYSTORE_PASSPHRASE environment variable before starting the server with TDE_z extension loaded.

2.101.24 25223

Keystore does not require passphrase. @1@ cannot be executed.

[Description]

pgx_set_keystore_passphrase function cannot be executed when TDE_z extension is used.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly

2.101.25 25224

encryption of the keystore "@1@" failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.101.26 25225

decryption of the keystore "@1@" failed: @2@

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.101.27 25226

keystore for Hardware-based encryption has been opened

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.102 Message Numbers Beginning with 70000

2.102.1 70001

Error loading default settings from driverconfig.properties

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.102.2 70002

Your security policy has prevented the connection from being attempted. You probably need to grant the connect java.net.SocketPermission to the database server host and port that you wish to connect to.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.3 70003

Something unusual has occurred to cause the driver to fail. Please report this exception.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.102.4 70004

Connection attempt timed out.

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.102.5 70005

Interrupted while attempting to connect.

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.6 70006

Method @1@ is not yet implemented.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.7 70007

Requested CopyIn but got @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.8 70008

Requested CopyOut but got @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.9 70009

Copying from database failed: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.102.10 70010

This copy stream is closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.11 70011

Read from copy failed.

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.12 70012

Cannot write to copy a byte of value @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.13 70013

A connection could not be made using the requested protocol @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.14 70014

Premature end of input stream, expected @1@ bytes, but only read @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.15 70015

Expected an EOF from server, got: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.16 70016

An unexpected result was returned by a query.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.17 70017

Illegal UTF-8 sequence: byte @1@ of @2@ byte sequence is not 10xxxxx: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.18 70018

Illegal UTF-8 sequence: @1@ bytes used to encode a @2@ byte value: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.19 70019

Illegal UTF-8 sequence: initial byte is @1@: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.20 70020

Illegal UTF-8 sequence: final value is out of range: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.21 70021

Illegal UTF-8 sequence: final value is a surrogate value: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.22 70022

Zero bytes may not occur in string parameters.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.23 70023

Zero bytes may not occur in identifiers.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.24 70024

Cannot convert an instance of @1@ to type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.25 70025

Connection to @1@ refused. Check that the hostname and port are correct and that the postmaster is accepting TCP/IP connections.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.26 70026

The connection attempt failed.

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.27 70027

The server does not support SSL.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.28 70028

An error occurred while setting up the SSL connection.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.29 70030

The server requested password-based authentication, but no password was provided.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.30 70031

The authentication type @1@ is not supported. Check that you have configured the pg_hba.conf file to include the client's IP address or subnet, and that it is using an authentication scheme supported by the driver.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.31 70032

Protocol error. Session setup failed.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.32 70034

The column index is out of range: @1@, number of columns: @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.33 70035

No value specified for parameter @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.34 70036

Expected command status BEGIN, got @1@.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.35 70037

Unexpected command status: @1@.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.36 70038

An I/O error occurred while sending to the backend.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.37 70039

Unknown Response Type @1@.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.38 70040

Ran out of memory retrieving query results.

[Description]

There was insufficient free space in the server's memory during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Estimate memory usage and take the following action:

- If the number of simultaneous connections from client applications is high, reduce it.
- If the number of simultaneous SQL executions is high, reduce it.

2.102.39 70044

CommandComplete expected COPY but got:

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.40 70045

Tried to obtain lock while already holding it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.41 70046

Tried to break lock on database connection

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.42 70047

Interrupted while waiting to obtain lock on database connection

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.43 70048

Unable to bind parameter values for statement.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.44 70049

Database connection failed when starting copy

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.45 70050

Tried to cancel an inactive copy operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.46 70051

Database connection failed when canceling copy operation

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.47 70052

Missing expected error response to copy cancel request

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.48 70053

Got @1@ error responses to single copy cancel request

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.49 70054

Tried to end inactive copy

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.50 70055

Database connection failed when ending copy

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- If the COMMIT process is not executed after update, add the COMMIT process.
 - If the total number of update records in a single transaction is high, split it into short transactions.
 - If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - Confirm that the database server has not stopped.
 - If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.51 70056

Tried to write to an inactive copy operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.52 70057

Database connection failed when writing to copy

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.53 70058

Tried to read from inactive copy

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.54 70059

Database connection failed when reading from copy

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.55 70060

Received CommandComplete "@1@" without an active copy operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.56 70061

Got CopyInResponse from server during an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.57 70062

Got CopyOutResponse from server during an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.58 70063

Got CopyData without an active copy operation

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.59 70064

Unexpected copydata from server for @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.60 70065

Unexpected packet type during copy: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.61 70066

Bind message length @1@ too long. This can be caused by very large or incorrect length specifications on InputStream parameters.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.62 70067

The server's client_encoding parameter was changed to @1@. The JDBC driver requires client_encoding to be UTF8 for correct operation.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.63 70068

The server's DateStyle parameter was changed to @1 @. The JDBC driver requires DateStyle to begin with ISO for correct operation.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.64 70069

The server's standard_conforming_strings parameter was reported as @1 @. The JDBC driver expected on or off.

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.102.65 70070

The driver currently does not support COPY operations.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.66 70071

This PooledConnection has already been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.67 70072

Connection has been closed automatically because a new connection was opened for the same PooledConnection or the PooledConnection has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.68 70073

Connection has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.69 70074

Statement has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.70 70075

Failed to setup DataSource.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.102.71 70076

DataSource has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.72 70077

Fastpath call @1@ - No result was returned and we expected an integer.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.73 70078

The fastpath function @1@ is unknown.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.74 70079

Conversion to type @1@ failed: @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.75 70080

Cannot tell if path is open or closed: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.76 70081

GSS Authentication failed

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
- a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.102.77 70082

The array index is out of range: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.78 70083

The array index is out of range: @1@, number of elements: @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.79 70084

Truncation of large objects is only implemented in 8.3 and later servers.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.80 70085

Cannot truncate LOB to a negative length.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.81 70086

PostgreSQL LOBs can only index to: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.82 70087

LOB positioning offsets start at 1.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.83 70088

free() was called on this LOB previously

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.84 70089

Unsupported value for stringtype parameter: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.85 70091

No results were returned by the query.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.86 70092

A result was returned when none was expected.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.102.87 70093

Custom type maps are not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.88 70094

Failed to create object for: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.89 70095

Unable to load the class @1@ responsible for the datatype @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.90 70096

Cannot change transaction read-only property in the middle of a transaction.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.91 70097

Cannot commit when autoCommit is enabled.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.92 70098

This connection has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.102.93 70099

Cannot rollback when autoCommit is enabled.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103 Message Numbers Beginning with 70100

2.103.1 70100

Cannot change transaction isolation level in the middle of a transaction.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.2 70101

Transaction isolation level @1@ not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.3 70102

Unable to translate data into the desired encoding.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.4 70103

Unable to determine a value for MaxIndexKeys due to missing system catalog data.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.5 70104

Unable to find name datatype in the system catalogs.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.6 70105

Operation requires a scrollable ResultSet, but this ResultSet is FORWARD_ONLY.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.7 70107

Can't use relative move methods while on the insert row.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.8 70108

Invalid fetch direction constant: @1@.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.9 70109

Cannot call cancelRowUpdates() when on the insert row.**[Description]**

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.10 70110

Cannot call deleteRow() when on the insert row.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.11 70111

Currently positioned before the start of the ResultSet. You cannot call deleteRow() here.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.12 70112

Currently positioned after the end of the ResultSet. You cannot call deleteRow() here.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.13 70113

There are no rows in this ResultSet.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.14 70114

Not on the insert row.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.15 70115

You must specify at least one column value to insert a row.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.16 70116

The JVM claims not to support the encoding: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.17 70117

Provided InputStream failed.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.18 70118

Provided Reader failed.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.19 70119

Can't refresh the insert row.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.20 70120

Cannot call updateRow() when on the insert row.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.21 70121

Cannot update the ResultSet because it is either before the start or after the end of the results.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.22 70122

ResultSets with concurrency CONCUR_READ_ONLY cannot be updated.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.23 70123

No primary key found for table @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.24 70124

Fetch size must be a value greater to or equal to 0.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.25 70125

Invalid character data was found. This is most likely caused by stored data containing characters that are invalid for the character set the database was created in. The most common example of this is storing 8bit data in a SQL_ASCII database.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.26 70126

Bad value for type @1@ : @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.27 70127

The column name @1@ was not found in this ResultSet.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.28 70128

ResultSet is not updateable. The query that generated this result set must select only one table, and must select all primary keys from that table. See the JDBC 2.1 API Specification, section 5.6 for more details.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.29 70129

This ResultSet is closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.30 70130

ResultSet not positioned properly, perhaps you need to call next.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.31 70131

Can't use query methods that take a query string on a PreparedStatement.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.32 70132

Multiple ResultSets were returned by the query.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.33 70133

A CallableStatement was executed with nothing returned.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.34 70134

A CallableStatement was executed with an invalid number of parameters

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.35 70135

A CallableStatement function was executed and the out parameter @1@ was of type @2@ however type @3@ was registered.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.36 70136

Maximum number of rows must be a value greater than or equal to 0.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.37 70137

Query timeout must be a value greater than or equals to 0.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.38 70138

The maximum field size must be a value greater than or equal to 0.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.39 70139

Unknown Types value.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.40 70140

Invalid stream length @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.41 70141

The JVM claims not to support the @1@ encoding.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.42 70142

Unknown type @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.43 70143

Cannot cast an instance of @1@ to type @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.44 70144

Unsupported Types value: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.45 70145

Can't infer the SQL type to use for an instance of @1@. Use setObject() with an explicit Types value to specify the type to use.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.46 70146

This statement does not declare an OUT parameter. Use '{' ?= call ... }' to declare one.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.47 70147

wasNull cannot be call before fetching a result.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.48 70148

Malformed function or procedure escape syntax at offset @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.49 70149

Parameter of type @1@ was registered, but call to get@2@ (sqltype=@3@) was made.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.50 70150

A CallableStatement was declared, but no call to registerOutParameter(1, <some type>) was made.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.51 70151

No function outputs were registered.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.52 70152

Results cannot be retrieved from a CallableStatement before it is executed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.53 70153

This statement has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.54 70154

Too many update results were returned.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.55 70155

Batch entry @1@ @2@ was aborted: @3@ Call getNextException to see other errors in the batch.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.56 70156

Unexpected error writing large object to database.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.57 70157

@1@ function takes one and only one argument.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.58 70158

@1@ function takes two and only two arguments.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.59 70159

@1 @ function takes four and only four argument.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.60 70160

@1 @ function takes two or three arguments.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.61 70161

@1 @ function doesn't take any argument.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.62 70162

@1 @ function takes three and only three arguments.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.63 70163

Interval @1@ not yet implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.64 70166

Unknown ResultSet holdability setting: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.65 70168

Cannot establish a savepoint in auto-commit mode.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.66 70169

Returning autogenerated keys is not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.67 70170

The parameter index is out of range: @1@, number of parameters: @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.68 70172

Returning autogenerated keys by column index is not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.69 70173

Cannot reference a savepoint after it has been released.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.70 70174

Cannot retrieve the id of a named savepoint.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.71 70175

Cannot retrieve the name of an unnamed savepoint.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.72 70176

Invalid UUID data.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.73 70177

Unable to find server array type for provided name @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.74 70178

Failed to set ClientInfo property: @1@

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.75 70179

ClientInfo property not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.76 70180

Unable to decode xml data.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.77 70181

Unknown XML Source class: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.78 70182

Unable to create SAXResult for SQLXML.

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.79 70183

Unable to create StAXResult for SQLXML

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.103.80 70184

Unknown XML Result class: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.81 70185

This SQLXML object has already been freed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.82 70186

This SQLXML object has not been initialized, so you cannot retrieve data from it.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.83 70187

Failed to convert binary xml data to encoding: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.84 70188

Unable to convert DOMResult SQLXML data to a string.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.85 70189

This SQLXML object has already been initialized, so you cannot manipulate it further.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.86 70191

Large Objects may not be used in auto-commit mode.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.87 70192

The SSLSocketFactory class provided @1@ could not be instantiated.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.88 70193

Conversion of interval failed

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.89 70194

Conversion of money failed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.90 70195

Transaction control methods setAutoCommit(true), commit, rollback and setSavePoint not allowed while an XA transaction is active.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.91 70196

Invalid flags

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.92 70197

xid must not be null

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.93 70198

Connection is busy with another transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.103.94 70199

suspend/resume not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104 Message Numbers Beginning with 70200

2.104.1 70200

Transaction interleaving not implemented

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.2 70201

Error disabling autocommit

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.104.3 70202

tried to call end without corresponding start call

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.4 70203

Not implemented: Prepare must be issued using the same connection that started the transaction

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.5 70204

Prepare called before end

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.6 70206

Error preparing transaction

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.104.7 70207

Invalid flag

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.8 70208

Error during recover

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.104.9 70209

Error rolling back prepared transaction

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.104.10 70210

Not implemented: one-phase commit must be issued using the same connection that was used to start it

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.11 70211

commit called before end

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.12 70212

Error during one-phase commit

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.104.13 70213

Not implemented: 2nd phase commit must be issued using an idle connection

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.14 70214

Error committing prepared transaction

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.104.15 70215

Heuristic commit/rollback not supported

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.16 70221

Could not find a server with specified targetServerType: @1@

[Description]

Could not find a suitable target server.

[System Processing]

Processing is aborted.

[Action]

Check following settings (host, IP address, port number, or targetServer):

- Connection string
- Connection service file
- Data source of JDBC or ODBC
- Environment variables for default connection parameter values(ex. PGHOST)
- Arguments of functions of libpq
- Options of command

2.104.17 70222

Invalid timeout (@1@<0).

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.18 70225

Invalid targetServerType value: @1@

[Description]

value of targetserver is invalid.

[System Processing]

Processing is aborted.

[Action]

Set one of the following:

- primary
- standby
- prefer_standby
- any(can be specified only JDBC)

2.104.19 70226

The sslservercertcn @1@ could not be verified.

[Description]

value of sslservercertcn is different from common name in the server certificate.

[System Processing]

Processing is aborted.

[Action]

Set SSL certificate's common name to sslservercertcn.

2.104.20 70227

The sslservercertcn @1@ could not be verified by hostnameverifier @2@.

[Description]

value of sslservercertcn is different from common name in the server certificate.

[System Processing]

Processing is aborted.

[Action]

- Set SSL certificate's common name to sslservercertcn.

- Check the program of class specified by hostnameverifier.

2.104.21 70228

Properties for the driver contains a non-string value for the key

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.104.22 70229

(pgjdbc: autodetected server-encoding to be @1 @, if the message is not readable, please check database logs and/or host, port, dbname, user, password, pg_hba.conf)

[Description]

An error occurred.

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

2.104.23 70230

Object is too large to send over the protocol.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.24 70231

No IOException expected from StringBuffer or StringBuilder

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.25 70232

oid type @1@ not known and not a number

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.26 70233

The SocketFactory class provided @1@ could not be instantiated.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.27 70234

Added parameters index out of range: @1@, number of columns: @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.28 70235

Invalid sslmode value: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.29 70237

Unsupported property name: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.30 70238

Fastpath call @1@ - No result was returned and we expected a numeric.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.31 70239

Fastpath call @1@ - No result was returned or wrong size while expecting an integer.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.32 70240

Fastpath call @1@ - No result was returned and we expected a long.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.33 70241

Fastpath call @1@ - No result was returned or wrong size while expecting a long.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.34 70242

@1@ parameter value must be an integer but was: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.35 70243

The sslfactoryarg property may not be empty.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.36 70244

The environment variable containing the server's SSL certificate must not be empty.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.37 70245

The system property containing the server's SSL certificate must not be empty.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.38 70246

The sslfactoryarg property must start with the prefix file:, classpath:, env:, sys:, or -----BEGIN CERTIFICATE-----.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.39 70247

An error occurred reading the certificate

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.40 70248

No X509TrustManager found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.41 70249

Could not find a java cryptographic algorithm: X.509 CertificateFactory not available.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.42 70250

Could not open SSL certificate file @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.43 70251

Loading the SSL certificate @1@ into a KeyManager failed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.44 70252

Could not read password for SSL key file, console is not available.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.45 70253

Could not read password for SSL key file by callbackhandler @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.46 70254

Could not decrypt SSL key file @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.47 70255

Could not read SSL key file @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.48 70256

Could not find a java cryptographic algorithm: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.49 70257

The password callback class provided @1@ could not be instantiated.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.50 70258

Could not open SSL root certificate file @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.51 70259

Could not read SSL root certificate file @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.52 70260

Loading the SSL root certificate @1@ into a TrustManager failed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.53 70261

Could not initialize SSL context.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.54 70262

SSL error: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.55 70263

The HostnameVerifier class provided @1@ could not be instantiated.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.56 70264

The hostname @1@ could not be verified by hostnameverifier @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.57 70266

One ore more ClientInfo failed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.58 70267

Can't use executeWithFlags(int) on a Statement.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.59 70268

Bad value for type timestamp/date/time: @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.60 70269

Unsupported binary encoding of @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.61 70270

Cannot convert the column of type @1@ to requested type @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.62 70271

No hstore extension installed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.63 70272

Unsupported properties: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.64 70293

SCRAM authentication is not supported by this driver. You need JDK >= 8 and pgjdbc >= 42.2.0 (not ".jre" versions).

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.65 70294

Finalizing a Connection that was never closed.

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.104.66 70295

Validating connection.

[Description]

The application or command terminated normally, but a warning was output.

[System Processing]

Processing will continue.

[Action]

Check the message text and confirm that the issue does not affect the expected outcome.

2.104.67 70296

Invalid elements @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.68 70297

Network timeout must be a value greater than or equal to 0.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.69 70298

Unable to set network timeout.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.104.70 70299

Unable to get network timeout.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105 Message Numbers Beginning with 70300

2.105.1 70300

No SCRAM mechanism(s) advertised by the server.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.2 70301

Invalid or unsupported by client SCRAM mechanisms

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.3 70302

Invalid server-first-message: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.4 70303

Invalid server-final-message: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.5 70304

SCRAM authentication failed, server returned error: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.6 70305

Invalid server SCRAM signature.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.7 70306

Enter SSL password:

[Description]

Terminated normally.

[System Processing]

Continues processing.

[Action]

No action required.

2.105.8 70307

Detail: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.9 70308

Hint: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.10 70309

Position: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.11 70310

Where: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.12 70311

Internal Query: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.13 70312

Location: File: @1@, Routine: @2@, Line: @3@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.14 70313

Server SQLState: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.15 70314

conversion to @1@ from @2@ not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.16 70315

Requested CopyDual but got @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.17 70316

CopyIn copy direction can't receive data

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.18 70317

An error occurred while trying to get the socket timeout.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.19 70318

An error occurred while trying to reset the socket timeout.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.20 70319

Got CopyBothResponse from server during an active @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.21 70320

Unable to parse the count in command completion tag: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.22 70321

Unexpected packet type during replication: @1@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.23 70322

This replication stream has been closed.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.24 70323

Cannot cast to boolean: "@1@"

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.25 70324

Unsupported type conversion to @2@.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.26 70325

Error releasing savepoint

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.105.27 70327

Invalid Inet data.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.105.28 70328

Server does not support temporary replication slots

[Description]

(Nothing)

[System Processing]

(Nothing)

[Action]

(Nothing)

2.106 Message Numbers Beginning with 80000

2.106.1 80001

The connection configuration file cannot be opened. detail: '@1@'

[Description]

The process to open the connection configuration file failed.

[System Processing]

Processing is aborted.

[Action]

This messages is output in the case of HA Database Ready.

Check the state of the connection configuration file, remove the cause of the error, and restart the application.

2.106.2 80002

Invalid definition statement format in connection configuration file. line number: @1@

[Description]

The format of a parameter definition statement in the connection configuration file is invalid.

[System Processing]

Processing is aborted.

[Action]

This messages is output in the case of HA Database Ready.

Correct the connection configuration file and restart the application.

2.106.3 80003

The same server name is specified by two or more SERVER parameters in the connection configuration file.

[Description]

The same server name is specified in multiple SERVER parameters in the connection configuration file.

[System Processing]

Processing is aborted.

[Action]

This messages is output in the case of HA Database Ready.

Correct the server name specified in the SERVER parameter of the connection configuration file, and restart the application.

2.106.4 80004

I/O error occurred during the reading of connection configuration file. file name: '@1@' detail: '@2@'

[Description]

An I/O error occurred during loading of the connection configuration file.

[System Processing]

Processing is aborted.

[Action]

This messages is output in the case of HA Database Ready.

Check the state of the connection configuration file, remove the cause of the error, and restart the application.

2.106.5 80005

CommandTimeout can't be less than zero.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.6 80006

The Connection is broken.

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.106.7 80007

The Connection is not open.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.8 80008

Parameter @1@ not found in query.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.9 80009

The Connection property can't be changed with an uncommitted transaction.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.10 80010

There is already an open DataReader associated with this Command which must be closed first.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.11 80011

@1@ does not exist in pg_proc

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.12 80012

Invalid parameter type: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.13 80013

Connection is not open

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.14 80014

Connection already open

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.15 80015

Invalid database name: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.16 80016

Connection string argument missing!

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.17 80017

Nested/Concurrent transactions aren't supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.18 80018

numeric value @1@ in ConnectionString exceeds maximum value @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.19 80019

numeric value @1@ in ConnectionString is below minimum value @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.20 80020

expecting @1@=[True/False] value in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.21 80021

expecting @1 @=[Numeric] value in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.22 80022

expecting @1 @=[Protocol Version] value in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.23 80023

key=value argument incorrect in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.24 80024

Attempt to set compatibility with version @1@ when using version @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.25 80025

There is already an open DataReader associated with this Command which must be closed first.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.26 80026

ApplicationName not supported.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.27 80027

Timeout while getting a connection from pool.

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.106.28 80028

Connection pool exceeds maximum size.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.29 80029

Not a COPY IN query: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.30 80030

Copy can only start in Ready state, not in @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.31 80031

Tried to set Position of network stream @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.32 80032

Tried to read non-readable @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.33 80033

Tried to seek non-seekable @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.34 80034

Tried to set length of network stream @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.35 80035

Not a COPY OUT query, not in @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.36 80036

Copy can only start in Ready state, not in @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.37 80037

Tried to set Position of network stream @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.38 80038

Tried to write non-writable @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.39 80039

Tried to flush read-only @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.40 80040

Tried to seek non-seekable @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.41 80041

Tried to set length of network stream @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.42 80042

Do not change stream of an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.43 80043

Do not change delimiter of an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.44 80044

Do not change separator of an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.45 80045

Do not change escape symbol of an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.46 80046

Do not change null symbol of an active @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.47 80047

Tried to add too many fields to a copy record with @1@ fields

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.48 80048

Invalid attempt to read when no data is present.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.49 80049

Column index out of range

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.50 80050

could not find a suitable target server

[Description]

Could not find a suitable target server.

[System Processing]

Processing is aborted.

[Action]

Check following settings (host, IP address, port number, or targetServer):

- Connection string
- Connection service file
- Data source of JDBC or ODBC
- Environment variables for default connection parameter values(ex. PGHOST)
- Arguments of functions of libpq
- Options of command

2.106.51 80051

server does not support auto connection switching

[Description]

The server does not support auto connection switching.

[System Processing]

Processing is aborted.

[Action]

Specify servers that support auto connection switching.

2.106.52 80052

Only AuthenticationClearTextPassword and AuthenticationMD5Password supported for now. Received: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.53 80053

A timeout has occurred. If you were establishing a connection, increase Timeout value in ConnectionString. If you were executing a command, increase the CommandTimeout value in ConnectionString or in your NpgsqlCommand object.

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.106.54 80054

Connection establishment timeout. Increase Timeout value in ConnectionString.

[Description]

Timeout occurred during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Check the following:

- If executing SQL that outputs a large volume of search results, add a conditional expression to filter the results further.
- If numerous SQLs are being simultaneously executed, reduce the number of simultaneously executed SQLs.
- If a large volume of data is to be updated in a single transaction, modify the SQL to reduce the volume of data to be updated in a single transaction.
- If executing a complex SQL, modify it to a simple SQL.
- Check if there are any problems in the network.
- Before conducting maintenance that involves the processing of a large volume of data, use the SET statement to temporarily increase the value of maintenance_work_mem.

2.106.55 80055

Failed to establish a connection to '@1@'.

[Description]

The database server was disconnected during execution of the application.

[System Processing]

Processing will be aborted.

[Action]

Communication may have been disconnected for the following reasons:

- An error occurred in the communication line (TCP/IP etc.)
- The database server terminated abnormally.

Take the following actions:

- Eliminate the cause of the communication disconnection.

Examine the application and check whether the transaction for implementing update is a long transaction. Judge whether it is a long transaction from the following viewpoints and modify the application.

- a) If the COMMIT process is not executed after update, add the COMMIT process.
 - b) If the total number of update records in a single transaction is high, split it into short transactions.
 - c) If search was conducted for a long period of time after update, execute COMMIT after update or review the search SQL statement.
- If none of the above situations applies, perform the following:
 - a) Confirm that the database server has not stopped.
 - b) If the database server is starting or stopping, re-execute the command after the database server starts.

2.106.56 80056

Ssl connection requested. No Ssl enabled connection from this host is configured.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.57 80057

Backend sent unrecognized response type: @1@

[Description]

An error occurred during communication between the application and the database server.

[System Processing]

Processing will be aborted.

[Action]

Check if there are any problems in the network, eliminate the cause of any error and re-execute the command.

2.106.58 80058

Store does not support specified edm type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.59 80059

Can't cast @1 @ into any valid DbType.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.60 80060

Cannot set NpgsqlDbType to just Array, Binary-Or with the element type (e.g. Array of Box is NpgsqlDbType.Array | NpgsqlDbType.Box).

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.61 80061

Can't cast @1 @ into NpgsqlParameter

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.62 80062

Invalid attempt to read from column ordinal '@1@'. With CommandBehavior.SequentialAccess, you may only read from column ordinal '@2@' or greater.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.63 80063

this[] index value

[Description]

An unexpected error occurred.

[System Processing]

Processing will be aborted.

[Action]

Contact Fujitsu technical support.

2.106.64 80064

Field not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.65 80065

No transaction in progress.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.66 80066

Savepoint is not supported by backend.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.67 80067

Savepoint name cannot have semicolon.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.68 80068

The collection is read-only

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.69 80069

NotSupported @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.70 80070

Require primitive EdmType

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.71 80071

NotSupported: @1@ @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.72 80072

The authData parameter can only be null at the first call to continue!

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.73 80073

SSPI returned invalid number of output buffers

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.74 80074

Dns hostname lookup timeout. Increase Timeout value in ConnectionString.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.75 80075

Could not load Npgsql.EntityFrameworkCoreLegacy assembly, is it installed?

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.76 80076

Npgsql.EntityFrameworkCoreLegacy assembly does not seem to contain the correct type!

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.77 80077

Invalid parameter name: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.78 80078

Parameter not found

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.79 80079

The parameter already belongs to a collection

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.80 80080

No parameter with the specified name exists in the collection

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.81 80081

Only AuthenticationClearTextPassword and AuthenticationMD5Password supported for now. Received: @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.82 80082

key=value argument incorrect in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.83 80083

expecting @1@=[True/False] value in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.84 80084

expecting @1 @=[Numeric] value in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.85 80085

numeric value @1 @ in ConnectionString exceeds maximum value @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.86 80086

numeric value @1 @ in ConnectionString is below minimum value @2@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.87 80087

expecting @1 @=[Protocol Version] value in ConnectionString

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.88 80088

The Transaction property can't be changed with an uncommitted transaction.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.89 80089

Only Text and StoredProcedure types supported!

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.90 80090

There have been errors reported by the backend.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.91 80091

There have been errors on @1@():

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.92 80092

There have been errors on @1 @(@2@):

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.93 80093

The Connection is not set.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.94 80094

Multiple queries not supported for this command type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.95 80095

Cannot derive function parameter of type VARIADIC

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.96 80096

Cannot derive function parameter of type TABLE

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.97 80097

ConnectionString cannot be empty.

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.98 80098

A SocketException occurred

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.106.99 80099

There have been errors on Open()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107 Message Numbers Beginning with 80100

2.107.1 80100

Error in Close()

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.2 80101

Insufficient backend data to describe dimension count in binary array header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.3 80102

Invalid array dimension count encountered in binary array header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.4 80103

Insufficient backend data to describe all expected dimensions in binary array header

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.5 80104

Out of backend data while reading binary array

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.6 80105

Expected a hex character, got

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.7 80106

Expected a hex character, got @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.8 80107

Expected an octal character, got @1@

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.9 80108

Object is immutable

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.10 80109

Unexpected integer binary field length

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.11 80110

Unexpected float binary field length

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.12 80111

Unable to cast data to NpgsqlPoint type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.13 80112

Unable to cast data to Rectangle type

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.14 80113

Type already mapped

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.15 80114

NpgsqlDbType already aliased

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.16 80115

DbType already aliased

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

2.107.17 80116

Type already aliased

[Description]

An error occurred during execution of the application or command.

[System Processing]

Processing will be aborted.

[Action]

Check the message text and confirm that the application is written correctly and the command is being used correctly.

Chapter 3 Mirroring Controller Messages

This chapter explains messages output by Mirroring Controller.

3.1 Message Numbers Beginning with MCA00000

3.1.1 MCA00001

could not read file "{0}": exception={1}: {2}

[Description]

Could not read the file.

[Parameters]

{0}: file name

{1}: exception type

{2}: exception detail

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the message, and then remove it.

3.1.2 MCA00002

{0}: wrong number of server ID in definition file "{1}"

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.3 MCA00003

{0}: server ID not found in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.4 MCA00004

{0}: server ID specified in definition file "{1}" too long (max {2} bytes) line {3}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: max length of server ID

{3}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.5 MCA00005

invalid host name or IP address "{1}" in definition file "{0}"

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: file name

{1}: host name or IP address

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.6 MCA00006

{0}: invalid port number in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.7 MCA00007

{0}: invalid format specified in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.8 MCA00008

{0}: invalid value for parameter "{2}" in definition file "{1}"

[Description]

Invalid parameter was found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.9 MCA00009

{0}: no value for parameter "{2}" specified in definition file "{1}"

[Description]

Invalid parameter was found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.10 MCA00010

{0}: unrecognized parameter "{2}" in definition file "{1}"

[Description]

Unrecognized parameter was found in definition file.

[Parameters]

{0}: file name

{1}: command name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.1.11 MCA00011

%s: no operation mode specified

[Description]

No operation mode was specified.

[Parameters]

%s: command name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying operation modes.

3.1.12 MCA00012

%s: unrecognized operation mode "%s"

[Description]

Unrecognized operation mode was specified.

[Parameters]

%s: command name

%s: operation mode

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying operation modes.

3.1.13 MCA00013

%s: option "%s" duplicated

[Description]

Certain option is duplicated.

[Parameters]

%s: command

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.1.14 MCA00014

%s: "%s" option conflicts with "%s" option

[Description]

Options are conflicting.

[Parameters]

%s: command

%s: option

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.1.15 MCA00015

%s: option requires an argument -- %s

[Description]

No argument specified for the option.

[Parameters]

%s: command

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.1.16 MCA00016

%s: neither "%s" option nor environment variable "%s" specified

[Description]

Both of required option and equivalent environment variable were not specified.

[Parameters]

%s: command

%s: option

%s: environment variable

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying required option or equivalent environment variable.

3.1.17 MCA00017

%s: out of memory

[Description]

Out of memory error occurred.

[Parameters]

%s: command

[System Processing]

Processing will be aborted.

[Action]

Obtain free memory space by stopping unnecessary processes or changing system settings.

3.1.18 MCA00018

out of memory

[Description]

Out of memory error occurred.

[System Processing]

Processing will be aborted.

[Action]

Obtain free memory space by stopping unnecessary processes or changing system settings.

3.1.19 MCA00019

detected an error on the monitored object "{0}({1)": {2}

[Description]

An error was detected on the monitored object.

[Parameters]

{0}: monitored object (server, database process, data storage destination directory, transaction log storage destination directory, tablespace directory)

{1}: object name (host name, database process name, directory path)

{2}: error detail ("no response:", "read/write error:" and detailed information)

[System Processing]

Perform failover or detaching.

If failover or detaching is already performed, these functions would be disabled.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.1.20 MCA00020

unexpected error occurred in the monitoring process: {0}

[Description]

Monitoring process cannot continue because an unexpected error was occurred during its processing.

[Parameters]

{0}: error detail

[System Processing]

Continues processing.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.1.21 MCA00021

starting to {2} from {0} to {1}.

[Description]

Switching standby server to primary server.

[Parameters]

{0}: server ID of primary server

{1}: server ID of standby server

{2}: "fail over" or "switch over"

[Action]

If Mirroring Controller executed switching automatically, find the message output before this message from system log or event log to identify the cause of switching, and then work around according to the Action of the message.

3.1.22 MCA00022

{2} completed.switched from {0} to {1}

[Description]

Switching standby server to primary server was completed.

[Parameters]

{0}: server ID of primary server

{1}: server ID of standby server

{2}: "fail over"or"switch over"

3.1.23 MCA00023

failed to {2} from {0} to {1}

[Description]

Failed to switch to primary server because of unexpected failure.

[Parameters]

{0}: server ID of primary server

{1}: server ID of standby server

{2}: "fail over"or"switch over"

[System Processing]

Processing of switching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.1.24 MCA00024

starting to detach standby server "{0}" {1}

[Description]

Detaching standby server because of failure detected on standby server.

[Parameters]

{0}: server ID

{1}: "automatically" or none

[Action]

If Mirroring Controller executed detaching automatically, find the message output before this message from system log or event log to identify the cause of detaching, and then work around according to the Action of the message.

3.1.25 MCA00025

detach standby server "{0}" completed {1}

[Description]

Detached standby server.

[Parameters]

{0}: server ID

{1}: "automatically" or none

3.1.26 MCA00026

failed to {2} standby server "{0}" {1}

[Description]

Failed to detach standby server.

[Parameters]

{0}: server ID

{1}: "automatically" or none

{2}: "detach"

[System Processing]

Processing of detaching will be aborted.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.1.27 MCA00027

another "{0}" command is running

[Description]

Cannot execute command with this operation mode because another command is running on the same or another server.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

There is a case executing another command. Wait for completion of another command on the same or another server, and then re-execute.

In addition, there are the following cases when using mc_ctl command.

There is a case under processing of a failover and an automatic detach by Mirroring Controller. Wait for completion of the processing under operation, and re-execute.

If any of the following cases occurs, there is a possibility that the processing of Mirroring Controller interrupts. Re-execute the mc_ctl command after restarting Mirroring Controller.

- When abnormality occurs in the network
- When another server is downed
- When Mirroring Controller is stopped forcibly

3.1.28 MCA00028

communication timeout of Mirroring Controller occurred server:"{0}"

[Description]

Either of the followings has occurred.

- communication timeout between mc_ctl command and Mirroring Controller process has occurred.
- communication timeout between Mirroring Controller processes have occurred.
- Terminating database instance was not completed in the specified time.

[Parameters]

{0}: server ("localhost" or server ID)

[System Processing]

Processing will be aborted.

[Action]

Completion synchronization for terminating database instance might have timed out, because connections remained. Disconnect all connections, and re-execute it.

Reduce CPU or network load caused by the other processes. If could not reduce it, extend remote_call_timeout in "server identifier".conf.

3.1.29 MCA00029

could not create PID file "{0}" of Mirroring Controller detail of cause:"{1}"

[Description]

Could not create PID file of Mirroring Controller.

[Parameters]

{0}: file name

{1}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the message, and then remove it.

3.1.30 MCA00030

could not remove PID file "%s" of Mirroring Controller detail of cause:"%s"

[Description]

Could not remove PID file of Mirroring Controller.

[Parameters]

%s: file name

%s: detail of cause

[Action]

Identify the cause according to the message, and then remove it.

3.1.31 MCA00031

could not read PID file "%s" of Mirroring Controller detail of cause:"%s"

[Description]

Could not read PID file of Mirroring Controller.

[Parameters]

%s: file name

%s: detail of cause

[Action]

Identify the cause according to the message, and then remove it.

3.1.32 MCA00032

invalid contents of PID file "%s" of Mirroring Controller

[Description]

The contents of PID file of Mirroring Controller is invalid.

[Parameters]

%s: file name

[System Processing]

Processing will be aborted.

[Action]

The following causes could be considered.

- The file was stored or replaced by mistake
- The file was corrupted

When starting Mirroring Controller, move or remove the file shown in the message.

When stopping Mirroring Controller, terminate forcibly mc_keeper process and terminate forcibly mc_agent process with using OS command.

3.1.33 MCA00033

Mirroring Controller is already running

[Description]

Mirroring Controller is already running.

[System Processing]

Processing will be aborted.

[Action]

If needed, stop Mirroring Controller, and re-execute.

3.1.34 MCA00034

cannot execute %s command because Mirroring Controller is not running

[Description]

Cannot execute Mirroring Controller command because Mirroring Controller process is not running.

[Parameters]

%s: command name

[System Processing]

Processing will be aborted.

[Action]

Start Mirroring Controller, and re-execute.

3.1.35 MCA00035

failed to start database instance

[Description]

Failed to start database instance.

[System Processing]

Processing will be aborted.

[Action]

Find the database message output in the log files of database output before this message, and then work around according to the Action of the message.

3.1.36 MCA00036

failed to stop database instance target server:"{0}"

[Description]

Failed to stop database instance.

[Parameters]

{0}: target server ("localhost" or server ID)

[System Processing]

Processing will be aborted.

[Action]

Find the database message output in the log files of database on the target server output before this message, and then work around according to the Action of the message.

3.1.37 MCA00037

Mirroring Controller option is not installed

[Description]

This functionality is enabled by installing Mirroring Controller option.

[System Processing]

Processing will be aborted.

[Action]

To use this functionality, install Mirroring Controller option, and then re-execute.

3.1.38 MCA00038

starting Mirroring Controller

[Description]

Starting Mirroring Controller.

3.1.39 MCA00039

Mirroring Controller started

[Description]

Mirroring Controller started.

3.1.40 MCA00040

failed to start Mirroring Controller

[Description]

Failed to start Mirroring Controller.

[System Processing]

Processing will be aborted.

[Action]

Work around according to the Action of the message output before this message.

On Windows, if there is no message outputted before this message, please refer to the message outputted to an event log.

3.1.41 MCA00041

stopping Mirroring Controller

[Description]

Stopping Mirroring Controller.

3.1.42 MCA00042

Mirroring Controller stopped target server:"{0}"

[Description]

Mirroring Controller stopped.

[Parameters]

{0}: target server ("localhost" or server ID)

3.1.43 MCA00043

failed to stop Mirroring Controller target server:"{0}"

[Description]

Failed to stop Mirroring Controller.

[Parameters]

{0}: target server ("localhost" or server ID)

[System Processing]

Processing will be aborted.

[Action]

Identify the cause from system log or event log on the target server, and work around.

3.1.44 MCA00044

stopping Mirroring Controller forcibly

[Description]

Stopping Mirroring Controller forcibly.

3.1.45 MCA00045

stopped Mirroring Controller forcibly

[Description]

Mirroring Controller stopped forcibly.

3.1.46 MCA00046

enabled failover target server:"{0}"

[Description]

Enabled failover and automatic detach.

[Parameters]

{0}: target server ("localhost" or server ID)

3.1.47 MCA00047

failed to enable failover target server:"{0}"

[Description]

Failed to enable failover and automatic detach.

[Parameters]

{0}: target server ("localhost" or server ID)

[System Processing]

Processing will be aborted.

[Action]

Identify the cause from messages on system log or event log, and work around.

3.1.48 MCA00048

disabled failover target server:"{0}"

[Description]

Disabled failover and automatic detach.

[Parameters]

{0}: target server ("localhost" or server ID)

3.1.49 MCA00049

failed to disable failover target server:"{0}"

[Description]

Failed to disable failover and automatic detach.

[Parameters]

{0}: target server ("localhost" or server ID)

[System Processing]

Processing will be aborted.

[Action]

Identify the cause from messages on system log or event log, and work around.

3.1.50 MCA00050

{0}: server ID "{2}" specified with option "{1}" does not exist in definition file "{3}"

[Description]

server ID specified with the option does not exist in definition file.

[Parameters]

{0}: command name

{1}: option

{2}: server ID

{3}: file name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options or definition file.

3.1.51 MCA00051

{0}: The IP address or host name of the server where the command was executed in is not found on the definition file "{1}"

[Description]

Either of the followings has occurred.

- The IP address or host name that does not exist is specified.
- The network interface is stopped.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter descriptions of "Cluster Operation Guide (Database Multiplexing)".

3.1.52 MCA00052

{0}: wrong server ID "{2}" in definition file "{1}"

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: server ID

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter descriptions of "Cluster Operation Guide (Database Multiplexing)".

3.1.53 MCA00053

failed to detach standby server

[Description]

Failed to detach standby server

because processing of detaching cannot be continued by something failure.

[System Processing]

Processing of detaching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.1.54 MCA00054

could not write to file "{0}": exception={1}: {2}

[Description]

Failed to detach or synchronize standby server because could not write to the file.

[Parameters]

{0}: file name

{1}: exception type

{2}: exception detail

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes, and detach or synchronize standby server according to "Actions when an Error Occurs" of "Cluster Operation Guide (Database Multiplexing)".

3.1.55 MCA00055

unexpected error occurred in the monitoring process: {0}

[Description]

Monitoring process could not continue because the unexpected error occurred.

[Parameters]

{0}: detail of cause

[System Processing]

Continues monitoring.

[Action]

Check the error detail and eliminate causes.

If you cannot clear the problem, contact Fujitsu technical support.

3.1.56 MCA00056

unexpected error occurred: {0}

[Description]

An unexpected error occurred.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate cause.

If you cannot clear the problem, contact Fujitsu technical support.

3.1.57 MCA00057

failed to stop Mirroring Controller forcibly

[Description]

Failed to stop Mirroring Controller forcibly.

[System Processing]

Processing will be aborted.

[Action]

Check [Action] of the message output before this message, and re-execute.

If re-execution fails, terminate forcibly mc_keeper process and terminate forcibly mc_agent process with using OS command.

3.1.58 MCA00058

could not access path "%s" specified as a directory for Mirroring Controller detail of cause: "%s"

[Description]

could not access path specified as a directory for Mirroring Controller.

[Parameters]

%s: path name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.1.59 MCA00059

system call error occurred: "%s" detail of cause: "%s"

[Description]

System call error occurred.

[Parameters]

%s: system call name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.1.60 MCA00060

could not get installation path

[Description]

Enterprise Postgres may not be installed.

[System Processing]

Processing will be aborted.

[Action]

Re-install Enterprise Postgres.

3.1.61 MCA00061

could not access path "%1\$s" for parameter "%2\$s" in definition file "%3\$s" detail of cause:"%4\$s"

[Description]

could not access path for parameter in definition file.

[Parameters]

%3\$s: file name

%2\$s: parameter name

%1\$s: path name

%4\$s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.1.62 MCA00062

promotion processing completed

[Description]

Promotion processing completed.

3.1.63 MCA00063

promotion processing failed

[Description]

Promotion processing failed.

[System Processing]

Processing will be aborted.

[Action]

Clear the problem according to [Action] of the message which was output before this message in system log or in database server log.

3.1.64 MCA00064

stopped database instance forcibly

[Description]

Database instance stopped forcibly.

3.1.65 MCA00065

failed to stop database instance forcibly

[Description]

Failed to stop database instance forcibly.

[System Processing]

Processing will be aborted.

[Action]

Clear the problem according to [Action] of the message which was output before this message in system log or in database server log.

3.1.66 MCA00067

did not switch during a degeneration use

[Description]

Did not switch during a degeneration use.

[System Processing]

Processing will be aborted.

[Action]

If Mirroring Controller executed switching automatically, find the message output before this message from system log or event log to identify the cause of degeneration, and then eliminate causes according to [Action] of the message and try to switch with command.

3.1.67 MCA00068

{0}: users other than an instance administrator have the access privileges for definition file "{1}"

[Description]

users other than an instance administrator have the access privileges for definition file.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Revoke all the access privileges for users other than an instance administrator.

MCA00069

could not execute because Mirroring Controller of the server "{0}" is not running

[Description]

Could not execute because Mirroring Controller is not running.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Start Mirroring Controller, and try to switch with command.

3.1.68 MCA00070

Try "%s --help" for more information.\n

[Description]

--help option can show more additional information.

[Parameters]

%s: command name

[System Processing]

None.

[Action]

Check the message output before this message, and refer to descriptions shown by '--help' option.

3.1.69 MCA00071

starting to {0}

[Description]

Switching standby server to primary server.

[Parameters]

{0}: "switch over"

3.1.70 MCA00072

failed to {0}

[Description]

Failed to switch to primary server because of an unexpected failure.

[Parameters]

{0}: "switch over"

[System Processing]

Processing of switching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then eliminate causes according to [Action] of the message.

3.1.71 MCA00073

error detected in handling of the database instance detail of cause:"{0}"

[Description]

Error detected in handling of the database instance for the following purposes.

- Obtain the port number of database instance
- Access to the data storage destination directory

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.1.72 MCA00074

could not read PID file "{0}" of Mirroring Controller detail of cause:"{1}"

[Description]

Could not read PID file of Mirroring Controller.

[Parameters]

{0}: file name

{1}: detail of cause

[Action]

Identify the cause according to the message, and then remove it.

3.1.73 MCA00075

invalid contents of PID file "{0}" of Mirroring Controller

[Description]

The contents of PID file of Mirroring Controller is invalid.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

The following causes could be considered.

- The file was stored or replaced by mistake
- The file was corrupted

When starting Mirroring Controller, move or remove the file shown in the message.

When stopping Mirroring Controller, terminate forcibly mc_keeper process and terminate forcibly mc_agent process with using OS command.

3.1.74 MCA00076

cannot execute "{0}" command because Mirroring Controller is not running

[Description]

Cannot execute Mirroring Controller command because Mirroring Controller process is not running.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Start Mirroring Controller, and re-execute.

3.1.75 MCA00077

%s: argument of option "%s" is too long

[Description]

Argument of option is too long.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.1.76 MCA00078

%s: invalid option -- %s

[Description]

Invalid option.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.1.77 MCA00079

%s: unnecessary operand "%s"

[Description]

Unnecessary operand.

[Parameters]

%s: command name

%s: operand

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting operand.

3.1.78 MCA00080

%s: unrecognized operation mode or no operation mode specified

[Description]

Unrecognized operation mode or no operation mode specified.

[Parameters]

%s: command name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting or specifying operation mode.

3.1.79 MCA00081

start to enable the parameter "{1}" required to build in the standby server "{0}"

[Description]

Start to enable the parameter required to build in the standby server.

[Parameters]

{0}: server ID

{1}: parameter name

3.1.80 MCA00082

enabling the parameter "{1}" required to build in the standby server "{0}" completed

[Description]

Enabling the parameter required to build in the standby server completed.

[Parameters]

{0}: server ID

{1}: parameter name

3.1.81 MCA00083

failed to enable the parameter "{1}" required to build in the standby server "{0}"

[Description]

Failed to enable the parameter required to build in the standby server.

The following causes could be considered.

- another command is running
- can not access definition file
- parameter does not exist

[Parameters]

{0}: server ID

{1}: parameter name

[System Processing]

Processing will be aborted.

[Action]

- If the parameter is not set

On the primary server, set the parameter of postgresql.conf file according to "parameter" description of "Cluster Operation Guide (Database Multiplexing)" and execute pg_ctl command with reload mode.

- Otherwise

Find the message output before this message from display, system log or event log, and then eliminate causes according to [Action] of the message. Then, on the primary server, set the parameter of postgresql.conf file according to "parameter" description of "Cluster Operation Guide (Database Multiplexing)" and execute pg_ctl command with reload mode.

3.1.82 MCA00084

primary server is already running

[Description]

Primary server is already running.

[System Processing]

Processing will be aborted.

[Action]

The standby server might be running without creating standby.signal. Create standby.signal, and re-execute.

3.1.83 MCA00085

cannot start Mirroring Controller because database instance is not running

[Description]

Cannot start Mirroring Controller because database instance is not running.

[System Processing]

Processing will be aborted.

[Action]

Start database instance, and re-execute.

3.1.84 MCA00086

could not get state of database instance detail of cause:"{0}"

[Description]

Could not get state of database instance.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.1.85 MCA00087

unusable character is included in path "%s" specified as a directory for Mirroring Controller

[Description]

Unusable character is included in path specified as a directory for Mirroring Controller.

[Parameters]

%s: path name

[System Processing]

Processing will be aborted.

[Action]

Correct the path specified as a directory for Mirroring Controller according to the message and mc_ctl command descriptions of "Reference".

3.1.86 MCA00088

%1\$s: unusable character is included in server ID "%3\$s" specified with option "%2\$s"

[Description]

Unusable character is included in server ID specified with option.

[Parameters]

%1\$s: command name

%2\$s: option

%3\$s: server ID

[System Processing]

Processing will be aborted.

[Action]

Correct the server ID specified with option according to the message and mc_ctl command descriptions of "Reference".

3.1.87 MCA00089

only instance administrator can execute this command

[Description]

Only instance administrator who created the directory for Mirroring Controller can execute this command.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command by the instance administrator who created the directory for Mirroring Controller.

3.1.88 MCA00090

could not read file "{0}": Permission denied

[Description]

No read permissions for the file.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command, after granting the read permissions to the file.

3.1.89 MCA00091

host name or IP address "{1}" of the primary server and the standby server in definition file "{0}" are same, but the --local-server option was not specified

[Description]

Host name or IP address of the primary server and the standby server in definition file are same, but the --local-server option was not specified.

[Parameters]

{0}: file name

{1}: host name or IP address

[System Processing]

Processing will be aborted.

[Action]

If the primary server and the standby server are built in the same server, execute the mc_ctl command with the --local-server option.

If the primary server and the standby server are built in the different server, correct host name or IP address in the definition file.

3.1.90 MCA00092

this feature is not available in this edition

[Description]

This feature is not available in this edition.

[System Processing]

Processing will be aborted

[Action]

Please install the right edition for this feature.

3.1.91 MCA00093

installation environment is destroyed

[Description]

Enterprise Postgres may not be installed correctly or may be destroyed.

[System Processing]

Processing will be aborted.

[Action]

Re-install Enterprise Postgres.

3.1.92 MCA00094

%s: invalid argument for option %s

[Description]

Invalid argument for option.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.1.93 MCA00095

could not remove file or directory "{0}"

[Description]

Could not remove the file or the directory.

[Parameters]

{0}: file name or directory name

[System Processing]

Processing will be aborted.

[Action]

Check the status of the file or the directory and eliminate causes, and then remove it.

3.1.94 MCA00096

could not write file "{0}": exception={1}: {2}

[Description]

Could not write the file.

[Parameters]

{0}: file name

{1}: exception type

{2}: exception detail

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the message, and then remove it.

3.1.95 MCA00097

setup of standby server completed

[Description]

Setup of standby server completed.

3.1.96 MCA00098

setup of standby server failed

[Description]

Setup of standby server failed.

[System Processing]

Processing will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then eliminate causes according to [Action] of the message.

3.1.97 MCA00099

{0}: server "{1}" is running as a standby server

[Description]

Could not continue processing because database instance to be duplicated is not running as a primary server.

[Parameters]

{0}: command name

{1}: server ID

[System Processing]

Processing will be aborted.

[Action]

Re-execute this command on the standby server to be set up.

3.2 Message Numbers Beginning with MCA00100

3.2.1 MCA00100

cannot execute {0} command because Mirroring Controller is running

[Description]

Cannot execute this command because Mirroring Controller is running on the server to be set up.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Execute this command on server where primary server is not running. If execute it on the right server, stop Mirroring Controller and then re-execute it.

3.2.2 MCA00101

cannot execute {0} command because database instance is running

[Description]

Cannot execute this command because database instance is running on the server to be set up.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Execute this command on server where primary server is not running. If execute it on the right server, stop database instance and then re-execute it.

3.2.3 MCA00102

{0}: invalid argument value {2} for option {1}

[Description]

Invalid argument for option.

[Parameters]

{0}: command name

{1}: option

{2}: argument value

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting argument value for the option.

3.2.4 MCA00103

could not move file or directory from {0} to {1}

[Description]

Could not move the file or the directory.

[Parameters]

{0}: source file or directory

{1}: target file or directory

[System Processing]

Processing will be aborted.

[Action]

Check the status of the file or the directory and eliminate causes, and then remove it.

3.2.5 MCA00104

could not create directory {0}

[Description]

Could not create the directory.

[Parameters]

{0}: target directory

[System Processing]

Processing will be aborted.

[Action]

Check the status of the directory and eliminate causes, and then remove it.

3.2.6 MCA00105

could not read the access privileges of {0}

[Description]

Could not read the access privileges.

[Parameters]

{0}: target directory

[System Processing]

Processing will be aborted.

[Action]

Check the status of the directory and eliminate causes, and then remove it.

3.2.7 MCA00106

failed to set the access privileges of {0}

[Description]

Failed to set the access privileges.

[Parameters]

{0}: target directory

[System Processing]

Processing will be aborted.

[Action]

Check the status of the directory and eliminate causes, and then remove it.

3.2.8 MCA00107

service "{0}" is not registered

[Description]

Service is not registered.

[Parameters]

{0}: Service name

[System Processing]

Processing will be aborted.

[Action]

Register service, and re-execute.

3.2.9 MCA00108

could not start service "{0}" detail of cause: "{1}"

[Description]

Could not start service.

[Parameters]

{0}: Service name

{1}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.2.10 MCA00109

could not start service "%s" detail of cause: "%s"

[Description]

Could not start service.

[Parameters]

%s: Service name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.2.11 MCA00110

service "%s" is not registered

[Description]

Service is not registered.

[Parameters]

%s: Service name

[System Processing]

Processing will be aborted.

[Action]

Register service, and re-execute.

3.2.12 MCA00111

Mirroring Controller service "%s" has been registered

[Description]

Mirroring Controller service has been registered with Windows Service.

[Parameters]

%s: Service name

3.2.13 MCA00112

Mirroring Controller service "%s" has been unregistered

[Description]

Mirroring Controller service has been unregistered from Windows Service.

[Parameters]

%s: Service name

3.2.14 MCA00113

service name "%s" is already in use

[Description]

Service name is already in use.

[Parameters]

%s: Service name

[System Processing]

Processing will be aborted.

[Action]

Check the service name, and re-execute.

3.2.15 MCA00114

could not register service "%s" detail of cause: "%s"

[Description]

An error occurred during registration of service.

[Parameters]

%s: Service name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.2.16 MCA00115

could not unregister service "%s" detail of cause: "%s"

[Description]

An error occurred during deregistration of service.

[Parameters]

%s: Service name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.2.17 MCA00116

%s: option "%s" is required

[Description]

A required option is not specified.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Specify the required option, and re-execute.

3.2.18 MCA00117

no authority to execute this command

[Description]

Only the administrative user can run this command.

[System Processing]

Processing will be aborted.

[Action]

Invoke the administrator's prompt, and re-execute this command.

3.2.19 MCA00119

could not receive respons from {0} server({1})

[Description]

An error was detected on the server.

[Parameters]

{0}: monitored object (server)

{1}: server type (primary, candidate primary, standby)

[System Processing]

Perform failover or detaching.

If failover or detaching is already performed, these functions would be disabled.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.2.20 MCA00120

detected streaming replication error in {0} server({1})

[Description]

A streaming replication error was detected.

[Parameters]

{0}: monitored object (database process)

{1}: server type (primary, candidate primary, standby)

[System Processing]

Perform failover or detaching.

If failover or detaching is already performed, these functions would be disabled.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.2.21 MCA00121

disk drives are available

[Description]

Database where data storage, transaction log storage and tablespaces are saved is working correctly.

3.2.22 MCA00122

a {0} server({1}) is running normally

[Description]

A server is running normally.

[Parameters]

{0}: server type (primary, candidate primary, standby)

{1}: monitored object (server)

3.2.23 MCA00123

Streaming Replication has started

[Description]

Streaming Replication has started

3.2.24 MCA00124

postmaster is running in {0} server({1})

[Description]

postmaster is running

[Parameters]

{0}: server type (primary, candidate primary, standby)

{1}: monitored object (server)

3.2.25 MCA00125

failed to get the standby server information

[Description]

Failed to get the standby server information

[System Processing]

Perform failover or detaching.

If failover or detaching is already performed, these functions would be disabled.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.2.26 MCA00126

{0} server({1}) was downed

[Description]

database server was downed

[Parameters]

{0}: server type (primary, candidate primary, standby)

{1}: monitored object (server)

[System Processing]

Perform failover or detaching.

If failover or detaching is already performed, these functions would be disabled.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.2.27 MCA00127

You can promote the standby server

[Description]

You can promote the standby server

3.2.28 MCA00128

You cannot promote the standby server

[Description]

You cannot promote the standby server

3.2.29 MCA00129

detected a disk I/O error in {0} server({1})

[Description]

A disk I/O error was detected.

[Parameters]

{0}: server type (primary, candidate primary, standby)

{1}: monitored object (server)

[System Processing]

Perform failover or detaching.

If failover or detaching is already performed, these functions would be disabled.

[Action]

Refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.2.30 MCA00130

starting to switch over forcibly

[Description]

Starting to switch over forcibly.

3.2.31 MCA00131

succeeded in switching over to {0} forcibly

[Description]

Switching standby server to primary server succeeded.

[Parameters]

{0}: server ID of standby server

3.2.32 MCA00132

failed to switch over to {0} forcibly

[Description]

Failed in processing of switching because of unexpected failure.

[Parameters]

{0}: server ID of standby server

[System Processing]

Processing of switching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.2.33 MCA00133

starting to detach standby server forcibly

[Description]

Starting to detach standby server forcibly.

3.2.34 MCA00134

succeeded in detaching standby server "{0}" completed forcibly

[Description]

Detached standby server succeeded.

[Parameters]

{0}: server ID

3.2.35 MCA00135

failed to detach standby server "{0}" forcibly

[Description]

Failed to detach standby server.

[Parameters]

{0}: server ID

[System Processing]

Processing of detaching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.2.36 MCA00136

{0}: the specified option is invalid: "{1}"

[Description]

the specified option is invalid.

[Parameters]

{0}: command name

{1}: option name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.2.37 MCA00137

disabled standby server "{0}" to automatically switch because of canceling the synchronous replication for standby server

[Description]

Disabled the standby server to automatically switch because of canceling the synchronous replication for standby server.

[Parameters]

{0}: server ID

3.2.38 MCA00138

disabled standby server "{0}" to automatically switch

[Description]

Disabled the standby server to automatically switch.

[Parameters]

{0}: server ID

3.2.39 MCA00139

failed to disable standby server "{0}" to automatically switch

[Description]

Failed to disable the standby server to automatically switch.

[Parameters]

{0}: server ID

[System processing]

Processing will be aborted.

[Action]

The following causes could be considered.

- An error was detected in database server

- Timeout waiting for between Mirroring Controller processes of database server
- Identify the cause from messages on system log or event log, and work around.

3.2.40 MCA00140

{0}: invalid server kind specified in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.41 MCA00141

{0}: server kind 'arbiter' do not specified in definition file "{2}" despite value 'arbitration' is specified parameter heartbeat_error_action in definition file "{1}"

[Description]

Server kind 'arbiter' do not been specified in network.conf despite value 'arbitration' is specified parameter heartbeat_error_action in "server identifier".conf

[Parameters]

{0}: command name

{1}: file name

{2}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.42 MCA00142

{0}: could not specify server kind 'arbiter' in definition file "{3}" because value '{2}' is specified parameter heartbeat_error_action in definition file "{1}"

[Description]

Could not specify server kind 'arbiter' in network.conf because value 'arbitration' is not specified parameter heartbeat_error_action in "server identifier".conf.

[Parameters]

{0}: command name

{1}: file name

{2}: message, arbitration, command, fallback

{3}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.43 MCA00143

{0}: second port number to use for the arbitration network is not specified in definition file "{1}"

[Description]

Second port number to use for the arbitration network is not specified in network.conf.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.44 MCA00144

{0}: could not specify second port number to use for the arbitration network in definition file "{3}" because value '{2}' is specified parameter heartbeat_error_action in definition file "{1}"

[Description]

Could not specify second port number to use for the arbitration network in network.conf.

[Parameters]

{0}: command name

{1}: file name

{2}: message, command, fallback

{3}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.45 MCA00145

{0}: second IP address to use for the arbitration network is not specified in definition file "{1}"

[Description]

Second IP address to use for the arbitration network is not specified in network.conf.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.46 MCA00146

{0}: cannot specify second IP Address on server kind 'arbiter' in definition file "{1}"

[Description]

Cannot specify second IP Address on server kind 'arbiter' in network.conf.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.47 MCA00147

{0}: could not use parameter '{3}' because value '{2}' is specified parameter heartbeat_error_action in definition file "{1}"

[Description]

Could not use parameter in "server identifier".conf.

[Parameters]

{0}: command name

{1}: file name

{2}: message, arbitration, command, fallback

{3}: parameter

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.48 MCA00148

{0}: could not use option "{3}" because value '{2}' is specified parameter heartbeat_error_action in definition file "{1}"

[Description]

Could not use this option.

[Parameters]

{0}: command

{1}: file name

{2}: message, arbitration, command, fallback

{3}: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options according to the message and mc_ctl command descriptions of "Reference".

3.2.49 MCA00149

requesting arbitration server "{0}" to connect

[Description]

Requesting arbitration server to connect.

[Parameters]

{0}: server ID

[System processing]

Requesting arbitration server to connect.

3.2.50 MCA00150

trying to connect to arbitration server "{0}"

[Description]

Trying to connect to arbitration server.

[Parameters]

{0}: server ID

[System processing]

Trying to connect to arbitration server until success.

3.2.51 MCA00151

succeeded in connection with arbitration server "{0}"

[Description]

Succeeded in connection with arbitration server.

[Parameters]

{0}: server ID

3.2.52 MCA00152

failed to connect to arbitration server "{0}" event:"{1}"

[Description]

Either of the followings has occurred.

- incorrect specification in network.conf
- error occurs in the network between database server and arbitration server
- Mirroring Controller Arbitration process is not running or in the stop processing
- Mirroring Controller Arbitration process or arbitration server detects an error

[Parameters]

{0}: server ID

{1}: "timeout" or "communication error"

[System Processing]

Processing will be aborted.

[Action]

Check the following and identify the cause, and eliminate cause.

- specification about server kind 'arbiter' in network.conf
- the value of arbiter_connect_timeout parameter in "server identifier".conf
- communication status between database server and arbitration server
- Mirroring Controller Arbitration process starting status
- the message in arbitration server

3.2.53 MCA00153

disconnected from arbitration server "{0}"

[Description]

Disconnected from arbitration server.

[Parameters]

{0}: sever ID

3.2.54 MCA00154

timeout waiting for communication with Mirroring Controller Arbitration process server:"{0}"

[Description]

Timeout waiting for communication between Mirroring Controller process and Mirroring Controller Arbitration process.

[Parameters]

{0}: server ID

[System Processing]

Try to connect to arbitration server.

[Action]

Check whether a network error between arbitration server and database server or an error of arbtration server was detected.

If an error was not detected, the value of `arbiter_alive_timeout` parameter in "server identifier".conf is too short.
Review and extend the value of `arbiter_alive_timeout` in "server identifier".conf.

3.2.55 MCA00155

failed to open communication environment detail of cause:"{0}"

[Description]

Failed to open communication environment.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

3.2.56 MCA00156

invalid port number for server "{0}" in definition file "{1}"

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: server ID

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.2.57 MCA00157

communication error with the arbitration server "{0}" occurred

[Description]

Communication error with the arbitration server occurred.

[Parameters]

{0}: server ID

[System Processing]

Trying to connect.

[Action]

Either of the followings has occurred.

- When Mirroring Controller Arbitration process of a arbitration server is not running
- When abnormality occurs in the network between a database server and arbitration server

Identify the cause from messages on system log or event log in arbitration server or database server, and work around.

3.2.58 MCA00158

failed to start Mirroring Controller because of could not connect to arbitration server "{0}"

[Description]

Failed to start Mirroring Controller because of could not connect to arbitration server.

[Parameters]

{0}: server ID

[System processing]

Processing will be aborted.

[Action]

Work around according to the Action of the message output before this message.

On Windows, if there is no message outputted before this message, please refer to the message outputted to an event log.

MCA00159

requesting arbitration server "{1}" to arbitrate for database server "{0}"

[Description]

Requesting arbitration server to arbitrate for the target server.

[Parameters]

{0}: server ID

{1}: server ID

[System processing]

Requesting arbitration server to arbitrate for the target server.

3.2.59 MCA00160

the arbitration server "{0}" arbitrated status of database server "{1}" as sanity

[Description]

The arbitration server arbitrated status of database server as sanity.

[Parameters]

{0}: server ID

{1}: server ID

3.2.60 MCA00161

the request for arbitration was omitted because fencing command for a database server "{0}" was finished already

[Description]

The request for arbitration was omitted because fencing command for a database server was finished already.

[Parameters]

{0}: server ID

3.2.61 MCA00162

arbitration processing cannot request because the "{0}" command is carrying out

[Description]

Cannot request arbitration processing because command is running on the same or another server.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

3.2.62 MCA00163

timeout waiting for requesting arbitration server "{0}" to arbitrate

[Description]

Timeout waiting for requesting arbitration server to arbitrate.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Switch or detach server in yourself according to descriptions of "Cluster Operation Guide (Database Multiplexing)".

3.2.63 MCA00164

requesting arbitration server "{0}" to fence database server "{1}"

[Description]

Requesting arbitration server to fence database server.

[Parameters]

{0}: server ID

{1}: server ID

[System Processing]

Requesting arbitration server to fence.

3.2.64 MCA00165

arbitration server "{0}" succeeded in fencing for database server "{1}"

[Description]

Arbtration server succeeded in executing fencing command for the target server.

[Parameters]

{0}: server ID

{1}: server ID

3.2.65 MCA00166

arbitration server "{0}" failed to fence for database server "{1}". detail of cause: check log file in arbitration server

[Description]

Arbitration process failed to execute fencing command for the target server.

[Parameters]

{0}: server ID

{1}: server ID

[System Processing]

Processing will be aborted.

[Action]

Check error message in arbitration server.

If needed, perform switch or detach the database server with manually operation according to descriptions of "Cluster Operation Guide (Database Multiplexing)".

3.2.66 MCA00167

timeout waiting for a request to fence to arbitration server "{0}"

[Description]

Timeout waiting for a request to fence to arbitration server.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Switch or detach server in yourself according to descriptions of "Cluster Operation Guide (Database Multiplexing)".

3.2.67 MCA00168

arbitration server "{0}" rejected the request to fence database server "{1}"

[Description]

Either of the followings is esteemed.

- The arbitration server is executing arbitration process
- Fencing command was executed just before

[Parameters]

{0}: server ID

{1}: server ID

3.2.68 MCA00169

could not request "{1}" because of disconnecting from arbitration server "{0}"

[Description]

Could not request arbitration server to arbitrate, fence or disable automatically switch because of disconnecting.

[Parameters]

{0}: server ID

{1}: "arbitration" or "fencing" or "disable automatically switch"

[System Processing]

Processing will be aborted.

[Action]

Either of the followings has occurred.

- Mirroring Controller Arbitration process is not running in arbitration server
- Abnormality occurs in the network between database server and arbitration server

Identify the cause from messages on system log or event log in arbitration server or database server, and work around.

3.2.69 MCA00170

rejeceted a request arbitration server "{1}" because database server "{0}" was beening fencing

[Description]

The following requirements shouldn't be executed if it is requested from the database server which is a fencing target.

- request to arbitrate
- request to fence

[Parameters]

{0}: server ID

{1}: server ID

[Action]

Processing will be aborted.

3.2.70 MCA00171

requested arbitration server "{0}" to disable standby server "{1}" to automatically switch

[Description]

Requested arbitraion server to disable the standby server to automatically switch.

[Parameters]

{0}: server ID

{1}: server ID

3.2.71 MCA00172

arbitration server "{0}" fenced standby server "{1}" because of failed to disable the standby server to automatically switch

[Description]

Arbitration server fenced the standby server because of failed to disable the standby server to automatically switch.

[Parameters]

{0}: server ID

{1}: server ID

3.2.72 MCA00173

arbitration server "{0}" tried to fence standby server "{1}" because of failed to disable the standby server to automatically switch, however fencing was failed

[Description]

Arbitration server tried to fence the standby server because of failed to disable the standby server to automatically switch, however fencing was failed.

[Parameters]

{0}: server ID

{1}: server ID

[System Processing]

Processing will be aborted.

[Action]

Switch or detach database server which error has been detected in yourself.

After, identify the cause from messages on system log or event log in arbitration server and work around.

3.2.73 MCA00174

requested standby server "{0}" to disable automatically switching

[Description]

Requested the standby server to disable automatically switching.

[Parameters]

{0}: server ID

3.2.74 MCA00175

{0}: cannot execute switching over forcibly other than on standby server

[Description]

Switching over forcibly needs to be executed only on standby server.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Check whether the server where the command was executed is correct.

Either, check that Mirroring Controller has been degenerate state yet.

3.2.75 MCA00176

{0}: cannot execute detaching forcibly other than on primary server

[Description]

Detaching forcibly needs to be executed only on primary server.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Check whether the server where the command was executed is correct.

Either, check that Mirroring Controller has been degenerate state yet.

3.2.76 MCA00177

forcible switch over to standby server "{0}" was requested although the data may be not synchronous with primary server

[Description]

Forcible switch over to standby server was requested although the data may be not synchronous with primary server.

[Parameters]

{0}: server ID

[System Processing]

Processing will be continued.

[Action]

Check the data of database server and recovery as necessary, after forcible switch over will be completed.

3.2.77 MCA00178

database server which is able to be switched over is not found

[Description]

Database server which is able to be switched over is not found.

[System Processing]

Processing will be aborted.

3.2.78 MCA00179

starting to detach standby server

[Description]

Starting to detach standby server.

3.2.79 MCA00180

database server which needs to be detached is not found

[Description]

Database server which needs to be detached is not found.

[System Processing]

Processing will be aborted.

3.2.80 MCA00181

database server already has been detached

[Description]

Database server already has been detached.

[System Processing]

Processing will be aborted.

3.2.81 MCA00182

failed to switch over forcibly

[Description]

Failed in processing of switching because of unexpected failure.

[System Processing]

Processing of switching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.2.82 MCA00183

failed to detach standby server forcibly

[Description]

Failed to detach standby server.

[System Processing]

Processing of detaching will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.2.83 MCA00184

could not {1} because {0} server is abnormal

[Description]

Could not switch over or detach because server is abnormal

[Parameters]

{0}: "primary" or "candidate primary" or "standby"

{1}: "switch over" or "detach"

[System Processing]

Processing will be aborted.

[Action]

Find the message output before this message in the log files on the target server, and work around according to the Action of the message.

3.2.84 MCA00185

value of heartbeat_error_action is different from the value of other server "{0}"

[Description]

Value of heartbeat_error_action is different from the value of other server "{0}".

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting value of heartbeat_error_action to the same value as another server.

3.2.85 MCA00186

restarting Mirroring Controller process because an its error was detected: %s

[Description]

Restarting Mirroring Controller process because an its error was detected.

[Parameters]

%s: error detail ("no response", "down")

[System Processing]

Restarting Mirroring Controller process.

3.2.86 MCA00187

Mirroring Controller process was restarted

[Description]

Mirroring Controller process was restarted.

3.2.87 MCA00188

failed to restart Mirroring Controller

[Description]

Failed to restart Mirooring Controller.

[System Processing]

Processing will be aborted.

[Action]

Work around according to the Action of the message output before this message.

On Windows, if there is no message outputted before this message, please refer to the message outputted to an event log.

After, execute the mc_ctl command to restart Mirroring Controller.

3.2.88 MCA00189

could not access "{0}" file detail of cause:"{1}"

[Description]

Could not access the process information file of OS.

[Parameters]

{0}: file name

{1}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.2.89 MCA00190

invalid contents of "{0}" file

[Description]

Invalid contents of /proc/[pid]/status file.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

Check whether mc_keeper process or mc_agent process exists with using OS command.

3.2.90 MCA00191

executing arbitration command and inquiring the result of arbitration

[Description]

Executing arbitration command that execute arbitration.

[System processing]

Degenerate depending on result of arbitration command.

3.2.91 MCA00192

executing fencing command

[Description]

Executing fencing command.

[System processing]

Processing will be continued depending on result of fencing command.

3.2.92 MCA00193

starting degenerate because of result of arbitration command for database server "{0}" result: "{1}"

[Description]

Starting degenerate because of result of arbitration command for target server.

[parameters]

{0}: server ID

{1}: return code of command

3.2.93 MCA00194

degeneracy is not executed because of result of arbitration command to database server "{0}" result: "{1}"

[Description]

Degeneracy is not executed because of result of arbitration command to target server.

[parameters]

{0}: server ID

{1}: return code of command

3.2.94 MCA00195

timeout has occurred during arbitration command has been executing to database server "{0}"

[Description]

Timeout has occurred during arbitration command has been executing to target server.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Check the state of database server and switch or detach the server with manually operation according to descriptions of "Cluster Operation Guide (Database Multiplexing)" as necessary.

When find process ID of arbitration command, terminate forcibly by using OS command.

3.2.95 MCA00196

{0}: two or more standby server names are specified in the parameter "synchronous_standby_names" in PostgreSQL

[Description]

multiple synchronous standby servers can not be monitored by Mirroring Controller.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying single standby server to synchronous_standby_names.

3.2.96 MCA00197

the arbitration server "{0}" didn't arbitrate status of database server "{1}" as sanity

[Description]

Status of the target server was not arbitrated as sanity by arbitration server.

[Parameters]

{0}: server ID

{1}: server ID

[System processing]

Start degenerate processing.

3.2.97 MCA00198

fencing command for database server "{0}" succeeded: result:"{1}"

[Description]

Fencing command for database server succeeded.

[parameters]

{0}: server ID

{1}: return code of command

[System processing]

Processing will be continued.

3.2.98 MCA00199

fencing command for database server "{0}" failed: result:"{1}"

[Description]

Fencing command for database server failed.

[parameters]

{0}: server ID

{1}: return code of command

[System processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

Switch or detach the server with manually operation according to descriptions of "Cluster Operation Guide (Database Multiplexing)" as necessary.

MCA00200

timeout waiting for the fencing command

[Description]

Timeout waiting for the fencing command.

[System processing]

Processing will be aborted.

[Action]

The value of fencing_command_timeout parameter in server identifier.conf is too short.

Review and extend the value of fencing_command_timeout parameter in arbitration.conf.

When find process ID of fencing command, terminate forcibly by using OS command.

3.3 Message Numbers Beginning with MCA00200

3.3.1 MCA00201

executing state-transition-command kind of command:{0}

[Description]

Executing state-transition-command.

[parameters]

{0}: kind of state-transition-command(post-switch, pre-detach, post-attach)

3.3.2 MCA00202

state-transition-command has done kind of command:{0}

[Description]

State-transition-command has done.

[parameters]

{0}: kind of state-transition-command(post-promote, pre-detach, post-attach)

[System processing]

Processing will be continued.

3.3.3 MCA00203

timeout has occurred to state-transition-command kind of command:{0}

[Description]

Timeout has occurred to state-transition-command.

[parameters]

{0}: kind of state-transition-command(post-promote, pre-detach, post-attach)

[System Processing]

Processing of state-transition-command will be aborted.

[Action]

If the process of state-transition-command remained, terminate the process forcibly by using OS command. After checking processing status of state-transition-command, exec the processing of the command manually.

3.3.4 MCA00204

detected recovery from an error on monitoring of table space({0})

[Description]

detected recovery from an error on monitoring of table space

[Parameters]

{0}: directory path of table space

3.3.5 MCA00205

detected no response on monitoring of database process

[Description]

Detected no response on monitoring of database process.

[System Processing]

Continues processing.

[Action]

Check the error detail and eliminate causes.

3.3.6 MCA00206

detected recovery from no response on monitoring of database process

[Description]

Detected recovery from no response on monitoring of database process.

3.3.7 MCA00207

{0}: the user name specified in parameter db_instance_username of definition file "{1}" is not database superuser

[Description]

The user name specified in parameter db_instance_username is not database superuser.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying a database superuser.

3.3.8 MCA00208

{0}: the user name specified in parameter db_instance_username of definition file "{1}" does not exist

[Description]

The user name specified in parameter db_instance_username does not exist.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying a database superuser.

3.3.9 MCA00209

{0}: could not specify second IP address to use for the arbitration network in definition file "{3}" because value '{2}' is specified parameter heartbeat_error_action in definition file "{1}"

[Description]

Could not specify second IP address to use for the arbitration network in network.conf.

[Parameters]

{0}: command name

{1}: file name

{2}: message, command, fallback

{3}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.10 MCA00210

{0}: cannot specify second port number on server kind 'arbiter' in definition file "{1}"

[Description]

Cannot specify second port number on server kind 'arbiter' in network.conf.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.11 MCA00211

{0}: could not use parameter "{2}" because parameter "{3}" is not specified in definition file "{1}"

[Description]

This parameter cannot be specified because the parameter with dependency is not specified in the definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

{3}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.12 MCA00212

{0}: primary_conninfo parameter is not specified in postgresql.auto.conf

[Description]

Primary_conninfo parameter is not specified in postgresql.auto.conf file.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Specify primary_conninfo parameter in postgresql.auto.conf file according to the description of "Setting Up the Standby Center" for disaster recovery of "Cluster Operation Guide (Database Multiplexing)".

3.3.13 MCA00213

values of parameters for abnormality monitoring of operating system or server in server definition file "{1}" are too small for value of heartbeat_interval in arbitration definition file of arbitration server "{0}"

[Description]

Because the values of parameters for abnormality monitoring of the operating system or server in the server definition file are too small compared with the value of heartbeat_interval in the arbitration definition file of the arbitration server, the arbitration for the target database server might be delayed.

[Parameters]

{0}: server ID

{1}: file name

[System Processing]

Depending on the start mode of the mc_ctl command, either of the following processes will be performed.

- When --async-connect-arbiter option is not specified

Processing will be aborted.

- When --async-connect-arbiter option is specified

Continues processing.

[Action]

Take either of the following actions.

- When --async-connect-arbiter option is not specified

Correct the value of parameters for abnormality monitoring of the operating system or server according to the message and "Tuning for Optimization of Degradation Using Abnormality Monitoring With the Arbitration Server" of "Cluster Operation Guide (Database Multiplexing)".

After that, re-execute the mc_ctl command.

- When --async-connect-arbiter option is specified

Correct the parameters for abnormality monitoring of the operating system or server according to the message and "Tuning for Optimization of Degradation Using Abnormality Monitoring With the Arbitration Server" of "Cluster Operation Guide (Database Multiplexing)".

After that, execute the mc_ctl command to restart Mirroring Controller.

3.3.14 MCA00214

{0}: keyword "{1}" is not specified for primary_conninfo parameter in postgresql.auto.conf

[Description]

The required keyword is not specified for primary_conninfo parameter in postgresql.auto.conf file.

[Parameters]

{0}: command name

{1}: keyword name

[System Processing]

Processing will be aborted.

[Action]

Specify the required keyword for primary_conninfo parameter in postgresql.auto.conf file according to the description of "Setting Up the Standby Center" for disaster recovery of "Cluster Operation Guide (Database Multiplexing)".

3.3.15 MCA00215

{0}: keyword "{3}" is not specified for parameter "{2}" in definition file "{1}"

[Description]

The keyword is not specified for the parameter in the definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

{3}: keyword name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.16 MCA00216

{0}: value that cannot be specified for keyword "{3}" of parameter "{2}" in definition file "{1}" is set

[Description]

The value that cannot be specified for keyword of the parameter in the definition file is set.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

{3}: keyword name

[System Processing]

Processing will be aborted.

[Action]

Take either of the following actions.

- When the keyword is application_name

Correct the definition file or postgresql.auto.conf file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

- Otherwise

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.17 MCA00217

{0}: could not use parameter "{3}" because parameter "{2}" is specified in definition file "{1}"

[Description]

This parameter cannot be specified because the parameter with exclusive relationship is specified in the definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

{3}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.18 MCA00218

{0}: value 'fallback' could not be specified for parameter heartbeat_error_action because parameter "{2}" is specified in definition file "{1}"

[Description]

The parameter with exclusive relationship is specified although 'fallback' is specified for heartbeat_error_action.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.19 MCA00219

you can switch the connection destination of streaming replication of server "{0}"

[Description]

You can switch the connection destination of streaming replication.

[Parameters]

{0}: server ID

3.3.20 MCA00220

you cannot switch the connection destination of streaming replication of server "{0}"

[Description]

You cannot switch the connection destination of streaming replication.

[Parameters]

{0}: server ID

3.3.21 MCA00221

start to build in standby server "{0}"

[Description]

Start to build in standby server.

[Parameters]

{0}: server ID

3.3.22 MCA00222

failed to build in standby server "{0}"

[Description]

Failed to build in standby server.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Find the message output before this message from display of own and other server, system log or event log, and then work around according to the Action of the message.

3.3.23 MCA00223

build in standby server "{0}" completed

[Description]

Build in standby server "{0}" completed.

[Parameters]

{0}: server ID

3.3.24 MCA00224

start to switch the connection destination of streaming replication

[Description]

Start to switch the connection destination of streaming replication.

3.3.25 MCA00225

failed to switch the connection destination of streaming replication

[Description]

Failed to switch the connection destination of streaming replication.

[System Processing]

Processing of switching will be aborted.

[Action]

Find the message output before this message from display of own and other server, system log or event log, and then work around according to the Action of the message.

3.3.26 MCA00226

start to switch the connection destination of streaming replication of server "{0}"

[Description]

Start to switch the connection destination of streaming replication.

[Parameters]

{0}: server ID

[Action]

If Mirroring Controller executed switching automatically, find the message output before this message from system log or event log to identify the cause of switching, and then work around according to the Action of the message.

3.3.27 MCA00227

failed to switch the connection destination of streaming replication of server "{0}"

[Description]

Failed to switch the connection destination of streaming replication.

[Parameters]

{0}: server ID

[System Processing]

Processing of switching will be aborted.

[Action]

Find the message output before this message from display own and other server, system log or event log, and then work around according to the Action of the message.

3.3.28 MCA00228

switch the connection destination of streaming replication of server "{0}" completed

[Description]

Switch the connection destination of streaming replication completed.

[Parameters]

{0}: server ID

3.3.29 MCA00229

switch forcibly the connection destination of streaming replication of server "{0}" completed

[Description]

Switch forcibly the connection destination of streaming replication completed.

[Parameters]

{0}: server ID

3.3.30 MCA00230

value of primary_conninfo parameter which is specified in postgresql.auto.conf file of server "{0}" has been updated to the value of parameter "{2}" which is specified in definition file "{1}"

[Description]

Value of primary_conninfo parameter which is specified in postgresql.auto.conf file has been updated.

[Parameters]

{0}: server ID

{1}: file name

{2}: parameter name

3.3.31 MCA00231

failed to update value of primary_conninfo parameter which is specified in postgresql.auto.conf file of server "{0}" detail of cause:"{1}"

[Description]

Failed to update value of primary_conninfo parameter which is specified in postgresql.auto.conf file.

[Parameters]

{0}: server ID

{1}: detail of cause

[Action]

Check the error detail and eliminate causes.

3.3.32 MCA00232

update value of parameter "{2}" to "{3}" which is specified in definition file "{1}" of server "{0}" has completed

[Description]

Update value of parameter which is specified in definition file has completed.

[Parameters]

{0}: server ID

{1}: file name

{2}: parameter name

{3}: primary, standby

3.3.33 MCA00233

failed to update value of parameter "{2}" which is specified in definition file "{1}" of server "{0}"

[Description]

Failed to update value of parameter which is specified in definition file.

[Parameters]

{0}: server ID

{1}: file name

[Action]

Find the message output before this message from display of own and other server, system log or event log, and then work around according to the Action of the message.

3.3.34 MCA00234

failed to check the consistency of LSN between server "{0}" and server "{1}"

[Description]

Failed to check the consistency of LSN between the server.

[Parameters]

{0}: server ID

{1}: server ID

[Action]

Find the message output before this message from display of own and other server, system log or event log, and then work around according to the Action of the message.

3.3.35 MCA00235

failed to update value of parameter "{2}" which is specified in file "{1}" of old candidate primary server "{0}"

[Description]

Failed to update value of parameter which is specified on old candidate primary server.

[Parameters]

{0}: server ID

{1}: file name

{2}: parameter name

[Action]

Either of the following processes will be performed before restarting OS if automatic start and stop of Mirroring Controller has been setting, otherwise building in old candidate primary server to new candidate primary server.

- When update postgresql.auto.conf file has failed

Update connection setting of primary_conninfo parameter which is specified in postgresql.auto.conf file to new candidate primary server by executing ALTER SYSTEM SET statement

- When update "server identifier".conf file has failed

Edit setting of standbycenter_mode parameter in 'standby' which is specified in "server identifier".conf file.

3.3.36 MCA00236

Mirroring Controller of the server "{0}" is not running

[Description]

Mirroring Controller of the server "{0}" is not running.

[Parameters]

{0}: server ID

3.3.37 MCA00237

invalid combination of server own server type:{0} other server type:{1}

[Description]

Invalid combination of server.

[Parameters]

{0}: own server type

{1}: other server type

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description to be set referring disaster recovery operation of "Cluster Operation Guide (Database Multiplexing)".

3.3.38 MCA00238

{0}: cannot execute detaching forcibly other than on operation center

[Description]

Detaching forcibly needs to be executed only on operation center.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

Check whether the server where the command was executed is correct.

3.3.39 MCA00239

standbycenter_mode parameter is specified in the definition file "{0}" of primary server

[Description]

standbycenter_mode parameter is specified in the definition file of primary server.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description to be set referring disaster recovery operation of "Cluster Operation Guide (Database Multiplexing)".

3.3.40 MCA00240

promoted to the primary server, although standbycenter_mode parameter is specified in the definition file "{1}" of the server "{0}"

[Description]

Promoted to the primary server, although standbycenter_mode parameter is specified in the definition file.

[Parameters]

{0}: server ID

{1}: file name

[System Processing]

Stop monitoring.

[Action]

Correct the definition file according to the message and parameter description to be set referring disaster recovery operation of "Cluster Operation Guide (Database Multiplexing)".

3.3.41 MCA00241

write permission is denied on definition file "{0}"

[Description]

Write permission is denied on definition file.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command, after granting the write permissions to the definition file.

3.3.42 MCA00242

{0}: invalid format value is specified for parameter "{2}" in definition file "{1}"

[Description]

The invalid format value is specified for parameter in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.3.43 MCA00243

{0}: value is not set to keyword "{1}" of primary_conninfo parameter in postgresql.auto.conf

[Description]

The value is not set to keyword of primary_conninfo parameter in postgresql.auto.conf.

[Parameters]

{0}: command name

{1}: keyword name

[System Processing]

Processing will be aborted.

[Action]

Set the value for the keyword of primary_conninfo parameter in postgresql.auto.conf file according to the description of "Setting Up the Standby Center" for disaster recovery of "Cluster Operation Guide (Database Multiplexing)".

3.3.44 MCA00244

failed to start monitoring of database process

[Description]

Failed to start monitoring of database process.

[System Processing]

Processing will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message. After that, execute the mc_ctl command to restart Mirroring Controller.

3.3.45 MCA00245

checking the consistency of LSN between server "{0}" and server "{1}" is not executed because candidate primary server is abnormal

[Description]

Checking the consistency of LSN is not executed because candidate primary server is abnormal.

[Parameters]

{0}: server ID

{1}: server ID

[System Processing]

Processing will be continued.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message, after switching over will be completed. After that, build in old candidate primary server to new candidate primary server.

3.4 Message Numbers Beginning with MCR00000

3.4.1 MCR00001

could not read file "{0}": exception={1}: {2}

[Description]

Could not read the file.

[Parameters]

{0}: file name

{1}: exception type

{2}: exception detail

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the message, and then remove it.

3.4.2 MCR00002

{0}: wrong number of server ID in definition file "{1}"

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.3 MCR00003

{0}: server ID specified in definition file "{1}" too long (max {2} bytes) line {3}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: max length of server ID

{3}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.4 MCR00004

{0}: wrong server ID in definition file "{1}"

[Description]

Could not use a server ID with same name in network.conf.

[Parameters]

{0}: command name

{1}: file name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter descriptions of "Cluster Operation Guide (Database Multiplexing)".

3.4.5 MCR00005

invalid host name or IP address "{1}" in definition file "{0}"

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: file name

{1}: host name or IP address

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.6 MCR00006

{0}: invalid port number in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.7 MCR00007

{0}: invalid format specified in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.8 MCR00008

{0}: invalid value for parameter "{2}" in definition file "{1}"

[Description]

Invalid parameter was found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.9 MCR00009

{0}: no value for parameter "{2}" specified in definition file "{1}"

[Description]

Invalid parameter was found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.10 MCR00010

{0}: unrecognized parameter "{2}" in definition file "{1}"

[Description]

Unrecognized parameter was found in definition file.

[Parameters]

{0}: file name

{1}: command name

{2}: parameter name

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.11 MCR00011

%s: option "%s" duplicated

[Description]

Certain option is duplicated.

[Parameters]

%s: command

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.4.12 MCR00012

%s: "%s" option conflicts with "%s" option

[Description]

Options are conflicting.

[Parameters]

%s: command

%s: option

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.4.13 MCR00013

%s: option requires an argument -- %s

[Description]

No argument specified for the option.

[Parameters]

%s: command

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.4.14 MCR00014

%s: neither "%s" option nor environment variable "%s" specified

[Description]

Both of required option and equivalent environment variable were not specified.

[Parameters]

%s: command

%s: option

%s: environment variable

[System Processing]

Processing will be aborted.

[Action]

Re-execute after specifying required option or equivalent environment variable.

3.4.15 MCR00015

%s: argument of option "%s" is too long

[Description]

Argument of option is too long.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.4.16 MCR00016

%s: invalid option -- %s

[Description]

Invalid option.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.4.17 MCR00017

%s: option "%s" is required

[Description]

A required option is not specified.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Specify the required option, and re-execute.

3.4.18 MCR00018

%s: unnecessary operand "%s"

[Description]

Unnecessary operand.

[Parameters]

%s: command name

%s: operand

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting operand.

3.4.19 MCR00019

%s: unrecognized operation mode or no operation mode specified

[Description]

Unrecognized operation mode or no operation mode specified.

[Parameters]

%s: command name

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting or specifying operation mode.

3.4.20 MCR00020

Try "%s --help" for more information.\n

[Description]

--help option can show more additional information.

[Parameters]

%s: command name

[System Processing]

None.

[Action]

Check the message output before this message, and refer to descriptions shown by '--help' option.

3.4.21 MCR00021

%s: out of memory

[Description]

Out of memory error occurred.

[Parameters]

%s: command

[System Processing]

Processing will be aborted.

[Action]

Obtain free memory space by stopping unnecessary processes or changing system settings.

3.4.22 MCR00022

another "{0}" command is running

[Description]

Cannot execute command with this operation mode because another command is running on the same or another server.

[Parameters]

{0}: command name

[System Processing]

Processing will be aborted.

[Action]

There is a case executing another command. Wait for completion of another command on the same or another server, and then re-execute.

In addition, there are the following cases when using mc_arb command.

There is a case under processing of an arbitration by Mirroring Controller Arbitration process. Wait for completion of the processing under operation, and re-execute.

If any of the following cases occurs, there is a possibility that the processing of Mirroring Controller Arbitration process interrupts. Re-execute the mc_arb command after restarting Mirroring Controller Arbitration process.

- When abnormality occurs in the network
- When another server is downed
- When Mirroring Controller Arbitration process is stopped forcibly

3.4.23 MCR00023

Mirroring Controller Arbitration process is already running

[Description]

Mirroring Controller Arbitration process is already running.

[System Processing]

Processing will be aborted.

[Action]

If needed, stop Mirroring Controller Arbitration process, and re-execute.

If could not start although Mirroring Controller Arbitration process not started, refer to the description about workaround for failure of "Cluster Operation Guide (Database Multiplexing)".

3.4.24 MCR00024

cannot execute %s command because Mirroring Controller Arbitration process is not running

[Description]

Cannot execute Mirroring Controller Arbitration process command because Mirroring Controller Arbitration process is not running.

[Parameters]

%s: command name

[System Processing]

Processing will be aborted.

[Action]

Start Mirroring Controller Arbitration process, and re-execute.

3.4.25 MCR00025

timeout waiting for communication with Mirroring Controller Arbitration process

[Description]

Timeout waiting for communication with Mirroring Controller Arbitration process.

[System processing]

Processing will be aborted.

[Action]

Check whether a network error was detected.

If an error was not detected, there is a possibility that the load of the system may be the cause, please re-execute after a while.

3.4.26 MCR00026

could not create PID file of Mirroring Controller Arbitration process detail of cause:"{0}"

[Description]

Could not create PID file of Mirroring Controller Arbitration process.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Identify the cause according to the message, and then remove it.

3.4.27 MCR00027

could not remove PID file of Mirroring Controller Arbitration process detail of cause:"%s"

[Description]

Could not remove PID file of Mirroring Controller Arbitration process.

[Parameters]

%s: detail of cause

[Action]

Identify the cause according to the message, and then remove it.

3.4.28 MCR00028

could not read PID file of Mirroring Controller Arbitration process detail of cause:"%s"

[Description]

Could not read PID file of Mirroring Controller Arbitration process.

[Parameters]

%s: detail of cause

[Action]

Identify the cause according to the message, and then remove it.

3.4.29 MCR00029

invalid contents of PID file "%s" of Mirroring Controller Arbitration process

[Description]

The contents of PID file of Mirroring Controller Arbitration process is invalid.

[Parameters]

%s: file name

[System Processing]

Processing will be aborted.

[Action]

The following causes could be considered.

- The file was stored or replaced by mistake
- The file was corrupted

When starting Mirroring Controller Arbitration process, move or remove the file shown in the message.

When stopped Mirroring Controller Arbitration process, find ID of process named "mc_arbiter" and terminate forcibly by using OS command.

3.4.30 MCR00030

unexpected error occurred: {0}

[Description]

An unexpected error occurred.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate cause.

If you cannot clear the problem, contact Fujitsu technical support.

3.4.31 MCR00031

system call error occurred:"%s" detail of cause:"%s"

[Description]

System call error occurred.

[Parameters]

%s: system call name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.32 MCR00032

failed to open communication environment detail of cause:"{0}"

[Description]

Failed to open communication environment.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

To investigate the cause of the occurrence from the message, and remove cause.

3.4.33 MCR00033

could not read file "{0}": Permission denied

[Description]

No read permissions for the file.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command, after granting the read permissions to the file.

3.4.34 MCR00034

could not read the access privileges of {0}

[Description]

Could not read the access privileges.

[Parameters]

{0}: target directory

[System Processing]

Processing will be aborted.

[Action]

Check the status of the directory and eliminate causes, and then remove it.

3.4.35 MCR00035

failed to set the access privileges of {0}

[Description]

Failed to set the access privileges.

[Parameters]

{0}: target directory

[System Processing]

Processing will be aborted.

[Action]

Check the status of the directory and eliminate causes, and then remove it.

3.4.36 MCR00036

could not get installation path

[Description]

FUJITSU Enterprise Postgres may not be installed.

[System Processing]

Processing will be aborted.

[Action]

Re-install FUJITSU Enterprise Postgres.

3.4.37 MCR00037

could not access "{0}" file detail of cause:"{1}"

[Description]

Could not access the process information file of OS.

[Parameters]

{0}: file name

{1}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.38 MCR00038

invalid contents of "{0}" file

[Description]

Invalid contents of /proc/[pid]/status file.

[Parameters]

{0}: file name

[System Processing]

Processing will be aborted.

[Action]

Check mc_arbiter process is existed or not in yourself.

3.4.39 MCR00039

unusable character is included in path "%s" specified as a directory for Mirroring Controller Arbitration process

[Description]

Unusable character is included in path specified as a directory for Mirroring Controller Arbitration process.

[Parameters]

%s: path name

[System Processing]

Processing will be aborted.

[Action]

Correct the path specified as a directory for Mirroring Controller Arbitration process according to the message and mc_arb command descriptions of "Reference".

3.4.40 MCR00040

could not access path "%s" specified as a directory for Mirroring Controller Arbitration process detail of cause:"%s"

[Description]

Could not access path specified as a directory for Mirroring Controller Arbitration process.

[Parameters]

%s: path name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.41 MCR00041

{0}: IP address "{2}" specified for parameter "my_address" in definition file "{1}" is not found

[Description]

IP address specified for my_address parameter in arbitration.conf is not found.

[Parameters]

{0}: command name

{1}: file name

{2}: IP address

[System Processing]

Processing will be aborted.

[Action]

Check whether IP address specified by my_address parameter in arbitration.conf is correct or IP address is valid.

3.4.42 MCR00042

could not access path "{0}" for parameter "{1}" in definition file "{2}" detail of cause:"{3}"

[Description]

Either of the followings has occurred.

- File does not exist
- You do not specify a file
- Could not read the access privileges

[Parameters]

- {0}: path name
- {1}: parameter name
- {2}: file name
- {3}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.43 MCR00043

{0}: users other than a command executor have the access privileges for definition file "{1}"

[Description]

Users other than a command executor have the access privileges for definition file.

[Parameters]

- {0}: command name
- {1}: file name

[System Processing]

Processing will be aborted.

[Action]

Revoke all the access privileges for any users other than a command executor.

3.4.44 MCR00044

only the owner of definition file "{0}" can execute this command

[Parameters]

- {0}: file name

[Description]

Only the owner who created the directory for Mirroring Controller Arbitration process can execute this command.

[System Processing]

Processing will be aborted.

[Action]

Re-execute the command by the owner who created the directory for Mirroring Controller Arbitration process.

3.4.45 MCR00045

starting Mirroring Controller Arbitration process

[Description]

Starting Mirroring Controller Arbitration process.

3.4.46 MCR00046

Mirroring Controller Arbitration process started

[Description]

Mirroring Controller Arbitration process started.

3.4.47 MCR00047

failed to start Mirroring Controller Arbitration process

[Description]

Failed to start Mirroring Controller Arbitration process.

[System Processing]

Processing will be aborted.

[Action]

Work around according to the Action of the message output before this message.

On Windows, if there is no message outputted before this message, please refer to the message outputted to an event log.

MCR00048

failed to report Mirroring Controller Arbitration process status

[Description]

Failed to report Mirroring Controller Arbitration process status.

[System Processing]

Processing will be aborted.

[Action]

Work around according to the Action of the message output before this message.

On Windows, if there is no message outputted before this message, please refer to the message outputted to an event log.

3.4.48 MCR00049

stopping Mirroring Controller Arbitration process

[Description]

Stopping Mirroring Controller Arbitration process.

3.4.49 MCR00050

Mirroring Controller Arbitration process stopped

[Description]

Mirroring Controller Arbitration process stopped.

3.4.50 MCR00051

could not stop Mirroring Controller Arbitration process because database server connects

[Description]

Could not stop Mirroring Controller Arbitration process because database server connects.

[System Processing]

Processing will be aborted.

[Action]

Execute mc_arb status command to find connected database server.

Re-execute after stopping Mirroring Controller on database server.

3.4.51 MCR00052

failed to stop Mirroring Controller Arbitration process

[Description]

Failed to stop Mirroring Controller Arbitration process.

[System Processing]

Processing will be aborted.

[Action]

Identify the cause from system log or event log on the target server, and work around.

3.4.52 MCR00053

stopping Mirroring Controller Arbitration process forcibly

[Description]

Stopping Mirroring Controller Arbitration process forcibly.

3.4.53 MCR00054

Mirroring Controller Arbitration process stopped forcibly

[Description]

Mirroring Controller Arbitration process stopped forcibly.

3.4.54 MCR00055

failed to stop Mirroring Controller Arbitration process forcibly

[Description]

Failed to stop Mirroring Controller Arbitration process forcibly.

[System Processing]

Processing will be aborted.

[Action]

Check [Action] of the message output before this message, and re-execute.

If re-execution fails, terminate forcibly mc_arbiter process with OS command.

3.4.55 MCR00056

database server "{0}" requested to arbitrate for database server "{1}" status

[Description]

Accepts a request to arbitrate from the database server which has detected an error.

[Parameters]

{0}: server ID

{1}: server ID

3.4.56 MCR00057

arbitrating the status of database server "{0}"

[Description]

Arbitrating for the status of the database server which was detected an error.

[Parameters]

{0}: server ID

[System Processing]

Arbitrating for the status of the database server which was detected an error.

3.4.57 MCR00058

received response from database server "{0}"

[Description]

A server is running normally.

[Parameters]

{0}: server ID

[System Processing]

Return result to database server.

3.4.58 MCR00059

could not receive response from database server "{0}"

[Description]

Detected the database server to be abnormal.

[Parameters]

{0}: server ID

[System Processing]

Execute fencing command.

3.4.59 MCR00060

rejected a request to arbitrate from database server "{0}"

[Description]

Either of the followings has occurred.

- Fencing command was executed just before
- The arbitration server was in the stop processing

[Parameters]

{0}: server ID

[System Processing]

Rejected a request to arbitrate from the database server.

3.4.60 MCR00061

database server "{0}" requested to fence database server "{1}"

[Description]

Accepted a request to fence from the database server which has detected an error.

[Parameters]

{0}: server ID

{1}: server ID

3.4.61 MCR00062

executing fencing command

[Description]

Executing fencing command.

[System processing]

Executing fencing command.

3.4.62 MCR00063

fencing command for database server "{0}" succeeded: result:"{1}"

[Description]

Fencing command for database server succeeded.

[parameters]

{0}: server ID

{1}: return code of command

[System processing]

Returning result to database server.

3.4.63 MCR00064

fencing command for database server "{0}" failed: result:"{1}"

[Description]

Fencing command for database server failed.

[parameters]

{0}: server ID

{1}: return code of command

[System processing]

Returning result to database server.

3.4.64 MCR00065

timeout waiting for the fencing command

[Description]

Timeout waiting for the fencing command.

[System processing]

Processing will be aborted.

[Action]

The value of fencing_command_timeout parameter in arbitration.conf is too short.

Review and extend the value of fencing_command_timeout parameter in arbitration.conf.

When find process ID of fencing command, terminate forcibly by using OS command.

3.4.65 MCR00066

rejected a request to fence from database server "{0}"

[Description]

Either of the followings is esteemed.

- The arbitration server has been executing arbitration process
- Fencing command has been executed just before
- The arbitration server was in the stop processing

[Parameters]

{0}: server ID

[System Processing]

Rejected a request to fence from database server.

3.4.66 MCR00067

rejected a request to fence from database server "{0}" because the database server is a fencing target

[Description]

The following requirements shouldn't be executed if it is requested from the database server which is a fencing target.

- request to arbitrate
- request to fence
- request to disable automatically switch

[Parameters]

{0}: server ID

[Action]

Processing will be aborted.

3.4.67 MCR00068

database server "{0}" requested to disable standby server "{1}" to automatically switch

[Description]

Accepted a request to disable the standby server to automatically switch.

[Parameters]

{0}: sever ID

{1}: sever ID

3.4.68 MCR00069

requested standby server "{0}" to disable automatically switching

[Description]

Requested the standby server to disable automatically switching.

[Parameters]

{0}: server ID

3.4.69 MCR00070

disabled standby server "{0}" to automatically switch

[Description]

Disabled the standby server to automatically switch.

[Parameters]

{0}: server ID

3.4.70 MCR00071

failed to disable standby server "{0}" to automatically switch

[Description]

Failed to disable the standby server to automatically switch.

[Parameters]

{0}: server ID

[System processing]

Executing fencing command.

3.4.71 MCR00072

omitted to disable standby server "{0}" to automatically switch

[Description]

It is not necessary to disable the standby server to automatically switch because a fencing for this database server is executing.

[Parameters]

{0}: server ID

[System processing]

Processing will be aborted.

3.4.72 MCR00073

connection was requested from database server "{0}"

[Description]

Connection was requested from database server.

[Parameters]

{0}: server ID

[Description]

Try connection to database server.

3.4.73 MCR00074

succeeded in connection with Mirroring Controller process of database server "{0}"

[Description]

Succeeded in connection with Mirroring Controller process of database server.

[Parameters]

{0}: server ID

3.4.74 MCR00075

rejected a request to connect from database server "{0}" because of during the fencing command execution

[Description]

Rejected a request to connect from database server because of during the fencing command execution.

[Parameters]

{0}: server ID

[Action]

Rejected a request to connect from database server.

3.4.75 MCR00076

disconnected from the database server "{0}"

[Description]

Disconnected from the database server.

[Parameters]

{0}: server ID

3.4.76 MCR00077

the disallowed IP address "{0}" tried to access

[Description]

The IP address which is different from the IP address in network.conf tried to access.

[parameters]

{0}: IP Adresses

[System Processing]

Connection will be rejected.

3.4.77 MCR00078

tried to access from database server with installed different product version IP address:"{0}"

[Description]

tried to access from database server with installed different product version.

[parameters]

{0}: IP address

[System Processing]

Connection will be rejected

[Action]

Match the product version level between arbitration server and database server.

3.4.78 MCR00079

the invalid server ID tried to access IP address:"{0}"

[Description]

The server ID which is different from the server ID in network.conf tried to access.

[Parameters]

{0}: IP address

[System Processing]

Connection will be rejected.

3.4.79 MCR00080

the combination of server IDs of arbitration server is incompatible with that of database server "{0}"

[Description]

The combination of server IDs of arbitration server is incompatible with that of the database server.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Check the network.conf of both database server and arbitration sever, and correct the file.

3.4.80 MCR00081

the invalid packet received

[Description]

The invalid packet received.

[System Processing]

Connection will be rejected.

3.4.81 MCR00082

{0}: invalid server kind specified in definition file "{1}" line {2}

[Description]

Invalid descriptions were found in definition file.

[Parameters]

{0}: command name

{1}: file name

{2}: line number

[System Processing]

Processing will be aborted.

[Action]

Correct the definition file according to the message and parameter description of "Cluster Operation Guide (Database Multiplexing)".

3.4.82 MCR00083

%s: invalid argument for option %s

[Description]

Invalid argument for option.

[Parameters]

%s: command name

%s: option

[System Processing]

Processing will be aborted.

[Action]

Re-execute after correcting options.

3.4.83 MCR00084

installation environment is destroyed

[Description]

FUJITSU Enterprise Postgres may not be installed correctly or may be destroyed.

[System Processing]

Processing will be aborted.

[Action]

Re-install FUJITSU Enterprise Postgres.

3.4.84 MCR00085

no authority to execute this command

[Description]

Only the user who possesses an administrative authority can run this command.

[System Processing]

Processing will be aborted.

[Action]

Invoke the administrator's prompt, and re-execute this command.

3.4.85 MCR00086

failed to start service "{0}" detail of cause:"{1}"

[Description]

Failed to start service.

[Parameters]

{0}: Service name

{1}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.86 MCR00087

service "{0}" is not registered

[Description]

Service is not registered.

[Parameters]

{0}: Service name

[System Processing]

Processing will be aborted.

[Action]

Register service, and re-execute.

3.4.87 MCR00088

service "%s" for Mirroring Controller Arbitration process was registered

[Description]

Service for Mirroring Controller Arbitration process was registered with Windows service.

[Parameters]

%s: Service name

3.4.88 MCR00089

failed to register service "%s" detail of cause:"%s"

[Description]

An error occurred during registration of service.

[Parameters]

%s: Service name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.89 MCR00090

service name "%s" is already in use

[Description]

Service name is already in use.

[Parameters]

%s: Service name

[System Processing]

Processing will be aborted.

[Action]

Check the service name, and re-execute.

3.4.90 MCR00091

service "%s" for Mirroring Controller Arbitration process was unregistered

[Description]

Service for Mirroring Controller Arbitration process was unregistered from Windows service.

[Parameters]

%s: Service name

3.4.91 MCR00092

failed to unregister service "%s" detail of cause:"%s"

[Description]

An error occurred during deregistration of service.

[Parameters]

%s: Service name

%s: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

3.4.92 MCR00093

an error occurred in Mirroring Controller Arbitration process: {0}

[Description]

An error occurred in Mirroring Controller Arbitration process.

[Parameters]

{0}: detail of cause

[System Processing]

Processing will be aborted.

[Action]

Check the error detail and eliminate causes.

If you cannot clear the problem, contact Fujitsu technical support.

After removing the cause of errors, execute mc_arb command with the -e option to stop Mirroring Controller Arbitration process forcibly.

After that, execute the mc_arb command to start Mirroring Controller Arbitration process.

3.4.93 MCR00094

value of heartbeat_interval in arbitration definition file "{1}" is too large compared with value of parameters for abnormality monitoring of operating system or server in server definition file of database server "{0}"

[Description]

Because the value of heartbeat_interval parameter in the arbitration definition file is too large compared with the value of parameters for abnormality monitoring of the operating system or server in the server definition file of the database server, the arbitration for the target database server might be delayed.

[Parameters]

{0}: server ID

{1}: file name

[System Processing]

Continues processing.

[Action]

Correct the parameters for abnormality monitoring of the operating system or server according to the message and "Tuning for Optimization of Degradation Using Abnormality Monitoring With the Arbitration Server" of "Cluster Operation Guide (Database Multiplexing)".

After that, execute the mc_arb command to restart Mirroring Controller Arbitration process.

3.4.94 MCR00095

start to monitor of database server "{0}"

[Description]

Start to monitor of the database server.

[Parameters]

{0}: server ID

3.4.95 MCR00096

failed to start monitoring of database server "{0}"

[Description]

Failed to start monitoring of the database server.

[Parameters]

{0}: server ID

[System Processing]

Processing will be aborted.

[Action]

Find the message output before this message from display, system log or event log, and then work around according to the Action of the message.

3.4.96 MCR00097

stop Mirroring Controller Arbitration process forcibly because an error has occurred in Mirroring Controller Arbitration process: {0}

[Description]

Stop Mirroring Controller Arbitration process forcibly because an error has occurred in Mirroring Controller Arbitration process

[Parameters]

{0}: detail of cause

[System Processing]

Mirroring Controller Arbitration process will be stopped forcibly.

[Action]

Check the error detail and eliminate causes.

If you cannot clear the problem, contact Fujitsu technical support.

After removing the cause of errors, execute the mc_arb command to start Mirroring Controller Arbitration process.

3.4.97 MCR00098

stop monitoring of database server "{0}"

[Description]

Stop monitoring of the database server.

[Parameters]

{0}: server ID

3.4.98 MCR00099

detected an error on database server "{0}"

[Description]

Either of the followings has occurred.

- The database server is downed
- The arbitration network is abnormal

[Parameters]

{0}: server ID

[System Processing]

Continues processing.

3.5 Message Numbers Beginning with MCR00100

3.5.1 MCR00100

detected recovery of database server "{0}"

[Description]

detected recovery of the database server.

[Parameters]

{0}: server ID

3.5.2 MCR00101

arbitration for database server "{0}" has been delayed

[Description]

Either of the followings has occurred.

- The parameters for abnormality monitoring of the operating system or server are not optimally tuned
- The arbitration server is not responding

[Parameters]

{0}: server ID

PostgreSQL 12.1 Documentation

The PostgreSQL Global Development Group

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Preface

This book is the official documentation of PostgreSQL. It has been written by the PostgreSQL developers and other volunteers in parallel to the development of the PostgreSQL software. It describes all the functionality that the current version of PostgreSQL officially supports.

To make the large amount of information about PostgreSQL manageable, this book has been organized in several parts. Each part is targeted at a different class of users, or at users in different stages of their PostgreSQL experience:

- Part I is an informal introduction for new users.
- Part II documents the SQL query language environment, including data types and functions, as well as user-level performance tuning. Every PostgreSQL user should read this.
- Part III describes the installation and administration of the server. Everyone who runs a PostgreSQL server, be it for private use or for others, should read this part.
- Part IV describes the programming interfaces for PostgreSQL client programs.
- Part V contains information for advanced users about the extensibility capabilities of the server. Topics include user-defined data types and functions.
- Part VI contains reference information about SQL commands, client and server programs. This part supports the other parts with structured information sorted by command or program.
- Part VII contains assorted information that might be of use to PostgreSQL developers.

1. What Is PostgreSQL?

PostgreSQL is an object-relational database management system (ORDBMS) based on POSTGRES, Version 4.2¹, developed at the University of California at Berkeley Computer Science Department. POSTGRES pioneered many concepts that only became available in some commercial database systems much later.

PostgreSQL is an open-source descendant of this original Berkeley code. It supports a large part of the SQL standard and offers many modern features:

- complex queries
- foreign keys
- triggers
- updatable views
- transactional integrity
- multiversion concurrency control

Also, PostgreSQL can be extended by the user in many ways, for example by adding new

- data types
- functions
- operators
- aggregate functions
- index methods
- procedural languages

And because of the liberal license, PostgreSQL can be used, modified, and distributed by anyone free of charge for any purpose, be it private, commercial, or academic.

2. A Brief History of PostgreSQL

¹ <http://db.cs.berkeley.edu/postgres.html>

The object-relational database management system now known as PostgreSQL is derived from the POSTGRES package written at the University of California at Berkeley. With over two decades of development behind it, PostgreSQL is now the most advanced open-source database available anywhere.

2.1. The Berkeley POSTGRES Project

The POSTGRES project, led by Professor Michael Stonebraker, was sponsored by the Defense Advanced Research Projects Agency (DARPA), the Army Research Office (ARO), the National Science Foundation (NSF), and ESL, Inc. The implementation of POSTGRES began in 1986. The initial concepts for the system were presented in [ston86], and the definition of the initial data model appeared in [rowe87]. The design of the rule system at that time was described in [ston87a]. The rationale and architecture of the storage manager were detailed in [ston87b].

POSTGRES has undergone several major releases since then. The first “demoware” system became operational in 1987 and was shown at the 1988 ACM-SIGMOD Conference. Version 1, described in [ston90a], was released to a few external users in June 1989. In response to a critique of the first rule system ([ston89]), the rule system was redesigned ([ston90b]), and Version 2 was released in June 1990 with the new rule system. Version 3 appeared in 1991 and added support for multiple storage managers, an improved query executor, and a rewritten rule system. For the most part, subsequent releases until Postgres95 (see below) focused on portability and reliability.

POSTGRES has been used to implement many different research and production applications. These include: a financial data analysis system, a jet engine performance monitoring package, an asteroid tracking database, a medical information database, and several geographic information systems. POSTGRES has also been used as an educational tool at several universities. Finally, Illustra Information Technologies (later merged into Informix², which is now owned by IBM³) picked up the code and commercialized it. In late 1992, POSTGRES became the primary data manager for the Sequoia 2000 scientific computing project⁴.

The size of the external user community nearly doubled during 1993. It became increasingly obvious that maintenance of the prototype code and support was taking up large amounts of time that should have been devoted to database research. In an effort to reduce this support burden, the Berkeley POSTGRES project officially ended with Version 4.2.

2.2. Postgres95

In 1994, Andrew Yu and Jolly Chen added an SQL language interpreter to POSTGRES. Under a new name, Postgres95 was subsequently released to the web to find its own way in the world as an open-source descendant of the original POSTGRES Berkeley code.

Postgres95 code was completely ANSI C and trimmed in size by 25%. Many internal changes improved performance and maintainability. Postgres95 release 1.0.x ran about 30-50% faster on the Wisconsin Benchmark compared to POSTGRES, Version 4.2. Apart from bug fixes, the following were the major enhancements:

- The query language PostQUEL was replaced with SQL (implemented in the server). (Interface library libpq was named after PostQUEL.) Subqueries were not supported until PostgreSQL (see below), but they could be imitated in Postgres95 with user-defined SQL functions. Aggregate functions were re-implemented. Support for the `GROUP BY` query clause was also added.
- A new program (psql) was provided for interactive SQL queries, which used GNU Readline. This largely superseded the old monitor program.
- A new front-end library, `libpqtc1`, supported Tcl-based clients. A sample shell, `pgtc1sh`, provided new Tcl commands to interface Tcl programs with the Postgres95 server.

² <https://www.ibm.com/analytics/informix>

³ <https://www.ibm.com/>

⁴ http://meteora.ucsd.edu/s2k/s2k_home.html

- The large-object interface was overhauled. The inversion large objects were the only mechanism for storing large objects. (The inversion file system was removed.)
- The instance-level rule system was removed. Rules were still available as rewrite rules.
- A short tutorial introducing regular SQL features as well as those of Postgres95 was distributed with the source code
- GNU make (instead of BSD make) was used for the build. Also, Postgres95 could be compiled with an unpatched GCC (data alignment of doubles was fixed).

2.3. PostgreSQL

By 1996, it became clear that the name “Postgres95” would not stand the test of time. We chose a new name, PostgreSQL, to reflect the relationship between the original POSTGRES and the more recent versions with SQL capability. At the same time, we set the version numbering to start at 6.0, putting the numbers back into the sequence originally begun by the Berkeley POSTGRES project.

Many people continue to refer to PostgreSQL as “Postgres” (now rarely in all capital letters) because of tradition or because it is easier to pronounce. This usage is widely accepted as a nickname or alias.

The emphasis during development of Postgres95 was on identifying and understanding existing problems in the server code. With PostgreSQL, the emphasis has shifted to augmenting features and capabilities, although work continues in all areas.

Details about what has happened in PostgreSQL since then can be found in Appendix E.

3. Conventions

The following conventions are used in the synopsis of a command: brackets ([and]) indicate optional parts. (In the synopsis of a Tcl command, question marks (?) are used instead, as is usual in Tcl.) Braces ({ and }) and vertical lines (|) indicate that you must choose one alternative. Dots (. . .) mean that the preceding element can be repeated.

Where it enhances the clarity, SQL commands are preceded by the prompt =>, and shell commands are preceded by the prompt \$. Normally, prompts are not shown, though.

An *administrator* is generally a person who is in charge of installing and running the server. A *user* could be anyone who is using, or wants to use, any part of the PostgreSQL system. These terms should not be interpreted too narrowly; this book does not have fixed presumptions about system administration procedures.

4. Further Information

Besides the documentation, that is, this book, there are other resources about PostgreSQL:

Wiki

The PostgreSQL wiki⁵ contains the project's FAQ⁶ (Frequently Asked Questions) list, TODO⁷ list, and detailed information about many more topics.

Web Site

The PostgreSQL web site⁸ carries details on the latest release and other information to make your work or play with PostgreSQL more productive.

⁵ <https://wiki.postgresql.org>

⁶ https://wiki.postgresql.org/wiki/Frequently_Asked_Questions

⁷ <https://wiki.postgresql.org/wiki/ToDo>

⁸ <https://www.postgresql.org>

Mailing Lists

The mailing lists are a good place to have your questions answered, to share experiences with other users, and to contact the developers. Consult the PostgreSQL web site for details.

Yourself!

PostgreSQL is an open-source project. As such, it depends on the user community for ongoing support. As you begin to use PostgreSQL, you will rely on others for help, either through the documentation or through the mailing lists. Consider contributing your knowledge back. Read the mailing lists and answer questions. If you learn something which is not in the documentation, write it up and contribute it. If you add features to the code, contribute them.

5. Bug Reporting Guidelines

When you find a bug in PostgreSQL we want to hear about it. Your bug reports play an important part in making PostgreSQL more reliable because even the utmost care cannot guarantee that every part of PostgreSQL will work on every platform under every circumstance.

The following suggestions are intended to assist you in forming bug reports that can be handled in an effective fashion. No one is required to follow them but doing so tends to be to everyone's advantage.

We cannot promise to fix every bug right away. If the bug is obvious, critical, or affects a lot of users, chances are good that someone will look into it. It could also happen that we tell you to update to a newer version to see if the bug happens there. Or we might decide that the bug cannot be fixed before some major rewrite we might be planning is done. Or perhaps it is simply too hard and there are more important things on the agenda. If you need help immediately, consider obtaining a commercial support contract.

5.1. Identifying Bugs

Before you report a bug, please read and re-read the documentation to verify that you can really do whatever it is you are trying. If it is not clear from the documentation whether you can do something or not, please report that too; it is a bug in the documentation. If it turns out that a program does something different from what the documentation says, that is a bug. That might include, but is not limited to, the following circumstances:

- A program terminates with a fatal signal or an operating system error message that would point to a problem in the program. (A counterexample might be a “disk full” message, since you have to fix that yourself.)
- A program produces the wrong output for any given input.
- A program refuses to accept valid input (as defined in the documentation).
- A program accepts invalid input without a notice or error message. But keep in mind that your idea of invalid input might be our idea of an extension or compatibility with traditional practice.
- PostgreSQL fails to compile, build, or install according to the instructions on supported platforms.

Here “program” refers to any executable, not only the backend process.

Being slow or resource-hogging is not necessarily a bug. Read the documentation or ask on one of the mailing lists for help in tuning your applications. Failing to comply to the SQL standard is not necessarily a bug either, unless compliance for the specific feature is explicitly claimed.

Before you continue, check on the TODO list and in the FAQ to see if your bug is already known. If you cannot decode the information on the TODO list, report your problem. The least we can do is make the TODO list clearer.

5.2. What to Report

The most important thing to remember about bug reporting is to state all the facts and only facts. Do not speculate what you think went wrong, what “it seemed to do”, or which part of the program has a fault. If you are not familiar with the implementation you would probably guess wrong and not help us a bit. And even if you are, educated explanations are a great supplement to but no substitute for facts. If we are going to fix the bug we still have to see it happen for ourselves first. Reporting the bare facts is relatively straightforward (you can probably copy and paste them from the screen) but all too often important details are left out because someone thought it does not matter or the report would be understood anyway.

The following items should be contained in every bug report:

- The exact sequence of steps *from program start-up* necessary to reproduce the problem. This should be self-contained; it is not enough to send in a bare `SELECT` statement without the preceding `CREATE TABLE` and `INSERT` statements, if the output should depend on the data in the tables. We do not have the time to reverse-engineer your database schema, and if we are supposed to make up our own data we would probably miss the problem.

The best format for a test case for SQL-related problems is a file that can be run through the `psql` frontend that shows the problem. (Be sure to not have anything in your `~/ .psqlrc` start-up file.) An easy way to create this file is to use `pg_dump` to dump out the table declarations and data needed to set the scene, then add the problem query. You are encouraged to minimize the size of your example, but this is not absolutely necessary. If the bug is reproducible, we will find it either way.

If your application uses some other client interface, such as PHP, then please try to isolate the offending queries. We will probably not set up a web server to reproduce your problem. In any case remember to provide the exact input files; do not guess that the problem happens for “large files” or “midsize databases”, etc. since this information is too inexact to be of use.

- The output you got. Please do not say that it “didn’t work” or “crashed”. If there is an error message, show it, even if you do not understand it. If the program terminates with an operating system error, say which. If nothing at all happens, say so. Even if the result of your test case is a program crash or otherwise obvious it might not happen on our platform. The easiest thing is to copy the output from the terminal, if possible.

Note

If you are reporting an error message, please obtain the most verbose form of the message. In `psql`, say `\set VERBOSITY verbose` beforehand. If you are extracting the message from the server log, set the run-time parameter `log_error_verbosity` to `verbose` so that all details are logged.

Note

In case of fatal errors, the error message reported by the client might not contain all the information available. Please also look at the log output of the database server. If you do not keep your server’s log output, this would be a good time to start doing so.

- The output you expected is very important to state. If you just write “This command gives me that output.” or “This is not what I expected.”, we might run it ourselves, scan the output, and think it looks OK and is exactly what we expected. We should not have to spend the time to decode the exact semantics behind your commands. Especially refrain from merely saying that “This is not what SQL says/Oracle does.” Digging out the correct behavior from SQL is not a fun undertaking,

nor do we all know how all the other relational databases out there behave. (If your problem is a program crash, you can obviously omit this item.)

- Any command line options and other start-up options, including any relevant environment variables or configuration files that you changed from the default. Again, please provide exact information. If you are using a prepackaged distribution that starts the database server at boot time, you should try to find out how that is done.
- Anything you did at all differently from the installation instructions.
- The PostgreSQL version. You can run the command `SELECT version();` to find out the version of the server you are connected to. Most executable programs also support a `--version` option; at least `postgres --version` and `psql --version` should work. If the function or the options do not exist then your version is more than old enough to warrant an upgrade. If you run a prepackaged version, such as RPMs, say so, including any subversion the package might have. If you are talking about a Git snapshot, mention that, including the commit hash.

If your version is older than 12.1 we will almost certainly tell you to upgrade. There are many bug fixes and improvements in each new release, so it is quite possible that a bug you have encountered in an older release of PostgreSQL has already been fixed. We can only provide limited support for sites using older releases of PostgreSQL; if you require more than we can provide, consider acquiring a commercial support contract.

- Platform information. This includes the kernel name and version, C library, processor, memory information, and so on. In most cases it is sufficient to report the vendor and version, but do not assume everyone knows what exactly “Debian” contains or that everyone runs on `x86_64`. If you have installation problems then information about the toolchain on your machine (compiler, make, and so on) is also necessary.

Do not be afraid if your bug report becomes rather lengthy. That is a fact of life. It is better to report everything the first time than us having to squeeze the facts out of you. On the other hand, if your input files are huge, it is fair to ask first whether somebody is interested in looking into it. Here is an article⁹ that outlines some more tips on reporting bugs.

Do not spend all your time to figure out which changes in the input make the problem go away. This will probably not help solving it. If it turns out that the bug cannot be fixed right away, you will still have time to find and share your work-around. Also, once again, do not waste your time guessing why the bug exists. We will find that out soon enough.

When writing a bug report, please avoid confusing terminology. The software package in total is called “PostgreSQL”, sometimes “Postgres” for short. If you are specifically talking about the backend process, mention that, do not just say “PostgreSQL crashes”. A crash of a single backend process is quite different from crash of the parent “postgres” process; please don't say “the server crashed” when you mean a single backend process went down, nor vice versa. Also, client programs such as the interactive frontend “psql” are completely separate from the backend. Please try to be specific about whether the problem is on the client or server side.

5.3. Where to Report Bugs

In general, send bug reports to the bug report mailing list at `<pgsql-bugs@lists.postgresql.org>`. You are requested to use a descriptive subject for your email message, perhaps parts of the error message.

Another method is to fill in the bug report web-form available at the project's web site¹⁰. Entering a bug report this way causes it to be mailed to the `<pgsql-bugs@lists.postgresql.org>` mailing list.

⁹ <https://www.chiark.greenend.org.uk/~sgtatham/bugs.html>

¹⁰ <https://www.postgresql.org/>

If your bug report has security implications and you'd prefer that it not become immediately visible in public archives, don't send it to `pgsql-bugs`. Security issues can be reported privately to `<security@postgresql.org>`.

Do not send bug reports to any of the user mailing lists, such as `<pgsql-sql@lists.postgresql.org>` or `<pgsql-general@lists.postgresql.org>`. These mailing lists are for answering user questions, and their subscribers normally do not wish to receive bug reports. More importantly, they are unlikely to fix them.

Also, please do *not* send reports to the developers' mailing list `<pgsql-hackers@lists.postgresql.org>`. This list is for discussing the development of PostgreSQL, and it would be nice if we could keep the bug reports separate. We might choose to take up a discussion about your bug report on `pgsql-hackers`, if the problem needs more review.

If you have a problem with the documentation, the best place to report it is the documentation mailing list `<pgsql-docs@lists.postgresql.org>`. Please be specific about what part of the documentation you are unhappy with.

If your bug is a portability problem on a non-supported platform, send mail to `<pgsql-hackers@lists.postgresql.org>`, so we (and you) can work on porting PostgreSQL to your platform.

Note

Due to the unfortunate amount of spam going around, all of the above lists will be moderated unless you are subscribed. That means there will be some delay before the email is delivered. If you wish to subscribe to the lists, please visit <https://lists.postgresql.org/> for instructions.

Part I. Tutorial

Welcome to the PostgreSQL Tutorial. The following few chapters are intended to give a simple introduction to PostgreSQL, relational database concepts, and the SQL language to those who are new to any one of these aspects. We only assume some general knowledge about how to use computers. No particular Unix or programming experience is required. This part is mainly intended to give you some hands-on experience with important aspects of the PostgreSQL system. It makes no attempt to be a complete or thorough treatment of the topics it covers.

After you have worked through this tutorial you might want to move on to reading Part II to gain a more formal knowledge of the SQL language, or Part IV for information about developing applications for PostgreSQL. Those who set up and manage their own server should also read Part III.

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Chapter 1. Getting Started

1.1. Installation

Before you can use PostgreSQL you need to install it, of course. It is possible that PostgreSQL is already installed at your site, either because it was included in your operating system distribution or because the system administrator already installed it. If that is the case, you should obtain information from the operating system documentation or your system administrator about how to access PostgreSQL.

If you are not sure whether PostgreSQL is already available or whether you can use it for your experimentation then you can install it yourself. Doing so is not hard and it can be a good exercise. PostgreSQL can be installed by any unprivileged user; no superuser (root) access is required.

If you are installing PostgreSQL yourself, then refer to Chapter 16 for instructions on installation, and return to this guide when the installation is complete. Be sure to follow closely the section about setting up the appropriate environment variables.

If your site administrator has not set things up in the default way, you might have some more work to do. For example, if the database server machine is a remote machine, you will need to set the `PGHOST` environment variable to the name of the database server machine. The environment variable `PGPORT` might also have to be set. The bottom line is this: if you try to start an application program and it complains that it cannot connect to the database, you should consult your site administrator or, if that is you, the documentation to make sure that your environment is properly set up. If you did not understand the preceding paragraph then read the next section.

1.2. Architectural Fundamentals

Before we proceed, you should understand the basic PostgreSQL system architecture. Understanding how the parts of PostgreSQL interact will make this chapter somewhat clearer.

In database jargon, PostgreSQL uses a client/server model. A PostgreSQL session consists of the following cooperating processes (programs):

- A server process, which manages the database files, accepts connections to the database from client applications, and performs database actions on behalf of the clients. The database server program is called `postgres`.
- The user's client (frontend) application that wants to perform database operations. Client applications can be very diverse in nature: a client could be a text-oriented tool, a graphical application, a web server that accesses the database to display web pages, or a specialized database maintenance tool. Some client applications are supplied with the PostgreSQL distribution; most are developed by users.

As is typical of client/server applications, the client and the server can be on different hosts. In that case they communicate over a TCP/IP network connection. You should keep this in mind, because the files that can be accessed on a client machine might not be accessible (or might only be accessible using a different file name) on the database server machine.

The PostgreSQL server can handle multiple concurrent connections from clients. To achieve this it starts (“forks”) a new process for each connection. From that point on, the client and the new server process communicate without intervention by the original `postgres` process. Thus, the master server process is always running, waiting for client connections, whereas client and associated server processes come and go. (All of this is of course invisible to the user. We only mention it here for completeness.)

1.3. Creating a Database

The first test to see whether you can access the database server is to try to create a database. A running PostgreSQL server can manage many databases. Typically, a separate database is used for each project or for each user.

Possibly, your site administrator has already created a database for your use. In that case you can omit this step and skip ahead to the next section.

To create a new database, in this example named `mydb`, you use the following command:

```
$ createdb mydb
```

If this produces no response then this step was successful and you can skip over the remainder of this section.

If you see a message similar to:

```
createdb: command not found
```

then PostgreSQL was not installed properly. Either it was not installed at all or your shell's search path was not set to include it. Try calling the command with an absolute path instead:

```
$ /usr/local/pgsql/bin/createdb mydb
```

The path at your site might be different. Contact your site administrator or check the installation instructions to correct the situation.

Another response could be this:

```
createdb: could not connect to database postgres: could not connect
to server: No such file or directory
    Is the server running locally and accepting
connections on Unix domain socket "/tmp/.s.PGSQL.5432"?
```

This means that the server was not started, or it was not started where `createdb` expected it. Again, check the installation instructions or consult the administrator.

Another response could be this:

```
createdb: could not connect to database postgres: FATAL:  role
"joe" does not exist
```

where your own login name is mentioned. This will happen if the administrator has not created a PostgreSQL user account for you. (PostgreSQL user accounts are distinct from operating system user accounts.) If you are the administrator, see Chapter 21 for help creating accounts. You will need to become the operating system user under which PostgreSQL was installed (usually `postgres`) to create the first user account. It could also be that you were assigned a PostgreSQL user name that is different from your operating system user name; in that case you need to use the `-U` switch or set the `PGUSER` environment variable to specify your PostgreSQL user name.

If you have a user account but it does not have the privileges required to create a database, you will see the following:

```
createdb: database creation failed: ERROR:  permission denied to
create database
```

Not every user has authorization to create new databases. If PostgreSQL refuses to create databases for you then the site administrator needs to grant you permission to create databases. Consult your site administrator if this occurs. If you installed PostgreSQL yourself then you should log in for the purposes of this tutorial under the user account that you started the server as.¹

You can also create databases with other names. PostgreSQL allows you to create any number of databases at a given site. Database names must have an alphabetic first character and are limited to 63 bytes in length. A convenient choice is to create a database with the same name as your current user name. Many tools assume that database name as the default, so it can save you some typing. To create that database, simply type:

```
$ createdb
```

If you do not want to use your database anymore you can remove it. For example, if you are the owner (creator) of the database `mydb`, you can destroy it using the following command:

```
$ dropdb mydb
```

(For this command, the database name does not default to the user account name. You always need to specify it.) This action physically removes all files associated with the database and cannot be undone, so this should only be done with a great deal of forethought.

More about `createdb` and `dropdb` can be found in `createdb` and `dropdb` respectively.

1.4. Accessing a Database

Once you have created a database, you can access it by:

- Running the PostgreSQL interactive terminal program, called *psql*, which allows you to interactively enter, edit, and execute SQL commands.
- Using an existing graphical frontend tool like pgAdmin or an office suite with ODBC or JDBC support to create and manipulate a database. These possibilities are not covered in this tutorial.
- Writing a custom application, using one of the several available language bindings. These possibilities are discussed further in Part IV.

You probably want to start up `psql` to try the examples in this tutorial. It can be activated for the `mydb` database by typing the command:

```
$ psql mydb
```

If you do not supply the database name then it will default to your user account name. You already discovered this scheme in the previous section using `createdb`.

In `psql`, you will be greeted with the following message:

```
psql (12.1)
Type "help" for help.

mydb=>
```

The last line could also be:

¹ As an explanation for why this works: PostgreSQL user names are separate from operating system user accounts. When you connect to a database, you can choose what PostgreSQL user name to connect as; if you don't, it will default to the same name as your current operating system account. As it happens, there will always be a PostgreSQL user account that has the same name as the operating system user that started the server, and it also happens that that user always has permission to create databases. Instead of logging in as that user you can also specify the `-U` option everywhere to select a PostgreSQL user name to connect as.

mydb=#

That would mean you are a database superuser, which is most likely the case if you installed the PostgreSQL instance yourself. Being a superuser means that you are not subject to access controls. For the purposes of this tutorial that is not important.

If you encounter problems starting `psql` then go back to the previous section. The diagnostics of `createdb` and `psql` are similar, and if the former worked the latter should work as well.

The last line printed out by `psql` is the prompt, and it indicates that `psql` is listening to you and that you can type SQL queries into a work space maintained by `psql`. Try out these commands:

```
mydb=> SELECT version();
                version
-----
 PostgreSQL 12.1 on x86_64-pc-linux-gnu, compiled by gcc (Debian
 4.9.2-10) 4.9.2, 64-bit
(1 row)
```

```
mydb=> SELECT current_date;
       date
-----
 2016-01-07
(1 row)
```

```
mydb=> SELECT 2 + 2;
 ?column?
-----
        4
(1 row)
```

The `psql` program has a number of internal commands that are not SQL commands. They begin with the backslash character, “\”. For example, you can get help on the syntax of various PostgreSQL SQL commands by typing:

```
mydb=> \h
```

To get out of `psql`, type:

```
mydb=> \q
```

and `psql` will quit and return you to your command shell. (For more internal commands, type `\?` at the `psql` prompt.) The full capabilities of `psql` are documented in `psql`. In this tutorial we will not use these features explicitly, but you can use them yourself when it is helpful.

Chapter 2. The SQL Language

2.1. Introduction

This chapter provides an overview of how to use SQL to perform simple operations. This tutorial is only intended to give you an introduction and is in no way a complete tutorial on SQL. Numerous books have been written on SQL, including [melt93] and [date97]. You should be aware that some PostgreSQL language features are extensions to the standard.

In the examples that follow, we assume that you have created a database named `mydb`, as described in the previous chapter, and have been able to start `psql`.

Examples in this manual can also be found in the PostgreSQL source distribution in the directory `src/tutorial/`. (Binary distributions of PostgreSQL might not compile these files.) To use those files, first change to that directory and run `make`:

```
$ cd ../src/tutorial
$ make
```

This creates the scripts and compiles the C files containing user-defined functions and types. Then, to start the tutorial, do the following:

```
$ cd ../tutorial
$ psql -s mydb
```

```
...
```

```
mydb=> \i basics.sql
```

The `\i` command reads in commands from the specified file. `psql`'s `-s` option puts you in single step mode which pauses before sending each statement to the server. The commands used in this section are in the file `basics.sql`.

2.2. Concepts

PostgreSQL is a *relational database management system* (RDBMS). That means it is a system for managing data stored in *relations*. Relation is essentially a mathematical term for *table*. The notion of storing data in tables is so commonplace today that it might seem inherently obvious, but there are a number of other ways of organizing databases. Files and directories on Unix-like operating systems form an example of a hierarchical database. A more modern development is the object-oriented database.

Each table is a named collection of *rows*. Each row of a given table has the same set of named *columns*, and each column is of a specific data type. Whereas columns have a fixed order in each row, it is important to remember that SQL does not guarantee the order of the rows within the table in any way (although they can be explicitly sorted for display).

Tables are grouped into databases, and a collection of databases managed by a single PostgreSQL server instance constitutes a database *cluster*.

2.3. Creating a New Table

You can create a new table by specifying the table name, along with all column names and their types:

```
CREATE TABLE weather (  
    city          varchar(80),  
    temp_lo      int,          -- low temperature  
    temp_hi      int,          -- high temperature  
    prcp         real,        -- precipitation  
    date         date  
);
```

You can enter this into `psql` with the line breaks. `psql` will recognize that the command is not terminated until the semicolon.

White space (i.e., spaces, tabs, and newlines) can be used freely in SQL commands. That means you can type the command aligned differently than above, or even all on one line. Two dashes (“--”) introduce comments. Whatever follows them is ignored up to the end of the line. SQL is case insensitive about key words and identifiers, except when identifiers are double-quoted to preserve the case (not done above).

`varchar(80)` specifies a data type that can store arbitrary character strings up to 80 characters in length. `int` is the normal integer type. `real` is a type for storing single precision floating-point numbers. `date` should be self-explanatory. (Yes, the column of type `date` is also named `date`. This might be convenient or confusing — you choose.)

PostgreSQL supports the standard SQL types `int`, `smallint`, `real`, `double precision`, `char(N)`, `varchar(N)`, `date`, `time`, `timestamp`, and `interval`, as well as other types of general utility and a rich set of geometric types. PostgreSQL can be customized with an arbitrary number of user-defined data types. Consequently, type names are not key words in the syntax, except where required to support special cases in the SQL standard.

The second example will store cities and their associated geographical location:

```
CREATE TABLE cities (  
    name          varchar(80),  
    location      point  
);
```

The `point` type is an example of a PostgreSQL-specific data type.

Finally, it should be mentioned that if you don't need a table any longer or want to recreate it differently you can remove it using the following command:

```
DROP TABLE tablename;
```

2.4. Populating a Table With Rows

The `INSERT` statement is used to populate a table with rows:

```
INSERT INTO weather VALUES ('San Francisco', 46, 50, 0.25,  
    '1994-11-27');
```

Note that all data types use rather obvious input formats. Constants that are not simple numeric values usually must be surrounded by single quotes (`'`), as in the example. The `date` type is actually quite flexible in what it accepts, but for this tutorial we will stick to the unambiguous format shown here.

The `point` type requires a coordinate pair as input, as shown here:

```
INSERT INTO cities VALUES ('San Francisco', '(-194.0, 53.0)');
```

The syntax used so far requires you to remember the order of the columns. An alternative syntax allows you to list the columns explicitly:

```
INSERT INTO weather (city, temp_lo, temp_hi, prcp, date)
VALUES ('San Francisco', 43, 57, 0.0, '1994-11-29');
```

You can list the columns in a different order if you wish or even omit some columns, e.g., if the precipitation is unknown:

```
INSERT INTO weather (date, city, temp_hi, temp_lo)
VALUES ('1994-11-29', 'Hayward', 54, 37);
```

Many developers consider explicitly listing the columns better style than relying on the order implicitly.

Please enter all the commands shown above so you have some data to work with in the following sections.

You could also have used `COPY` to load large amounts of data from flat-text files. This is usually faster because the `COPY` command is optimized for this application while allowing less flexibility than `INSERT`. An example would be:

```
COPY weather FROM '/home/user/weather.txt';
```

where the file name for the source file must be available on the machine running the backend process, not the client, since the backend process reads the file directly. You can read more about the `COPY` command in `COPY`.

2.5. Querying a Table

To retrieve data from a table, the table is *queried*. An SQL `SELECT` statement is used to do this. The statement is divided into a select list (the part that lists the columns to be returned), a table list (the part that lists the tables from which to retrieve the data), and an optional qualification (the part that specifies any restrictions). For example, to retrieve all the rows of table `weather`, type:

```
SELECT * FROM weather;
```

Here `*` is a shorthand for “all columns”.¹ So the same result would be had with:

```
SELECT city, temp_lo, temp_hi, prcp, date FROM weather;
```

The output should be:

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27
San Francisco	43	57	0	1994-11-29
Hayward	37	54		1994-11-29

(3 rows)

¹ While `SELECT *` is useful for off-the-cuff queries, it is widely considered bad style in production code, since adding a column to the table would change the results.

You can write expressions, not just simple column references, in the select list. For example, you can do:

```
SELECT city, (temp_hi+temp_lo)/2 AS temp_avg, date FROM weather;
```

This should give:

city	temp_avg	date
San Francisco	48	1994-11-27
San Francisco	50	1994-11-29
Hayward	45	1994-11-29

(3 rows)

Notice how the AS clause is used to relabel the output column. (The AS clause is optional.)

A query can be “qualified” by adding a WHERE clause that specifies which rows are wanted. The WHERE clause contains a Boolean (truth value) expression, and only rows for which the Boolean expression is true are returned. The usual Boolean operators (AND, OR, and NOT) are allowed in the qualification. For example, the following retrieves the weather of San Francisco on rainy days:

```
SELECT * FROM weather
  WHERE city = 'San Francisco' AND prcp > 0.0;
```

Result:

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27

(1 row)

You can request that the results of a query be returned in sorted order:

```
SELECT * FROM weather
  ORDER BY city;
```

city	temp_lo	temp_hi	prcp	date
Hayward	37	54		1994-11-29
San Francisco	43	57	0	1994-11-29
San Francisco	46	50	0.25	1994-11-27

In this example, the sort order isn't fully specified, and so you might get the San Francisco rows in either order. But you'd always get the results shown above if you do:

```
SELECT * FROM weather
  ORDER BY city, temp_lo;
```

You can request that duplicate rows be removed from the result of a query:

```
SELECT DISTINCT city
  FROM weather;
```

```

      city
-----
 Hayward
 San Francisco
(2 rows)

```

Here again, the result row ordering might vary. You can ensure consistent results by using `DISTINCT` and `ORDER BY` together:²

```

SELECT DISTINCT city
   FROM weather
  ORDER BY city;

```

2.6. Joins Between Tables

Thus far, our queries have only accessed one table at a time. Queries can access multiple tables at once, or access the same table in such a way that multiple rows of the table are being processed at the same time. A query that accesses multiple rows of the same or different tables at one time is called a *join* query. As an example, say you wish to list all the weather records together with the location of the associated city. To do that, we need to compare the `city` column of each row of the weather table with the `name` column of all rows in the `cities` table, and select the pairs of rows where these values match.

Note

This is only a conceptual model. The join is usually performed in a more efficient manner than actually comparing each possible pair of rows, but this is invisible to the user.

This would be accomplished by the following query:

```

SELECT *
   FROM weather, cities
  WHERE city = name;

```

```

      city      | temp_lo | temp_hi | prcp | date       | name
-----+-----+-----+-----+-----+-----
 | location
-----+-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----+-----
 San Francisco |      46 |      50 | 0.25 | 1994-11-27 | San
 Francisco | (-194,53)
 San Francisco |      43 |      57 | 0    | 1994-11-29 | San
 Francisco | (-194,53)
(2 rows)

```

Observe two things about the result set:

- There is no result row for the city of Hayward. This is because there is no matching entry in the `cities` table for Hayward, so the join ignores the unmatched rows in the weather table. We will see shortly how this can be fixed.

² In some database systems, including older versions of PostgreSQL, the implementation of `DISTINCT` automatically orders the rows and so `ORDER BY` is unnecessary. But this is not required by the SQL standard, and current PostgreSQL does not guarantee that `DISTINCT` causes the rows to be ordered.

- There are two columns containing the city name. This is correct because the lists of columns from the `weather` and `cities` tables are concatenated. In practice this is undesirable, though, so you will probably want to list the output columns explicitly rather than using `*`:

```
SELECT city, temp_lo, temp_hi, prcp, date, location
       FROM weather, cities
       WHERE city = name;
```

Exercise: Attempt to determine the semantics of this query when the `WHERE` clause is omitted.

Since the columns all had different names, the parser automatically found which table they belong to. If there were duplicate column names in the two tables you'd need to *qualify* the column names to show which one you meant, as in:

```
SELECT weather.city, weather.temp_lo, weather.temp_hi,
       weather.prcp, weather.date, cities.location
       FROM weather, cities
       WHERE cities.name = weather.city;
```

It is widely considered good style to qualify all column names in a join query, so that the query won't fail if a duplicate column name is later added to one of the tables.

Join queries of the kind seen thus far can also be written in this alternative form:

```
SELECT *
       FROM weather INNER JOIN cities ON (weather.city = cities.name);
```

This syntax is not as commonly used as the one above, but we show it here to help you understand the following topics.

Now we will figure out how we can get the Hayward records back in. What we want the query to do is to scan the `weather` table and for each row to find the matching `cities` row(s). If no matching row is found we want some “empty values” to be substituted for the `cities` table's columns. This kind of query is called an *outer join*. (The joins we have seen so far are inner joins.) The command looks like this:

```
SELECT *
       FROM weather LEFT OUTER JOIN cities ON (weather.city =
       cities.name);
```

city location	temp_lo	temp_hi	prcp	date	name
Hayward	37	54		1994-11-29	
San Francisco (-194,53)	46	50	0.25	1994-11-27	San
San Francisco (-194,53)	43	57	0	1994-11-29	San

(3 rows)

This query is called a *left outer join* because the table mentioned on the left of the join operator will have each of its rows in the output at least once, whereas the table on the right will only have those rows output that match some row of the left table. When outputting a left-table row for which there is no right-table match, empty (null) values are substituted for the right-table columns.

Exercise: There are also right outer joins and full outer joins. Try to find out what those do.

We can also join a table against itself. This is called a *self join*. As an example, suppose we wish to find all the weather records that are in the temperature range of other weather records. So we need to compare the `temp_lo` and `temp_hi` columns of each `weather` row to the `temp_lo` and `temp_hi` columns of all other `weather` rows. We can do this with the following query:

```
SELECT W1.city, W1.temp_lo AS low, W1.temp_hi AS high,
       W2.city, W2.temp_lo AS low, W2.temp_hi AS high
FROM weather W1, weather W2
WHERE W1.temp_lo < W2.temp_lo
AND W1.temp_hi > W2.temp_hi;
```

city	low	high	city	low	high
San Francisco	43	57	San Francisco	46	50
Hayward	37	54	San Francisco	46	50

(2 rows)

Here we have relabeled the `weather` table as `W1` and `W2` to be able to distinguish the left and right side of the join. You can also use these kinds of aliases in other queries to save some typing, e.g.:

```
SELECT *
FROM weather w, cities c
WHERE w.city = c.name;
```

You will encounter this style of abbreviating quite frequently.

2.7. Aggregate Functions

Like most other relational database products, PostgreSQL supports *aggregate functions*. An aggregate function computes a single result from multiple input rows. For example, there are aggregates to compute the `count`, `sum`, `avg` (average), `max` (maximum) and `min` (minimum) over a set of rows.

As an example, we can find the highest low-temperature reading anywhere with:

```
SELECT max(temp_lo) FROM weather;
```

```
max
-----
 46
(1 row)
```

If we wanted to know what city (or cities) that reading occurred in, we might try:

```
SELECT city FROM weather WHERE temp_lo = max(temp_lo);      WRONG
```

but this will not work since the aggregate `max` cannot be used in the `WHERE` clause. (This restriction exists because the `WHERE` clause determines which rows will be included in the aggregate calculation; so obviously it has to be evaluated before aggregate functions are computed.) However, as is often the case the query can be restated to accomplish the desired result, here by using a *subquery*:

```
SELECT city FROM weather
```

```
WHERE temp_lo = (SELECT max(temp_lo) FROM weather);
```

```

      city
-----
San Francisco
(1 row)

```

This is OK because the subquery is an independent computation that computes its own aggregate separately from what is happening in the outer query.

Aggregates are also very useful in combination with `GROUP BY` clauses. For example, we can get the maximum low temperature observed in each city with:

```
SELECT city, max(temp_lo)
FROM weather
GROUP BY city;
```

```

      city      | max
-----+-----
 Hayward       |   37
San Francisco  |   46
(2 rows)

```

which gives us one output row per city. Each aggregate result is computed over the table rows matching that city. We can filter these grouped rows using `HAVING`:

```
SELECT city, max(temp_lo)
FROM weather
GROUP BY city
HAVING max(temp_lo) < 40;
```

```

      city      | max
-----+-----
 Hayward       |   37
(1 row)

```

which gives us the same results for only the cities that have all `temp_lo` values below 40. Finally, if we only care about cities whose names begin with “S”, we might do:

```
SELECT city, max(temp_lo)
FROM weather
WHERE city LIKE 'S%'           -- I
GROUP BY city
HAVING max(temp_lo) < 40;
```

I The `LIKE` operator does pattern matching and is explained in Section 9.7.

It is important to understand the interaction between aggregates and SQL's `WHERE` and `HAVING` clauses. The fundamental difference between `WHERE` and `HAVING` is this: `WHERE` selects input rows before groups and aggregates are computed (thus, it controls which rows go into the aggregate computation), whereas `HAVING` selects group rows after groups and aggregates are computed. Thus, the `WHERE` clause must not contain aggregate functions; it makes no sense to try to use an aggregate to determine which rows will be inputs to the aggregates. On the other hand, the `HAVING` clause always contains aggregate functions. (Strictly speaking, you are allowed to write a `HAVING` clause that doesn't use

aggregates, but it's seldom useful. The same condition could be used more efficiently at the WHERE stage.)

In the previous example, we can apply the city name restriction in WHERE, since it needs no aggregate. This is more efficient than adding the restriction to HAVING, because we avoid doing the grouping and aggregate calculations for all rows that fail the WHERE check.

2.8. Updates

You can update existing rows using the UPDATE command. Suppose you discover the temperature readings are all off by 2 degrees after November 28. You can correct the data as follows:

```
UPDATE weather
  SET temp_hi = temp_hi - 2, temp_lo = temp_lo - 2
  WHERE date > '1994-11-28';
```

Look at the new state of the data:

```
SELECT * FROM weather;
```

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27
San Francisco	41	55	0	1994-11-29
Hayward	35	52		1994-11-29

(3 rows)

2.9. Deletions

Rows can be removed from a table using the DELETE command. Suppose you are no longer interested in the weather of Hayward. Then you can do the following to delete those rows from the table:

```
DELETE FROM weather WHERE city = 'Hayward';
```

All weather records belonging to Hayward are removed.

```
SELECT * FROM weather;
```

city	temp_lo	temp_hi	prcp	date
San Francisco	46	50	0.25	1994-11-27
San Francisco	41	55	0	1994-11-29

(2 rows)

One should be wary of statements of the form

```
DELETE FROM tablename;
```

Without a qualification, DELETE will remove *all* rows from the given table, leaving it empty. The system will not request confirmation before doing this!

Chapter 3. Advanced Features

3.1. Introduction

In the previous chapter we have covered the basics of using SQL to store and access your data in PostgreSQL. We will now discuss some more advanced features of SQL that simplify management and prevent loss or corruption of your data. Finally, we will look at some PostgreSQL extensions.

This chapter will on occasion refer to examples found in Chapter 2 to change or improve them, so it will be useful to have read that chapter. Some examples from this chapter can also be found in `advanced.sql` in the tutorial directory. This file also contains some sample data to load, which is not repeated here. (Refer to Section 2.1 for how to use the file.)

3.2. Views

Refer back to the queries in Section 2.6. Suppose the combined listing of weather records and city location is of particular interest to your application, but you do not want to type the query each time you need it. You can create a *view* over the query, which gives a name to the query that you can refer to like an ordinary table:

```
CREATE VIEW myview AS
  SELECT city, temp_lo, temp_hi, prcp, date, location
     FROM weather, cities
     WHERE city = name;
```

```
SELECT * FROM myview;
```

Making liberal use of views is a key aspect of good SQL database design. Views allow you to encapsulate the details of the structure of your tables, which might change as your application evolves, behind consistent interfaces.

Views can be used in almost any place a real table can be used. Building views upon other views is not uncommon.

3.3. Foreign Keys

Recall the `weather` and `cities` tables from Chapter 2. Consider the following problem: You want to make sure that no one can insert rows in the `weather` table that do not have a matching entry in the `cities` table. This is called maintaining the *referential integrity* of your data. In simplistic database systems this would be implemented (if at all) by first looking at the `cities` table to check if a matching record exists, and then inserting or rejecting the new `weather` records. This approach has a number of problems and is very inconvenient, so PostgreSQL can do this for you.

The new declaration of the tables would look like this:

```
CREATE TABLE cities (
  city      varchar(80) primary key,
  location  point
);

CREATE TABLE weather (
  city      varchar(80) references cities(city),
  temp_lo  int,
```

```
        temp_hi    int,  
        prcp      real,  
        date      date  
    );
```

Now try inserting an invalid record:

```
INSERT INTO weather VALUES ('Berkeley', 45, 53, 0.0, '1994-11-28');
```

```
ERROR: insert or update on table "weather" violates foreign key  
constraint "weather_city_fkey"  
DETAIL: Key (city)=(Berkeley) is not present in table "cities".
```

The behavior of foreign keys can be finely tuned to your application. We will not go beyond this simple example in this tutorial, but just refer you to Chapter 5 for more information. Making correct use of foreign keys will definitely improve the quality of your database applications, so you are strongly encouraged to learn about them.

3.4. Transactions

Transactions are a fundamental concept of all database systems. The essential point of a transaction is that it bundles multiple steps into a single, all-or-nothing operation. The intermediate states between the steps are not visible to other concurrent transactions, and if some failure occurs that prevents the transaction from completing, then none of the steps affect the database at all.

For example, consider a bank database that contains balances for various customer accounts, as well as total deposit balances for branches. Suppose that we want to record a payment of \$100.00 from Alice's account to Bob's account. Simplifying outrageously, the SQL commands for this might look like:

```
UPDATE accounts SET balance = balance - 100.00  
    WHERE name = 'Alice';  
UPDATE branches SET balance = balance - 100.00  
    WHERE name = (SELECT branch_name FROM accounts WHERE name =  
    'Alice');  
UPDATE accounts SET balance = balance + 100.00  
    WHERE name = 'Bob';  
UPDATE branches SET balance = balance + 100.00  
    WHERE name = (SELECT branch_name FROM accounts WHERE name =  
    'Bob');
```

The details of these commands are not important here; the important point is that there are several separate updates involved to accomplish this rather simple operation. Our bank's officers will want to be assured that either all these updates happen, or none of them happen. It would certainly not do for a system failure to result in Bob receiving \$100.00 that was not debited from Alice. Nor would Alice long remain a happy customer if she was debited without Bob being credited. We need a guarantee that if something goes wrong partway through the operation, none of the steps executed so far will take effect. Grouping the updates into a *transaction* gives us this guarantee. A transaction is said to be *atomic*: from the point of view of other transactions, it either happens completely or not at all.

We also want a guarantee that once a transaction is completed and acknowledged by the database system, it has indeed been permanently recorded and won't be lost even if a crash ensues shortly thereafter. For example, if we are recording a cash withdrawal by Bob, we do not want any chance that the debit to his account will disappear in a crash just after he walks out the bank door. A transactional database guarantees that all the updates made by a transaction are logged in permanent storage (i.e., on disk) before the transaction is reported complete.

Another important property of transactional databases is closely related to the notion of atomic updates: when multiple transactions are running concurrently, each one should not be able to see the incomplete changes made by others. For example, if one transaction is busy totalling all the branch balances, it would not do for it to include the debit from Alice's branch but not the credit to Bob's branch, nor vice versa. So transactions must be all-or-nothing not only in terms of their permanent effect on the database, but also in terms of their visibility as they happen. The updates made so far by an open transaction are invisible to other transactions until the transaction completes, whereupon all the updates become visible simultaneously.

In PostgreSQL, a transaction is set up by surrounding the SQL commands of the transaction with `BEGIN` and `COMMIT` commands. So our banking transaction would actually look like:

```
BEGIN;  
UPDATE accounts SET balance = balance - 100.00  
    WHERE name = 'Alice';  
-- etc etc  
COMMIT;
```

If, partway through the transaction, we decide we do not want to commit (perhaps we just noticed that Alice's balance went negative), we can issue the command `ROLLBACK` instead of `COMMIT`, and all our updates so far will be canceled.

PostgreSQL actually treats every SQL statement as being executed within a transaction. If you do not issue a `BEGIN` command, then each individual statement has an implicit `BEGIN` and (if successful) `COMMIT` wrapped around it. A group of statements surrounded by `BEGIN` and `COMMIT` is sometimes called a *transaction block*.

Note

Some client libraries issue `BEGIN` and `COMMIT` commands automatically, so that you might get the effect of transaction blocks without asking. Check the documentation for the interface you are using.

It's possible to control the statements in a transaction in a more granular fashion through the use of *savepoints*. Savepoints allow you to selectively discard parts of the transaction, while committing the rest. After defining a savepoint with `SAVEPOINT`, you can if needed roll back to the savepoint with `ROLLBACK TO`. All the transaction's database changes between defining the savepoint and rolling back to it are discarded, but changes earlier than the savepoint are kept.

After rolling back to a savepoint, it continues to be defined, so you can roll back to it several times. Conversely, if you are sure you won't need to roll back to a particular savepoint again, it can be released, so the system can free some resources. Keep in mind that either releasing or rolling back to a savepoint will automatically release all savepoints that were defined after it.

All this is happening within the transaction block, so none of it is visible to other database sessions. When and if you commit the transaction block, the committed actions become visible as a unit to other sessions, while the rolled-back actions never become visible at all.

Remembering the bank database, suppose we debit \$100.00 from Alice's account, and credit Bob's account, only to find later that we should have credited Wally's account. We could do it using savepoints like this:

```
BEGIN;  
UPDATE accounts SET balance = balance - 100.00  
    WHERE name = 'Alice';  
SAVEPOINT my_savepoint;
```

```

UPDATE accounts SET balance = balance + 100.00
  WHERE name = 'Bob';
-- oops ... forget that and use Wally's account
ROLLBACK TO my_savepoint;
UPDATE accounts SET balance = balance + 100.00
  WHERE name = 'Wally';
COMMIT;

```

This example is, of course, oversimplified, but there's a lot of control possible in a transaction block through the use of savepoints. Moreover, `ROLLBACK TO` is the only way to regain control of a transaction block that was put in aborted state by the system due to an error, short of rolling it back completely and starting again.

3.5. Window Functions

A *window function* performs a calculation across a set of table rows that are somehow related to the current row. This is comparable to the type of calculation that can be done with an aggregate function. However, window functions do not cause rows to become grouped into a single output row like non-window aggregate calls would. Instead, the rows retain their separate identities. Behind the scenes, the window function is able to access more than just the current row of the query result.

Here is an example that shows how to compare each employee's salary with the average salary in his or her department:

```

SELECT depname, empno, salary, avg(salary) OVER (PARTITION BY
  depname) FROM empsalary;

```

depname	empno	salary	avg
develop	11	5200	5020.000000000000000000
develop	7	4200	5020.000000000000000000
develop	9	4500	5020.000000000000000000
develop	8	6000	5020.000000000000000000
develop	10	5200	5020.000000000000000000
personnel	5	3500	3700.000000000000000000
personnel	2	3900	3700.000000000000000000
sales	3	4800	4866.666666666666666667
sales	1	5000	4866.666666666666666667
sales	4	4800	4866.666666666666666667

(10 rows)

The first three output columns come directly from the table `empsalary`, and there is one output row for each row in the table. The fourth column represents an average taken across all the table rows that have the same `depname` value as the current row. (This actually is the same function as the non-window `avg` aggregate, but the `OVER` clause causes it to be treated as a window function and computed across the window frame.)

A window function call always contains an `OVER` clause directly following the window function's name and argument(s). This is what syntactically distinguishes it from a normal function or non-window aggregate. The `OVER` clause determines exactly how the rows of the query are split up for processing by the window function. The `PARTITION BY` clause within `OVER` divides the rows into groups, or partitions, that share the same values of the `PARTITION BY` expression(s). For each row, the window function is computed across the rows that fall into the same partition as the current row.

You can also control the order in which rows are processed by window functions using `ORDER BY` within `OVER`. (The window `ORDER BY` does not even have to match the order in which the rows are output.) Here is an example:

```
SELECT depname, empno, salary,
       rank() OVER (PARTITION BY depname ORDER BY salary DESC)
FROM empsalary;
```

depname	empno	salary	rank
develop	8	6000	1
develop	10	5200	2
develop	11	5200	2
develop	9	4500	4
develop	7	4200	5
personnel	2	3900	1
personnel	5	3500	2
sales	1	5000	1
sales	4	4800	2
sales	3	4800	2

(10 rows)

As shown here, the `rank` function produces a numerical rank for each distinct `ORDER BY` value in the current row's partition, using the order defined by the `ORDER BY` clause. `rank` needs no explicit parameter, because its behavior is entirely determined by the `OVER` clause.

The rows considered by a window function are those of the “virtual table” produced by the query's `FROM` clause as filtered by its `WHERE`, `GROUP BY`, and `HAVING` clauses if any. For example, a row removed because it does not meet the `WHERE` condition is not seen by any window function. A query can contain multiple window functions that slice up the data in different ways using different `OVER` clauses, but they all act on the same collection of rows defined by this virtual table.

We already saw that `ORDER BY` can be omitted if the ordering of rows is not important. It is also possible to omit `PARTITION BY`, in which case there is a single partition containing all rows.

There is another important concept associated with window functions: for each row, there is a set of rows within its partition called its *window frame*. Some window functions act only on the rows of the window frame, rather than of the whole partition. By default, if `ORDER BY` is supplied then the frame consists of all rows from the start of the partition up through the current row, plus any following rows that are equal to the current row according to the `ORDER BY` clause. When `ORDER BY` is omitted the default frame consists of all rows in the partition.¹ Here is an example using `sum`:

```
SELECT salary, sum(salary) OVER () FROM empsalary;
```

salary	sum
5200	47100
5000	47100
3500	47100
4800	47100
3900	47100
4200	47100
4500	47100
4800	47100
6000	47100
5200	47100

(10 rows)

¹ There are options to define the window frame in other ways, but this tutorial does not cover them. See Section 4.2.8 for details.

Above, since there is no `ORDER BY` in the `OVER` clause, the window frame is the same as the partition, which for lack of `PARTITION BY` is the whole table; in other words each sum is taken over the whole table and so we get the same result for each output row. But if we add an `ORDER BY` clause, we get very different results:

```
SELECT salary, sum(salary) OVER (ORDER BY salary) FROM empsalary;
```

salary	sum
3500	3500
3900	7400
4200	11600
4500	16100
4800	25700
4800	25700
5000	30700
5200	41100
5200	41100
6000	47100

(10 rows)

Here the sum is taken from the first (lowest) salary up through the current one, including any duplicates of the current one (notice the results for the duplicated salaries).

Window functions are permitted only in the `SELECT` list and the `ORDER BY` clause of the query. They are forbidden elsewhere, such as in `GROUP BY`, `HAVING` and `WHERE` clauses. This is because they logically execute after the processing of those clauses. Also, window functions execute after non-window aggregate functions. This means it is valid to include an aggregate function call in the arguments of a window function, but not vice versa.

If there is a need to filter or group rows after the window calculations are performed, you can use a sub-select. For example:

```
SELECT depname, empno, salary, enroll_date
FROM
  (SELECT depname, empno, salary, enroll_date,
         rank() OVER (PARTITION BY depname ORDER BY salary DESC,
                    empno) AS pos
   FROM empsalary
  ) AS ss
WHERE pos < 3;
```

The above query only shows the rows from the inner query having rank less than 3.

When a query involves multiple window functions, it is possible to write out each one with a separate `OVER` clause, but this is duplicative and error-prone if the same windowing behavior is wanted for several functions. Instead, each windowing behavior can be named in a `WINDOW` clause and then referenced in `OVER`. For example:

```
SELECT sum(salary) OVER w, avg(salary) OVER w
FROM empsalary
WINDOW w AS (PARTITION BY depname ORDER BY salary DESC);
```

More details about window functions can be found in Section 4.2.8, Section 9.21, Section 7.2.5, and the `SELECT` reference page.

3.6. Inheritance

Inheritance is a concept from object-oriented databases. It opens up interesting new possibilities of database design.

Let's create two tables: A table `cities` and a table `capitals`. Naturally, capitals are also cities, so you want some way to show the capitals implicitly when you list all cities. If you're really clever you might invent some scheme like this:

```
CREATE TABLE capitals (  
    name          text,  
    population    real,  
    altitude      int,    -- (in ft)  
    state         char(2)  
);  
  
CREATE TABLE non_capitals (  
    name          text,  
    population    real,  
    altitude      int     -- (in ft)  
);  
  
CREATE VIEW cities AS  
    SELECT name, population, altitude FROM capitals  
    UNION  
    SELECT name, population, altitude FROM non_capitals;
```

This works OK as far as querying goes, but it gets ugly when you need to update several rows, for one thing.

A better solution is this:

```
CREATE TABLE cities (  
    name          text,  
    population    real,  
    altitude      int     -- (in ft)  
);  
  
CREATE TABLE capitals (  
    state         char(2)  
) INHERITS (cities);
```

In this case, a row of `capitals` *inherits* all columns (`name`, `population`, and `altitude`) from its *parent*, `cities`. The type of the column `name` is `text`, a native PostgreSQL type for variable length character strings. State capitals have an extra column, `state`, that shows their state. In PostgreSQL, a table can inherit from zero or more other tables.

For example, the following query finds the names of all cities, including state capitals, that are located at an altitude over 500 feet:

```
SELECT name, altitude  
    FROM cities  
    WHERE altitude > 500;
```

which returns:

name	altitude
Las Vegas	2174
Mariposa	1953
Madison	845

(3 rows)

On the other hand, the following query finds all the cities that are not state capitals and are situated at an altitude over 500 feet:

```
SELECT name, altitude
FROM ONLY cities
WHERE altitude > 500;
```

name	altitude
Las Vegas	2174
Mariposa	1953

(2 rows)

Here the `ONLY` before `cities` indicates that the query should be run over only the `cities` table, and not tables below `cities` in the inheritance hierarchy. Many of the commands that we have already discussed — `SELECT`, `UPDATE`, and `DELETE` — support this `ONLY` notation.

Note

Although inheritance is frequently useful, it has not been integrated with unique constraints or foreign keys, which limits its usefulness. See Section 5.10 for more detail.

3.7. Conclusion

PostgreSQL has many features not touched upon in this tutorial introduction, which has been oriented toward newer users of SQL. These features are discussed in more detail in the remainder of this book.

If you feel you need more introductory material, please visit the PostgreSQL web site² for links to more resources.

² <https://www.postgresql.org>

Part II. The SQL Language

This part describes the use of the SQL language in PostgreSQL. We start with describing the general syntax of SQL, then explain how to create the structures to hold data, how to populate the database, and how to query it. The middle part lists the available data types and functions for use in SQL commands. The rest treats several aspects that are important for tuning a database for optimal performance.

The information in this part is arranged so that a novice user can follow it start to end to gain a full understanding of the topics without having to refer forward too many times. The chapters are intended to be self-contained, so that advanced users can read the chapters individually as they choose. The information in this part is presented in a narrative fashion in topical units. Readers looking for a complete description of a particular command should see Part VI.

Readers of this part should know how to connect to a PostgreSQL database and issue SQL commands. Readers that are unfamiliar with these issues are encouraged to read Part I first. SQL commands are typically entered using the PostgreSQL interactive terminal `psql`, but other programs that have similar functionality can be used as well.

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Chapter 4. SQL Syntax

This chapter describes the syntax of SQL. It forms the foundation for understanding the following chapters which will go into detail about how SQL commands are applied to define and modify data.

We also advise users who are already familiar with SQL to read this chapter carefully because it contains several rules and concepts that are implemented inconsistently among SQL databases or that are specific to PostgreSQL.

4.1. Lexical Structure

SQL input consists of a sequence of *commands*. A command is composed of a sequence of *tokens*, terminated by a semicolon (“;”). The end of the input stream also terminates a command. Which tokens are valid depends on the syntax of the particular command.

A token can be a *key word*, an *identifier*, a *quoted identifier*, a *literal* (or constant), or a special character symbol. Tokens are normally separated by whitespace (space, tab, newline), but need not be if there is no ambiguity (which is generally only the case if a special character is adjacent to some other token type).

For example, the following is (syntactically) valid SQL input:

```
SELECT * FROM MY_TABLE;  
UPDATE MY_TABLE SET A = 5;  
INSERT INTO MY_TABLE VALUES (3, 'hi there');
```

This is a sequence of three commands, one per line (although this is not required; more than one command can be on a line, and commands can usefully be split across lines).

Additionally, *comments* can occur in SQL input. They are not tokens, they are effectively equivalent to whitespace.

The SQL syntax is not very consistent regarding what tokens identify commands and which are operands or parameters. The first few tokens are generally the command name, so in the above example we would usually speak of a “SELECT”, an “UPDATE”, and an “INSERT” command. But for instance the UPDATE command always requires a SET token to appear in a certain position, and this particular variation of INSERT also requires a VALUES in order to be complete. The precise syntax rules for each command are described in Part VI.

4.1.1. Identifiers and Key Words

Tokens such as SELECT, UPDATE, or VALUES in the example above are examples of *key words*, that is, words that have a fixed meaning in the SQL language. The tokens MY_TABLE and A are examples of *identifiers*. They identify names of tables, columns, or other database objects, depending on the command they are used in. Therefore they are sometimes simply called “names”. Key words and identifiers have the same lexical structure, meaning that one cannot know whether a token is an identifier or a key word without knowing the language. A complete list of key words can be found in Appendix C.

SQL identifiers and key words must begin with a letter (a-z, but also letters with diacritical marks and non-Latin letters) or an underscore (_). Subsequent characters in an identifier or key word can be letters, underscores, digits (0-9), or dollar signs (\$). Note that dollar signs are not allowed in identifiers according to the letter of the SQL standard, so their use might render applications less portable. The SQL standard will not define a key word that contains digits or starts or ends with an underscore, so identifiers of this form are safe against possible conflict with future extensions of the standard.

The system uses no more than `NAMEDATALEN-1` bytes of an identifier; longer names can be written in commands, but they will be truncated. By default, `NAMEDATALEN` is 64 so the maximum identifier length is 63 bytes. If this limit is problematic, it can be raised by changing the `NAMEDATALEN` constant in `src/include/pg_config_manual.h`.

Key words and unquoted identifiers are case insensitive. Therefore:

```
UPDATE MY_TABLE SET A = 5;
```

can equivalently be written as:

```
uPDaTE my_Table SeT a = 5;
```

A convention often used is to write key words in upper case and names in lower case, e.g.:

```
UPDATE my_table SET a = 5;
```

There is a second kind of identifier: the *delimited identifier* or *quoted identifier*. It is formed by enclosing an arbitrary sequence of characters in double-quotes (`"`). A delimited identifier is always an identifier, never a key word. So `"select"` could be used to refer to a column or table named `"select"`, whereas an unquoted `select` would be taken as a key word and would therefore provoke a parse error when used where a table or column name is expected. The example can be written with quoted identifiers like this:

```
UPDATE "my_table" SET "a" = 5;
```

Quoted identifiers can contain any character, except the character with code zero. (To include a double quote, write two double quotes.) This allows constructing table or column names that would otherwise not be possible, such as ones containing spaces or ampersands. The length limitation still applies.

A variant of quoted identifiers allows including escaped Unicode characters identified by their code points. This variant starts with `U&` (upper or lower case `U` followed by ampersand) immediately before the opening double quote, without any spaces in between, for example `U&"foo"`. (Note that this creates an ambiguity with the operator `&`. Use spaces around the operator to avoid this problem.) Inside the quotes, Unicode characters can be specified in escaped form by writing a backslash followed by the four-digit hexadecimal code point number or alternatively a backslash followed by a plus sign followed by a six-digit hexadecimal code point number. For example, the identifier `"data"` could be written as

```
U&"d\0061t\+000061"
```

The following less trivial example writes the Russian word `"slon"` (elephant) in Cyrillic letters:

```
U&"\0441\043B\043E\043D"
```

If a different escape character than backslash is desired, it can be specified using the `UESCAPE` clause after the string, for example:

```
U&"d!0061t!+000061" UESCAPE '!'
```

The escape character can be any single character other than a hexadecimal digit, the plus sign, a single quote, a double quote, or a whitespace character. Note that the escape character is written in single quotes, not double quotes.

To include the escape character in the identifier literally, write it twice.

The Unicode escape syntax works only when the server encoding is UTF8. When other server encodings are used, only code points in the ASCII range (up to \007F) can be specified. Both the 4-digit and the 6-digit form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than U+FFFF, although the availability of the 6-digit form technically makes this unnecessary. (Surrogate pairs are not stored directly, but combined into a single code point that is then encoded in UTF-8.)

Quoting an identifier also makes it case-sensitive, whereas unquoted names are always folded to lower case. For example, the identifiers `FOO`, `foo`, and `"foo"` are considered the same by PostgreSQL, but `"FOO"` and `"FOO"` are different from these three and each other. (The folding of unquoted names to lower case in PostgreSQL is incompatible with the SQL standard, which says that unquoted names should be folded to upper case. Thus, `foo` should be equivalent to `"FOO"` not `"foo"` according to the standard. If you want to write portable applications you are advised to always quote a particular name or never quote it.)

4.1.2. Constants

There are three kinds of *implicitly-typed constants* in PostgreSQL: strings, bit strings, and numbers. Constants can also be specified with explicit types, which can enable more accurate representation and more efficient handling by the system. These alternatives are discussed in the following subsections.

4.1.2.1. String Constants

A string constant in SQL is an arbitrary sequence of characters bounded by single quotes (`'`), for example `'This is a string'`. To include a single-quote character within a string constant, write two adjacent single quotes, e.g., `'Dianne 's horse'`. Note that this is *not* the same as a double-quote character (`"`).

Two string constants that are only separated by whitespace *with at least one newline* are concatenated and effectively treated as if the string had been written as one constant. For example:

```
SELECT 'foo'
'bar' ;
```

is equivalent to:

```
SELECT 'foobar' ;
```

but:

```
SELECT 'foo'      'bar' ;
```

is not valid syntax. (This slightly bizarre behavior is specified by SQL; PostgreSQL is following the standard.)

4.1.2.2. String Constants with C-Style Escapes

PostgreSQL also accepts “escape” string constants, which are an extension to the SQL standard. An escape string constant is specified by writing the letter `E` (upper or lower case) just before the opening single quote, e.g., `E'foo'`. (When continuing an escape string constant across lines, write `E` only before the first opening quote.) Within an escape string, a backslash character (`\`) begins a C-like *backslash escape* sequence, in which the combination of backslash and following character(s) represent a special byte value, as shown in Table 4.1.

Table 4.1. Backslash Escape Sequences

Backslash Escape Sequence	Interpretation
<code>\b</code>	backspace
<code>\f</code>	form feed
<code>\n</code>	newline
<code>\r</code>	carriage return
<code>\t</code>	tab
<code>\o</code> , <code>\oo</code> , <code>\ooo</code> ($o = 0 - 7$)	octal byte value
<code>\xh</code> , <code>\xhh</code> ($h = 0 - 9, A - F$)	hexadecimal byte value
<code>\uxxxx</code> , <code>\Uxxxxxxxx</code> ($x = 0 - 9, A - F$)	16 or 32-bit hexadecimal Unicode character value

Any other character following a backslash is taken literally. Thus, to include a backslash character, write two backslashes (`\\`). Also, a single quote can be included in an escape string by writing `\'`, in addition to the normal way of `'`.

It is your responsibility that the byte sequences you create, especially when using the octal or hexadecimal escapes, compose valid characters in the server character set encoding. When the server encoding is UTF-8, then the Unicode escapes or the alternative Unicode escape syntax, explained in Section 4.1.2.3, should be used instead. (The alternative would be doing the UTF-8 encoding by hand and writing out the bytes, which would be very cumbersome.)

The Unicode escape syntax works fully only when the server encoding is UTF8. When other server encodings are used, only code points in the ASCII range (up to `\u007F`) can be specified. Both the 4-digit and the 8-digit form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than U+FFFF, although the availability of the 8-digit form technically makes this unnecessary. (When surrogate pairs are used when the server encoding is UTF8, they are first combined into a single code point that is then encoded in UTF-8.)

Caution

If the configuration parameter `standard_conforming_strings` is `off`, then PostgreSQL recognizes backslash escapes in both regular and escape string constants. However, as of PostgreSQL 9.1, the default is `on`, meaning that backslash escapes are recognized only in escape string constants. This behavior is more standards-compliant, but might break applications which rely on the historical behavior, where backslash escapes were always recognized. As a workaround, you can set this parameter to `off`, but it is better to migrate away from using backslash escapes. If you need to use a backslash escape to represent a special character, write the string constant with an `E`.

In addition to `standard_conforming_strings`, the configuration parameters `escape_string_warning` and `backslash_quote` govern treatment of backslashes in string constants.

The character with the code zero cannot be in a string constant.

4.1.2.3. String Constants with Unicode Escapes

PostgreSQL also supports another type of escape syntax for strings that allows specifying arbitrary Unicode characters by code point. A Unicode escape string constant starts with `U&` (upper or lower case letter `U` followed by ampersand) immediately before the opening quote, without any spaces in between, for example `U&'foo'`. (Note that this creates an ambiguity with the operator `&`. Use spaces around the operator to avoid this problem.) Inside the quotes, Unicode characters can be specified

in escaped form by writing a backslash followed by the four-digit hexadecimal code point number or alternatively a backslash followed by a plus sign followed by a six-digit hexadecimal code point number. For example, the string 'data' could be written as

```
U&'d\0061t\+000061'
```

The following less trivial example writes the Russian word “slon” (elephant) in Cyrillic letters:

```
U&' \0441\043B\043E\043D'
```

If a different escape character than backslash is desired, it can be specified using the `UESCAPE` clause after the string, for example:

```
U&'d!0061t!+000061' UESCAPE '!'
```

The escape character can be any single character other than a hexadecimal digit, the plus sign, a single quote, a double quote, or a whitespace character.

The Unicode escape syntax works only when the server encoding is UTF8. When other server encodings are used, only code points in the ASCII range (up to `\007F`) can be specified. Both the 4-digit and the 6-digit form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than `U+FFFF`, although the availability of the 6-digit form technically makes this unnecessary. (When surrogate pairs are used when the server encoding is UTF8, they are first combined into a single code point that is then encoded in UTF-8.)

Also, the Unicode escape syntax for string constants only works when the configuration parameter `standard_conforming_strings` is turned on. This is because otherwise this syntax could confuse clients that parse the SQL statements to the point that it could lead to SQL injections and similar security issues. If the parameter is set to off, this syntax will be rejected with an error message.

To include the escape character in the string literally, write it twice.

4.1.2.4. Dollar-Quoted String Constants

While the standard syntax for specifying string constants is usually convenient, it can be difficult to understand when the desired string contains many single quotes or backslashes, since each of those must be doubled. To allow more readable queries in such situations, PostgreSQL provides another way, called “dollar quoting”, to write string constants. A dollar-quoted string constant consists of a dollar sign (`$`), an optional “tag” of zero or more characters, another dollar sign, an arbitrary sequence of characters that makes up the string content, a dollar sign, the same tag that began this dollar quote, and a dollar sign. For example, here are two different ways to specify the string “Dianne's horse” using dollar quoting:

```
$$Dianne's horse$$
$SomeTag$Dianne's horse$SomeTag$
```

Notice that inside the dollar-quoted string, single quotes can be used without needing to be escaped. Indeed, no characters inside a dollar-quoted string are ever escaped: the string content is always written literally. Backslashes are not special, and neither are dollar signs, unless they are part of a sequence matching the opening tag.

It is possible to nest dollar-quoted string constants by choosing different tags at each nesting level. This is most commonly used in writing function definitions. For example:

```
$function$
```

```

BEGIN
    RETURN ($1 ~ $q$[\t\r\n\v\\]$q$);
END;
$function$

```

Here, the sequence `q[\t\r\n\v\\]q` represents a dollar-quoted literal string `[\t\r\n\v\\]`, which will be recognized when the function body is executed by PostgreSQL. But since the sequence does not match the outer dollar quoting delimiter `$function$`, it is just some more characters within the constant so far as the outer string is concerned.

The tag, if any, of a dollar-quoted string follows the same rules as an unquoted identifier, except that it cannot contain a dollar sign. Tags are case sensitive, so `tagString contenttag` is correct, but `TAGString contenttag` is not.

A dollar-quoted string that follows a keyword or identifier must be separated from it by whitespace; otherwise the dollar quoting delimiter would be taken as part of the preceding identifier.

Dollar quoting is not part of the SQL standard, but it is often a more convenient way to write complicated string literals than the standard-compliant single quote syntax. It is particularly useful when representing string constants inside other constants, as is often needed in procedural function definitions. With single-quote syntax, each backslash in the above example would have to be written as four backslashes, which would be reduced to two backslashes in parsing the original string constant, and then to one when the inner string constant is re-parsed during function execution.

4.1.2.5. Bit-String Constants

Bit-string constants look like regular string constants with a `B` (upper or lower case) immediately before the opening quote (no intervening whitespace), e.g., `B'1001'`. The only characters allowed within bit-string constants are 0 and 1.

Alternatively, bit-string constants can be specified in hexadecimal notation, using a leading `X` (upper or lower case), e.g., `X'1FF'`. This notation is equivalent to a bit-string constant with four binary digits for each hexadecimal digit.

Both forms of bit-string constant can be continued across lines in the same way as regular string constants. Dollar quoting cannot be used in a bit-string constant.

4.1.2.6. Numeric Constants

Numeric constants are accepted in these general forms:

```

digits
digits.[digits][e[+-]digits]
[digits].digits[e[+-]digits]
digite[+-]digits

```

where *digits* is one or more decimal digits (0 through 9). At least one digit must be before or after the decimal point, if one is used. At least one digit must follow the exponent marker (*e*), if one is present. There cannot be any spaces or other characters embedded in the constant. Note that any leading plus or minus sign is not actually considered part of the constant; it is an operator applied to the constant.

These are some examples of valid numeric constants:

```

42
3.5
4.
.001

```

```
5e2
1.925e-3
```

A numeric constant that contains neither a decimal point nor an exponent is initially presumed to be type `integer` if its value fits in type `integer` (32 bits); otherwise it is presumed to be type `bigint` if its value fits in type `bigint` (64 bits); otherwise it is taken to be type `numeric`. Constants that contain decimal points and/or exponents are always initially presumed to be type `numeric`.

The initially assigned data type of a numeric constant is just a starting point for the type resolution algorithms. In most cases the constant will be automatically coerced to the most appropriate type depending on context. When necessary, you can force a numeric value to be interpreted as a specific data type by casting it. For example, you can force a numeric value to be treated as type `real` (`float4`) by writing:

```
REAL '1.23' -- string style
1.23::REAL -- PostgreSQL (historical) style
```

These are actually just special cases of the general casting notations discussed next.

4.1.2.7. Constants of Other Types

A constant of an *arbitrary* type can be entered using any one of the following notations:

```
type 'string'
'string'::type
CAST ( 'string' AS type )
```

The string constant's text is passed to the input conversion routine for the type called *type*. The result is a constant of the indicated type. The explicit type cast can be omitted if there is no ambiguity as to the type the constant must be (for example, when it is assigned directly to a table column), in which case it is automatically coerced.

The string constant can be written using either regular SQL notation or dollar-quoting.

It is also possible to specify a type coercion using a function-like syntax:

```
typename ( 'string' )
```

but not all type names can be used in this way; see Section 4.2.9 for details.

The `::`, `CAST()`, and function-call syntaxes can also be used to specify run-time type conversions of arbitrary expressions, as discussed in Section 4.2.9. To avoid syntactic ambiguity, the *type* `'string'` syntax can only be used to specify the type of a simple literal constant. Another restriction on the *type* `'string'` syntax is that it does not work for array types; use `::` or `CAST()` to specify the type of an array constant.

The `CAST()` syntax conforms to SQL. The *type* `'string'` syntax is a generalization of the standard: SQL specifies this syntax only for a few data types, but PostgreSQL allows it for all types. The syntax with `::` is historical PostgreSQL usage, as is the function-call syntax.

4.1.3. Operators

An operator name is a sequence of up to `NAMEDATALEN-1` (63 by default) characters from the following list:

+ - * / < > = ~ ! @ # % ^ & | ` ?

There are a few restrictions on operator names, however:

- -- and /* cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multiple-character operator name cannot end in + or -, unless the name also contains at least one of these characters:

~ ! @ # % ^ & | ` ?

For example, @- is an allowed operator name, but *- is not. This restriction allows PostgreSQL to parse SQL-compliant queries without requiring spaces between tokens.

When working with non-SQL-standard operator names, you will usually need to separate adjacent operators with spaces to avoid ambiguity. For example, if you have defined a left unary operator named @, you cannot write X*@Y; you must write X* @Y to ensure that PostgreSQL reads it as two operator names not one.

4.1.4. Special Characters

Some characters that are not alphanumeric have a special meaning that is different from being an operator. Details on the usage can be found at the location where the respective syntax element is described. This section only exists to advise the existence and summarize the purposes of these characters.

- A dollar sign (\$) followed by digits is used to represent a positional parameter in the body of a function definition or a prepared statement. In other contexts the dollar sign can be part of an identifier or a dollar-quoted string constant.
- Parentheses (()) have their usual meaning to group expressions and enforce precedence. In some cases parentheses are required as part of the fixed syntax of a particular SQL command.
- Brackets [[]] are used to select the elements of an array. See Section 8.15 for more information on arrays.
- Commas (,) are used in some syntactical constructs to separate the elements of a list.
- The semicolon (;) terminates an SQL command. It cannot appear anywhere within a command, except within a string constant or quoted identifier.
- The colon (:) is used to select “slices” from arrays. (See Section 8.15.) In certain SQL dialects (such as Embedded SQL), the colon is used to prefix variable names.
- The asterisk (*) is used in some contexts to denote all the fields of a table row or composite value. It also has a special meaning when used as the argument of an aggregate function, namely that the aggregate does not require any explicit parameter.
- The period (.) is used in numeric constants, and to separate schema, table, and column names.

4.1.5. Comments

A comment is a sequence of characters beginning with double dashes and extending to the end of the line, e.g.:

```
-- This is a standard SQL comment
```

Alternatively, C-style block comments can be used:

```
/* multiline comment
 * with nesting: /* nested block comment */
 */
```

where the comment begins with `/*` and extends to the matching occurrence of `*/`. These block comments nest, as specified in the SQL standard but unlike C, so that one can comment out larger blocks of code that might contain existing block comments.

A comment is removed from the input stream before further syntax analysis and is effectively replaced by whitespace.

4.1.6. Operator Precedence

Table 4.2 shows the precedence and associativity of the operators in PostgreSQL. Most operators have the same precedence and are left-associative. The precedence and associativity of the operators is hard-wired into the parser.

You will sometimes need to add parentheses when using combinations of binary and unary operators. For instance:

```
SELECT 5 ! - 6;
```

will be parsed as:

```
SELECT 5 ! (- 6);
```

because the parser has no idea — until it is too late — that `!` is defined as a postfix operator, not an infix one. To get the desired behavior in this case, you must write:

```
SELECT (5 !) - 6;
```

This is the price one pays for extensibility.

Table 4.2. Operator Precedence (highest to lowest)

Operator/Element	Associativity	Description
.	left	table/column name separator
::	left	PostgreSQL-style typecast
[]	left	array element selection
+ -	right	unary plus, unary minus
^	left	exponentiation
* / %	left	multiplication, division, modulo
+ -	left	addition, subtraction
(any other operator)	left	all other native and user-defined operators
BETWEEN IN LIKE ILIKE SIMILAR		range containment, set membership, string matching
< > = <= >= <>		comparison operators
IS ISNULL NOTNULL		IS TRUE, IS FALSE, IS NULL, IS DISTINCT FROM, etc

Operator/Element	Associativity	Description
NOT	right	logical negation
AND	left	logical conjunction
OR	left	logical disjunction

Note that the operator precedence rules also apply to user-defined operators that have the same names as the built-in operators mentioned above. For example, if you define a “+” operator for some custom data type it will have the same precedence as the built-in “+” operator, no matter what yours does.

When a schema-qualified operator name is used in the OPERATOR syntax, as for example in:

```
SELECT 3 OPERATOR(pg_catalog.+) 4;
```

the OPERATOR construct is taken to have the default precedence shown in Table 4.2 for “any other operator”. This is true no matter which specific operator appears inside OPERATOR().

Note

PostgreSQL versions before 9.5 used slightly different operator precedence rules. In particular, <= >= and <> used to be treated as generic operators; IS tests used to have higher priority; and NOT BETWEEN and related constructs acted inconsistently, being taken in some cases as having the precedence of NOT rather than BETWEEN. These rules were changed for better compliance with the SQL standard and to reduce confusion from inconsistent treatment of logically equivalent constructs. In most cases, these changes will result in no behavioral change, or perhaps in “no such operator” failures which can be resolved by adding parentheses. However there are corner cases in which a query might change behavior without any parsing error being reported. If you are concerned about whether these changes have silently broken something, you can test your application with the configuration parameter operator_precedence_warning turned on to see if any warnings are logged.

4.2. Value Expressions

Value expressions are used in a variety of contexts, such as in the target list of the SELECT command, as new column values in INSERT or UPDATE, or in search conditions in a number of commands. The result of a value expression is sometimes called a *scalar*, to distinguish it from the result of a table expression (which is a table). Value expressions are therefore also called *scalar expressions* (or even simply *expressions*). The expression syntax allows the calculation of values from primitive parts using arithmetic, logical, set, and other operations.

A value expression is one of the following:

- A constant or literal value
- A column reference
- A positional parameter reference, in the body of a function definition or prepared statement
- A subscripted expression
- A field selection expression
- An operator invocation
- A function call

- An aggregate expression
- A window function call
- A type cast
- A collation expression
- A scalar subquery
- An array constructor
- A row constructor
- Another value expression in parentheses (used to group subexpressions and override precedence)

In addition to this list, there are a number of constructs that can be classified as an expression but do not follow any general syntax rules. These generally have the semantics of a function or operator and are explained in the appropriate location in Chapter 9. An example is the `IS NULL` clause.

We have already discussed constants in Section 4.1.2. The following sections discuss the remaining options.

4.2.1. Column References

A column can be referenced in the form:

correlation.columnname

correlation is the name of a table (possibly qualified with a schema name), or an alias for a table defined by means of a `FROM` clause. The correlation name and separating dot can be omitted if the column name is unique across all the tables being used in the current query. (See also Chapter 7.)

4.2.2. Positional Parameters

A positional parameter reference is used to indicate a value that is supplied externally to an SQL statement. Parameters are used in SQL function definitions and in prepared queries. Some client libraries also support specifying data values separately from the SQL command string, in which case parameters are used to refer to the out-of-line data values. The form of a parameter reference is:

\$number

For example, consider the definition of a function, `dept`, as:

```
CREATE FUNCTION dept(text) RETURNS dept
  AS $$ SELECT * FROM dept WHERE name = $1 $$
LANGUAGE SQL;
```

Here the `$1` references the value of the first function argument whenever the function is invoked.

4.2.3. Subscripts

If an expression yields a value of an array type, then a specific element of the array value can be extracted by writing

expression[subscript]

or multiple adjacent elements (an “array slice”) can be extracted by writing

```
expression[lower_subscript:upper_subscript]
```

(Here, the brackets [] are meant to appear literally.) Each *subscript* is itself an expression, which must yield an integer value.

In general the array *expression* must be parenthesized, but the parentheses can be omitted when the expression to be subscripted is just a column reference or positional parameter. Also, multiple subscripts can be concatenated when the original array is multidimensional. For example:

```
mytable.arraycolumn[4]  
mytable.two_d_column[17][34]  
$1[10:42]  
(arrayfunction(a,b))[42]
```

The parentheses in the last example are required. See Section 8.15 for more about arrays.

4.2.4. Field Selection

If an expression yields a value of a composite type (row type), then a specific field of the row can be extracted by writing

```
expression.fieldname
```

In general the row *expression* must be parenthesized, but the parentheses can be omitted when the expression to be selected from is just a table reference or positional parameter. For example:

```
mytable.mycolumn  
$1.somecolumn  
(rowfunction(a,b)).col3
```

(Thus, a qualified column reference is actually just a special case of the field selection syntax.) An important special case is extracting a field from a table column that is of a composite type:

```
(compositemcol).somefield  
(mytable.compositemcol).somefield
```

The parentheses are required here to show that *compositemcol* is a column name not a table name, or that *mytable* is a table name not a schema name in the second case.

You can ask for all fields of a composite value by writing *.**:

```
(compositemcol).*
```

This notation behaves differently depending on context; see Section 8.16.5 for details.

4.2.5. Operator Invocations

There are three possible syntaxes for an operator invocation:

```
expression operator expression (binary infix operator)  
operator expression (unary prefix operator)
```

expression operator (unary postfix operator)

where the *operator* token follows the syntax rules of Section 4.1.3, or is one of the key words AND, OR, and NOT, or is a qualified operator name in the form:

```
OPERATOR(schema.operatorname)
```

Which particular operators exist and whether they are unary or binary depends on what operators have been defined by the system or the user. Chapter 9 describes the built-in operators.

4.2.6. Function Calls

The syntax for a function call is the name of a function (possibly qualified with a schema name), followed by its argument list enclosed in parentheses:

```
function_name ([expression [, expression ... ] ] )
```

For example, the following computes the square root of 2:

```
sqrt(2)
```

The list of built-in functions is in Chapter 9. Other functions can be added by the user.

When issuing queries in a database where some users mistrust other users, observe security precautions from Section 10.3 when writing function calls.

The arguments can optionally have names attached. See Section 4.3 for details.

Note

A function that takes a single argument of composite type can optionally be called using field-selection syntax, and conversely field selection can be written in functional style. That is, the notations `col(table)` and `table.col` are interchangeable. This behavior is not SQL-standard but is provided in PostgreSQL because it allows use of functions to emulate “computed fields”. For more information see Section 8.16.5.

4.2.7. Aggregate Expressions

An *aggregate expression* represents the application of an aggregate function across the rows selected by a query. An aggregate function reduces multiple inputs to a single output value, such as the sum or average of the inputs. The syntax of an aggregate expression is one of the following:

```
aggregate_name (expression [ , ... ] [ order_by_clause ] ) [ FILTER  
  ( WHERE filter_clause ) ]  
aggregate_name (ALL expression [ , ... ] [ order_by_clause ] )  
  [ FILTER ( WHERE filter_clause ) ]  
aggregate_name (DISTINCT expression [ , ... ] [ order_by_clause ] )  
  [ FILTER ( WHERE filter_clause ) ]  
aggregate_name ( * ) [ FILTER ( WHERE filter_clause ) ]  
aggregate_name ( [ expression [ , ... ] ] ) WITHIN GROUP  
  ( order_by_clause ) [ FILTER ( WHERE filter_clause ) ]
```

where *aggregate_name* is a previously defined aggregate (possibly qualified with a schema name) and *expression* is any value expression that does not itself contain an aggregate expression or

a window function call. The optional *order_by_clause* and *filter_clause* are described below.

The first form of aggregate expression invokes the aggregate once for each input row. The second form is the same as the first, since ALL is the default. The third form invokes the aggregate once for each distinct value of the expression (or distinct set of values, for multiple expressions) found in the input rows. The fourth form invokes the aggregate once for each input row; since no particular input value is specified, it is generally only useful for the `count (*)` aggregate function. The last form is used with *ordered-set* aggregate functions, which are described below.

Most aggregate functions ignore null inputs, so that rows in which one or more of the expression(s) yield null are discarded. This can be assumed to be true, unless otherwise specified, for all built-in aggregates.

For example, `count (*)` yields the total number of input rows; `count (f1)` yields the number of input rows in which `f1` is non-null, since `count` ignores nulls; and `count (distinct f1)` yields the number of distinct non-null values of `f1`.

Ordinarily, the input rows are fed to the aggregate function in an unspecified order. In many cases this does not matter; for example, `min` produces the same result no matter what order it receives the inputs in. However, some aggregate functions (such as `array_agg` and `string_agg`) produce results that depend on the ordering of the input rows. When using such an aggregate, the optional *order_by_clause* can be used to specify the desired ordering. The *order_by_clause* has the same syntax as for a query-level ORDER BY clause, as described in Section 7.5, except that its expressions are always just expressions and cannot be output-column names or numbers. For example:

```
SELECT array_agg(a ORDER BY b DESC) FROM table;
```

When dealing with multiple-argument aggregate functions, note that the ORDER BY clause goes after all the aggregate arguments. For example, write this:

```
SELECT string_agg(a, ',' ORDER BY a) FROM table;
```

not this:

```
SELECT string_agg(a ORDER BY a, ',') FROM table; -- incorrect
```

The latter is syntactically valid, but it represents a call of a single-argument aggregate function with two ORDER BY keys (the second one being rather useless since it's a constant).

If DISTINCT is specified in addition to an *order_by_clause*, then all the ORDER BY expressions must match regular arguments of the aggregate; that is, you cannot sort on an expression that is not included in the DISTINCT list.

Note

The ability to specify both DISTINCT and ORDER BY in an aggregate function is a PostgreSQL extension.

Placing ORDER BY within the aggregate's regular argument list, as described so far, is used when ordering the input rows for general-purpose and statistical aggregates, for which ordering is optional. There is a subclass of aggregate functions called *ordered-set aggregates* for which an *order_by_clause* is *required*, usually because the aggregate's computation is only sensible in terms of a specific ordering of its input rows. Typical examples of ordered-set aggregates include rank and percentile calculations. For an ordered-set aggregate, the *order_by_clause* is written inside

`WITHIN GROUP (...)`, as shown in the final syntax alternative above. The expressions in the *order_by_clause* are evaluated once per input row just like regular aggregate arguments, sorted as per the *order_by_clause*'s requirements, and fed to the aggregate function as input arguments. (This is unlike the case for a non-`WITHIN GROUP order_by_clause`, which is not treated as argument(s) to the aggregate function.) The argument expressions preceding `WITHIN GROUP`, if any, are called *direct arguments* to distinguish them from the *aggregated arguments* listed in the *order_by_clause*. Unlike regular aggregate arguments, direct arguments are evaluated only once per aggregate call, not once per input row. This means that they can contain variables only if those variables are grouped by `GROUP BY`; this restriction is the same as if the direct arguments were not inside an aggregate expression at all. Direct arguments are typically used for things like percentile fractions, which only make sense as a single value per aggregation calculation. The direct argument list can be empty; in this case, write just `()` not `(*)`. (PostgreSQL will actually accept either spelling, but only the first way conforms to the SQL standard.)

An example of an ordered-set aggregate call is:

```
SELECT percentile_cont(0.5) WITHIN GROUP (ORDER BY income) FROM
households;
percentile_cont
-----
                50489
```

which obtains the 50th percentile, or median, value of the `income` column from table `households`. Here, `0.5` is a direct argument; it would make no sense for the percentile fraction to be a value varying across rows.

If `FILTER` is specified, then only the input rows for which the *filter_clause* evaluates to true are fed to the aggregate function; other rows are discarded. For example:

```
SELECT
    count(*) AS unfiltered,
    count(*) FILTER (WHERE i < 5) AS filtered
FROM generate_series(1,10) AS s(i);
unfiltered | filtered
-----+-----
                10 |          4
(1 row)
```

The predefined aggregate functions are described in Section 9.20. Other aggregate functions can be added by the user.

An aggregate expression can only appear in the result list or `HAVING` clause of a `SELECT` command. It is forbidden in other clauses, such as `WHERE`, because those clauses are logically evaluated before the results of aggregates are formed.

When an aggregate expression appears in a subquery (see Section 4.2.11 and Section 9.22), the aggregate is normally evaluated over the rows of the subquery. But an exception occurs if the aggregate's arguments (and *filter_clause* if any) contain only outer-level variables: the aggregate then belongs to the nearest such outer level, and is evaluated over the rows of that query. The aggregate expression as a whole is then an outer reference for the subquery it appears in, and acts as a constant over any one evaluation of that subquery. The restriction about appearing only in the result list or `HAVING` clause applies with respect to the query level that the aggregate belongs to.

4.2.8. Window Function Calls

A *window function call* represents the application of an aggregate-like function over some portion of the rows selected by a query. Unlike non-window aggregate calls, this is not tied to grouping of the

selected rows into a single output row — each row remains separate in the query output. However the window function has access to all the rows that would be part of the current row's group according to the grouping specification (`PARTITION BY` list) of the window function call. The syntax of a window function call is one of the following:

```
function_name ([expression [, expression ... ]]) [ FILTER
  ( WHERE filter_clause ) ] OVER window_name
function_name ([expression [, expression ... ]]) [ FILTER
  ( WHERE filter_clause ) ] OVER ( window_definition )
function_name ( * ) [ FILTER ( WHERE filter_clause ) ]
  OVER window_name
function_name ( * ) [ FILTER ( WHERE filter_clause ) ] OVER
  ( window_definition )
```

where *window_definition* has the syntax

```
[ existing_window_name ]
[ PARTITION BY expression [, ...] ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
  { FIRST | LAST } ] [, ...] ]
[ frame_clause ]
```

The optional *frame_clause* can be one of

```
{ RANGE | ROWS | GROUPS } frame_start [ frame_exclusion ]
{ RANGE | ROWS | GROUPS } BETWEEN frame_start AND frame_end
[ frame_exclusion ]
```

where *frame_start* and *frame_end* can be one of

```
UNBOUNDED PRECEDING
offset PRECEDING
CURRENT ROW
offset FOLLOWING
UNBOUNDED FOLLOWING
```

and *frame_exclusion* can be one of

```
EXCLUDE CURRENT ROW
EXCLUDE GROUP
EXCLUDE TIES
EXCLUDE NO OTHERS
```

Here, *expression* represents any value expression that does not itself contain window function calls.

window_name is a reference to a named window specification defined in the query's `WINDOW` clause. Alternatively, a full *window_definition* can be given within parentheses, using the same syntax as for defining a named window in the `WINDOW` clause; see the `SELECT` reference page for details. It's worth pointing out that `OVER wname` is not exactly equivalent to `OVER (wname ...)`; the latter implies copying and modifying the window definition, and will be rejected if the referenced window specification includes a frame clause.

The `PARTITION BY` clause groups the rows of the query into *partitions*, which are processed separately by the window function. `PARTITION BY` works similarly to a query-level `GROUP BY` clause,

except that its expressions are always just expressions and cannot be output-column names or numbers. Without `PARTITION BY`, all rows produced by the query are treated as a single partition. The `ORDER BY` clause determines the order in which the rows of a partition are processed by the window function. It works similarly to a query-level `ORDER BY` clause, but likewise cannot use output-column names or numbers. Without `ORDER BY`, rows are processed in an unspecified order.

The *frame_clause* specifies the set of rows constituting the *window frame*, which is a subset of the current partition, for those window functions that act on the frame instead of the whole partition. The set of rows in the frame can vary depending on which row is the current row. The frame can be specified in `RANGE`, `ROWS` or `GROUPS` mode; in each case, it runs from the *frame_start* to the *frame_end*. If *frame_end* is omitted, the end defaults to `CURRENT ROW`.

A *frame_start* of `UNBOUNDED PRECEDING` means that the frame starts with the first row of the partition, and similarly a *frame_end* of `UNBOUNDED FOLLOWING` means that the frame ends with the last row of the partition.

In `RANGE` or `GROUPS` mode, a *frame_start* of `CURRENT ROW` means the frame starts with the current row's first *peer* row (a row that the window's `ORDER BY` clause sorts as equivalent to the current row), while a *frame_end* of `CURRENT ROW` means the frame ends with the current row's last peer row. In `ROWS` mode, `CURRENT ROW` simply means the current row.

In the *offset PRECEDING* and *offset FOLLOWING* frame options, the *offset* must be an expression not containing any variables, aggregate functions, or window functions. The meaning of the *offset* depends on the frame mode:

- In `ROWS` mode, the *offset* must yield a non-null, non-negative integer, and the option means that the frame starts or ends the specified number of rows before or after the current row.
- In `GROUPS` mode, the *offset* again must yield a non-null, non-negative integer, and the option means that the frame starts or ends the specified number of *peer groups* before or after the current row's peer group, where a peer group is a set of rows that are equivalent in the `ORDER BY` ordering. (There must be an `ORDER BY` clause in the window definition to use `GROUPS` mode.)
- In `RANGE` mode, these options require that the `ORDER BY` clause specify exactly one column. The *offset* specifies the maximum difference between the value of that column in the current row and its value in preceding or following rows of the frame. The data type of the *offset* expression varies depending on the data type of the ordering column. For numeric ordering columns it is typically of the same type as the ordering column, but for datetime ordering columns it is an `interval`. For example, if the ordering column is of type `date` or `timestamp`, one could write `RANGE BETWEEN '1 day' PRECEDING AND '10 days' FOLLOWING`. The *offset* is still required to be non-null and non-negative, though the meaning of “non-negative” depends on its data type.

In any case, the distance to the end of the frame is limited by the distance to the end of the partition, so that for rows near the partition ends the frame might contain fewer rows than elsewhere.

Notice that in both `ROWS` and `GROUPS` mode, `0 PRECEDING` and `0 FOLLOWING` are equivalent to `CURRENT ROW`. This normally holds in `RANGE` mode as well, for an appropriate data-type-specific meaning of “zero”.

The *frame_exclusion* option allows rows around the current row to be excluded from the frame, even if they would be included according to the frame start and frame end options. `EXCLUDE CURRENT ROW` excludes the current row from the frame. `EXCLUDE GROUP` excludes the current row and its ordering peers from the frame. `EXCLUDE TIES` excludes any peers of the current row from the frame, but not the current row itself. `EXCLUDE NO OTHERS` simply specifies explicitly the default behavior of not excluding the current row or its peers.

The default framing option is `RANGE UNBOUNDED PRECEDING`, which is the same as `RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW`. With `ORDER BY`, this sets the frame to be all rows from the partition start up through the current row's last `ORDER BY` peer. Without

`ORDER BY`, this means all rows of the partition are included in the window frame, since all rows become peers of the current row.

Restrictions are that *frame_start* cannot be `UNBOUNDED FOLLOWING`, *frame_end* cannot be `UNBOUNDED PRECEDING`, and the *frame_end* choice cannot appear earlier in the above list of *frame_start* and *frame_end* options than the *frame_start* choice does — for example `RANGE BETWEEN CURRENT ROW AND offset PRECEDING` is not allowed. But, for example, `ROWS BETWEEN 7 PRECEDING AND 8 PRECEDING` is allowed, even though it would never select any rows.

If `FILTER` is specified, then only the input rows for which the *filter_clause* evaluates to true are fed to the window function; other rows are discarded. Only window functions that are aggregates accept a `FILTER` clause.

The built-in window functions are described in Table 9.60. Other window functions can be added by the user. Also, any built-in or user-defined general-purpose or statistical aggregate can be used as a window function. (Ordered-set and hypothetical-set aggregates cannot presently be used as window functions.)

The syntaxes using `*` are used for calling parameter-less aggregate functions as window functions, for example `count(*) OVER (PARTITION BY x ORDER BY y)`. The asterisk (`*`) is customarily not used for window-specific functions. Window-specific functions do not allow `DISTINCT` or `ORDER BY` to be used within the function argument list.

Window function calls are permitted only in the `SELECT` list and the `ORDER BY` clause of the query.

More information about window functions can be found in Section 3.5, Section 9.21, and Section 7.2.5.

4.2.9. Type Casts

A type cast specifies a conversion from one data type to another. PostgreSQL accepts two equivalent syntaxes for type casts:

```
CAST ( expression AS type )
expression::type
```

The `CAST` syntax conforms to SQL; the syntax with `::` is historical PostgreSQL usage.

When a cast is applied to a value expression of a known type, it represents a run-time type conversion. The cast will succeed only if a suitable type conversion operation has been defined. Notice that this is subtly different from the use of casts with constants, as shown in Section 4.1.2.7. A cast applied to an unadorned string literal represents the initial assignment of a type to a literal constant value, and so it will succeed for any type (if the contents of the string literal are acceptable input syntax for the data type).

An explicit type cast can usually be omitted if there is no ambiguity as to the type that a value expression must produce (for example, when it is assigned to a table column); the system will automatically apply a type cast in such cases. However, automatic casting is only done for casts that are marked “OK to apply implicitly” in the system catalogs. Other casts must be invoked with explicit casting syntax. This restriction is intended to prevent surprising conversions from being applied silently.

It is also possible to specify a type cast using a function-like syntax:

```
typename ( expression )
```

However, this only works for types whose names are also valid as function names. For example, `double precision` cannot be used this way, but the equivalent `float8` can. Also, the names `in-`

`interval`, `time`, and `timestamp` can only be used in this fashion if they are double-quoted, because of syntactic conflicts. Therefore, the use of the function-like cast syntax leads to inconsistencies and should probably be avoided.

Note

The function-like syntax is in fact just a function call. When one of the two standard cast syntaxes is used to do a run-time conversion, it will internally invoke a registered function to perform the conversion. By convention, these conversion functions have the same name as their output type, and thus the “function-like syntax” is nothing more than a direct invocation of the underlying conversion function. Obviously, this is not something that a portable application should rely on. For further details see `CREATE CAST`.

4.2.10. Collation Expressions

The `COLLATE` clause overrides the collation of an expression. It is appended to the expression it applies to:

```
expr COLLATE collation
```

where *collation* is a possibly schema-qualified identifier. The `COLLATE` clause binds tighter than operators; parentheses can be used when necessary.

If no collation is explicitly specified, the database system either derives a collation from the columns involved in the expression, or it defaults to the default collation of the database if no column is involved in the expression.

The two common uses of the `COLLATE` clause are overriding the sort order in an `ORDER BY` clause, for example:

```
SELECT a, b, c FROM tbl WHERE ... ORDER BY a COLLATE "C";
```

and overriding the collation of a function or operator call that has locale-sensitive results, for example:

```
SELECT * FROM tbl WHERE a > 'foo' COLLATE "C";
```

Note that in the latter case the `COLLATE` clause is attached to an input argument of the operator we wish to affect. It doesn't matter which argument of the operator or function call the `COLLATE` clause is attached to, because the collation that is applied by the operator or function is derived by considering all arguments, and an explicit `COLLATE` clause will override the collations of all other arguments. (Attaching non-matching `COLLATE` clauses to more than one argument, however, is an error. For more details see Section 23.2.) Thus, this gives the same result as the previous example:

```
SELECT * FROM tbl WHERE a COLLATE "C" > 'foo';
```

But this is an error:

```
SELECT * FROM tbl WHERE (a > 'foo') COLLATE "C";
```

because it attempts to apply a collation to the result of the `>` operator, which is of the non-collatable data type `boolean`.

4.2.11. Scalar Subqueries

A scalar subquery is an ordinary `SELECT` query in parentheses that returns exactly one row with one column. (See Chapter 7 for information about writing queries.) The `SELECT` query is executed and the single returned value is used in the surrounding value expression. It is an error to use a query that returns more than one row or more than one column as a scalar subquery. (But if, during a particular execution, the subquery returns no rows, there is no error; the scalar result is taken to be null.) The subquery can refer to variables from the surrounding query, which will act as constants during any one evaluation of the subquery. See also Section 9.22 for other expressions involving subqueries.

For example, the following finds the largest city population in each state:

```
SELECT name, (SELECT max(pop) FROM cities WHERE cities.state =
             states.name)
           FROM states;
```

4.2.12. Array Constructors

An array constructor is an expression that builds an array value using values for its member elements. A simple array constructor consists of the key word `ARRAY`, a left square bracket `[`, a list of expressions (separated by commas) for the array element values, and finally a right square bracket `]`. For example:

```
SELECT ARRAY[1,2,3+4];
       array
-----
   {1,2,7}
(1 row)
```

By default, the array element type is the common type of the member expressions, determined using the same rules as for `UNION` or `CASE` constructs (see Section 10.5). You can override this by explicitly casting the array constructor to the desired type, for example:

```
SELECT ARRAY[1,2,22.7]::integer[];
       array
-----
   {1,2,23}
(1 row)
```

This has the same effect as casting each expression to the array element type individually. For more on casting, see Section 4.2.9.

Multidimensional array values can be built by nesting array constructors. In the inner constructors, the key word `ARRAY` can be omitted. For example, these produce the same result:

```
SELECT ARRAY[ARRAY[1,2], ARRAY[3,4]];
       array
-----
   {{1,2},{3,4}}
(1 row)

SELECT ARRAY[[1,2],[3,4]];
       array
-----
   {{1,2},{3,4}}
(1 row)
```

Since multidimensional arrays must be rectangular, inner constructors at the same level must produce sub-arrays of identical dimensions. Any cast applied to the outer ARRAY constructor propagates automatically to all the inner constructors.

Multidimensional array constructor elements can be anything yielding an array of the proper kind, not only a sub-ARRAY construct. For example:

```
CREATE TABLE arr(f1 int[], f2 int[]);

INSERT INTO arr VALUES (ARRAY[[1,2],[3,4]], ARRAY[[5,6],[7,8]]);

SELECT ARRAY[f1, f2, '{{9,10},{11,12}}'::int[]] FROM arr;
          array
-----
{{ {1,2},{3,4}},{ {5,6},{7,8}},{ {9,10},{11,12} }}
(1 row)
```

You can construct an empty array, but since it's impossible to have an array with no type, you must explicitly cast your empty array to the desired type. For example:

```
SELECT ARRAY[]::integer[];
          array
-----
{}
(1 row)
```

It is also possible to construct an array from the results of a subquery. In this form, the array constructor is written with the key word ARRAY followed by a parenthesized (not bracketed) subquery. For example:

```
SELECT ARRAY(SELECT oid FROM pg_proc WHERE proname LIKE 'bytea%');
          array
-----
{2011,1954,1948,1952,1951,1244,1950,2005,1949,1953,2006,31,2412,2413}
(1 row)

SELECT ARRAY(SELECT ARRAY[i, i*2] FROM generate_series(1,5) AS
a(i));
          array
-----
{{1,2},{2,4},{3,6},{4,8},{5,10}}
(1 row)
```

The subquery must return a single column. If the subquery's output column is of a non-array type, the resulting one-dimensional array will have an element for each row in the subquery result, with an element type matching that of the subquery's output column. If the subquery's output column is of an array type, the result will be an array of the same type but one higher dimension; in this case all the subquery rows must yield arrays of identical dimensionality, else the result would not be rectangular.

The subscripts of an array value built with ARRAY always begin with one. For more information about arrays, see Section 8.15.

4.2.13. Row Constructors

A row constructor is an expression that builds a row value (also called a composite value) using values for its member fields. A row constructor consists of the key word ROW, a left parenthesis, zero or

more expressions (separated by commas) for the row field values, and finally a right parenthesis. For example:

```
SELECT ROW(1,2.5,'this is a test');
```

The key word ROW is optional when there is more than one expression in the list.

A row constructor can include the syntax *rowvalue.**, which will be expanded to a list of the elements of the row value, just as occurs when the *.** syntax is used at the top level of a SELECT list (see Section 8.16.5). For example, if table *t* has columns *f1* and *f2*, these are the same:

```
SELECT ROW(t.*, 42) FROM t;
SELECT ROW(t.f1, t.f2, 42) FROM t;
```

Note

Before PostgreSQL 8.2, the *.** syntax was not expanded in row constructors, so that writing `ROW(t.*, 42)` created a two-field row whose first field was another row value. The new behavior is usually more useful. If you need the old behavior of nested row values, write the inner row value without *.**, for instance `ROW(t, 42)`.

By default, the value created by a ROW expression is of an anonymous record type. If necessary, it can be cast to a named composite type — either the row type of a table, or a composite type created with `CREATE TYPE AS`. An explicit cast might be needed to avoid ambiguity. For example:

```
CREATE TABLE mytable(f1 int, f2 float, f3 text);

CREATE FUNCTION getf1(mytable) RETURNS int AS 'SELECT $1.f1'
LANGUAGE SQL;

-- No cast needed since only one getf1() exists
SELECT getf1(ROW(1,2.5,'this is a test'));
getf1
-----
      1
(1 row)

CREATE TYPE myrowtype AS (f1 int, f2 text, f3 numeric);

CREATE FUNCTION getf1(myrowtype) RETURNS int AS 'SELECT $1.f1'
LANGUAGE SQL;

-- Now we need a cast to indicate which function to call:
SELECT getf1(ROW(1,2.5,'this is a test'));
ERROR:  function getf1(record) is not unique

SELECT getf1(ROW(1,2.5,'this is a test')::mytable);
getf1
-----
      1
(1 row)

SELECT getf1(CAST(ROW(11,'this is a test',2.5) AS myrowtype));
getf1
```

```
-----  
      11  
(1 row)
```

Row constructors can be used to build composite values to be stored in a composite-type table column, or to be passed to a function that accepts a composite parameter. Also, it is possible to compare two row values or test a row with `IS NULL` or `IS NOT NULL`, for example:

```
SELECT ROW(1,2.5,'this is a test') = ROW(1, 3, 'not the same');  
  
SELECT ROW(table.*) IS NULL FROM table; -- detect all-null rows
```

For more detail see Section 9.23. Row constructors can also be used in connection with subqueries, as discussed in Section 9.22.

4.2.14. Expression Evaluation Rules

The order of evaluation of subexpressions is not defined. In particular, the inputs of an operator or function are not necessarily evaluated left-to-right or in any other fixed order.

Furthermore, if the result of an expression can be determined by evaluating only some parts of it, then other subexpressions might not be evaluated at all. For instance, if one wrote:

```
SELECT true OR somefunc();
```

then `somefunc()` would (probably) not be called at all. The same would be the case if one wrote:

```
SELECT somefunc() OR true;
```

Note that this is not the same as the left-to-right “short-circuiting” of Boolean operators that is found in some programming languages.

As a consequence, it is unwise to use functions with side effects as part of complex expressions. It is particularly dangerous to rely on side effects or evaluation order in `WHERE` and `HAVING` clauses, since those clauses are extensively reprocessed as part of developing an execution plan. Boolean expressions (`AND/OR/NOT` combinations) in those clauses can be reorganized in any manner allowed by the laws of Boolean algebra.

When it is essential to force evaluation order, a `CASE` construct (see Section 9.17) can be used. For example, this is an untrustworthy way of trying to avoid division by zero in a `WHERE` clause:

```
SELECT ... WHERE x > 0 AND y/x > 1.5;
```

But this is safe:

```
SELECT ... WHERE CASE WHEN x > 0 THEN y/x > 1.5 ELSE false END;
```

A `CASE` construct used in this fashion will defeat optimization attempts, so it should only be done when necessary. (In this particular example, it would be better to sidestep the problem by writing `y > 1.5*x` instead.)

`CASE` is not a cure-all for such issues, however. One limitation of the technique illustrated above is that it does not prevent early evaluation of constant subexpressions. As described in Section 37.7, functions and operators marked `IMMUTABLE` can be evaluated when the query is planned rather than when it is executed. Thus for example

```
SELECT CASE WHEN x > 0 THEN x ELSE 1/0 END FROM tab;
```

is likely to result in a division-by-zero failure due to the planner trying to simplify the constant subexpression, even if every row in the table has $x > 0$ so that the `ELSE` arm would never be entered at run time.

While that particular example might seem silly, related cases that don't obviously involve constants can occur in queries executed within functions, since the values of function arguments and local variables can be inserted into queries as constants for planning purposes. Within PL/pgSQL functions, for example, using an `IF-THEN-ELSE` statement to protect a risky computation is much safer than just nesting it in a `CASE` expression.

Another limitation of the same kind is that a `CASE` cannot prevent evaluation of an aggregate expression contained within it, because aggregate expressions are computed before other expressions in a `SELECT` list or `HAVING` clause are considered. For example, the following query can cause a division-by-zero error despite seemingly having protected against it:

```
SELECT CASE WHEN min(employees) > 0
           THEN avg(expenses / employees)
           END
FROM departments;
```

The `min()` and `avg()` aggregates are computed concurrently over all the input rows, so if any row has `employees` equal to zero, the division-by-zero error will occur before there is any opportunity to test the result of `min()`. Instead, use a `WHERE` or `FILTER` clause to prevent problematic input rows from reaching an aggregate function in the first place.

4.3. Calling Functions

PostgreSQL allows functions that have named parameters to be called using either *positional* or *named* notation. Named notation is especially useful for functions that have a large number of parameters, since it makes the associations between parameters and actual arguments more explicit and reliable. In positional notation, a function call is written with its argument values in the same order as they are defined in the function declaration. In named notation, the arguments are matched to the function parameters by name and can be written in any order. For each notation, also consider the effect of function argument types, documented in Section 10.3.

In either notation, parameters that have default values given in the function declaration need not be written in the call at all. But this is particularly useful in named notation, since any combination of parameters can be omitted; while in positional notation parameters can only be omitted from right to left.

PostgreSQL also supports *mixed* notation, which combines positional and named notation. In this case, positional parameters are written first and named parameters appear after them.

The following examples will illustrate the usage of all three notations, using the following function definition:

```
CREATE FUNCTION concat_lower_or_upper(a text, b text, uppercase
    boolean DEFAULT false)
RETURNS text
AS
$$
SELECT CASE
    WHEN $3 THEN UPPER($1 || ' ' || $2)
    ELSE LOWER($1 || ' ' || $2)
```

```
        END;  
$$  
LANGUAGE SQL IMMUTABLE STRICT;
```

Function `concat_lower_or_upper` has two mandatory parameters, `a` and `b`. Additionally there is one optional parameter `uppercase` which defaults to `false`. The `a` and `b` inputs will be concatenated, and forced to either upper or lower case depending on the `uppercase` parameter. The remaining details of this function definition are not important here (see Chapter 37 for more information).

4.3.1. Using Positional Notation

Positional notation is the traditional mechanism for passing arguments to functions in PostgreSQL. An example is:

```
SELECT concat_lower_or_upper('Hello', 'World', true);  
   concat_lower_or_upper  
-----  
   HELLO WORLD  
(1 row)
```

All arguments are specified in order. The result is upper case since `uppercase` is specified as `true`. Another example is:

```
SELECT concat_lower_or_upper('Hello', 'World');  
   concat_lower_or_upper  
-----  
   hello world  
(1 row)
```

Here, the `uppercase` parameter is omitted, so it receives its default value of `false`, resulting in lower case output. In positional notation, arguments can be omitted from right to left so long as they have defaults.

4.3.2. Using Named Notation

In named notation, each argument's name is specified using `=>` to separate it from the argument expression. For example:

```
SELECT concat_lower_or_upper(a => 'Hello', b => 'World');  
   concat_lower_or_upper  
-----  
   hello world  
(1 row)
```

Again, the argument `uppercase` was omitted so it is set to `false` implicitly. One advantage of using named notation is that the arguments may be specified in any order, for example:

```
SELECT concat_lower_or_upper(a => 'Hello', b => 'World', uppercase  
=> true);  
   concat_lower_or_upper  
-----  
   HELLO WORLD  
(1 row)
```

```
SELECT concat_lower_or_upper(a => 'Hello', uppercase => true, b =>
    'World');
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

An older syntax based on "!=" is supported for backward compatibility:

```
SELECT concat_lower_or_upper(a != 'Hello', uppercase != true, b !=
    'World');
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

4.3.3. Using Mixed Notation

The mixed notation combines positional and named notation. However, as already mentioned, named arguments cannot precede positional arguments. For example:

```
SELECT concat_lower_or_upper('Hello', 'World', uppercase => true);
concat_lower_or_upper
-----
HELLO WORLD
(1 row)
```

In the above query, the arguments `a` and `b` are specified positionally, while `uppercase` is specified by name. In this example, that adds little except documentation. With a more complex function having numerous parameters that have default values, named or mixed notation can save a great deal of writing and reduce chances for error.

Note

Named and mixed call notations currently cannot be used when calling an aggregate function (but they do work when an aggregate function is used as a window function).

Chapter 5. Data Definition

This chapter covers how one creates the database structures that will hold one's data. In a relational database, the raw data is stored in tables, so the majority of this chapter is devoted to explaining how tables are created and modified and what features are available to control what data is stored in the tables. Subsequently, we discuss how tables can be organized into schemas, and how privileges can be assigned to tables. Finally, we will briefly look at other features that affect the data storage, such as inheritance, table partitioning, views, functions, and triggers.

5.1. Table Basics

A table in a relational database is much like a table on paper: It consists of rows and columns. The number and order of the columns is fixed, and each column has a name. The number of rows is variable — it reflects how much data is stored at a given moment. SQL does not make any guarantees about the order of the rows in a table. When a table is read, the rows will appear in an unspecified order, unless sorting is explicitly requested. This is covered in Chapter 7. Furthermore, SQL does not assign unique identifiers to rows, so it is possible to have several completely identical rows in a table. This is a consequence of the mathematical model that underlies SQL but is usually not desirable. Later in this chapter we will see how to deal with this issue.

Each column has a data type. The data type constrains the set of possible values that can be assigned to a column and assigns semantics to the data stored in the column so that it can be used for computations. For instance, a column declared to be of a numerical type will not accept arbitrary text strings, and the data stored in such a column can be used for mathematical computations. By contrast, a column declared to be of a character string type will accept almost any kind of data but it does not lend itself to mathematical calculations, although other operations such as string concatenation are available.

PostgreSQL includes a sizable set of built-in data types that fit many applications. Users can also define their own data types. Most built-in data types have obvious names and semantics, so we defer a detailed explanation to Chapter 8. Some of the frequently used data types are `integer` for whole numbers, `numeric` for possibly fractional numbers, `text` for character strings, `date` for dates, `time` for time-of-day values, and `timestamp` for values containing both date and time.

To create a table, you use the aptly named `CREATE TABLE` command. In this command you specify at least a name for the new table, the names of the columns and the data type of each column. For example:

```
CREATE TABLE my_first_table (  
    first_column text,  
    second_column integer  
);
```

This creates a table named `my_first_table` with two columns. The first column is named `first_column` and has a data type of `text`; the second column has the name `second_column` and the type `integer`. The table and column names follow the identifier syntax explained in Section 4.1.1. The type names are usually also identifiers, but there are some exceptions. Note that the column list is comma-separated and surrounded by parentheses.

Of course, the previous example was heavily contrived. Normally, you would give names to your tables and columns that convey what kind of data they store. So let's look at a more realistic example:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric
```

);

(The numeric type can store fractional components, as would be typical of monetary amounts.)

Tip

When you create many interrelated tables it is wise to choose a consistent naming pattern for the tables and columns. For instance, there is a choice of using singular or plural nouns for table names, both of which are favored by some theorist or other.

There is a limit on how many columns a table can contain. Depending on the column types, it is between 250 and 1600. However, defining a table with anywhere near this many columns is highly unusual and often a questionable design.

If you no longer need a table, you can remove it using the DROP TABLE command. For example:

```
DROP TABLE my_first_table;
DROP TABLE products;
```

Attempting to drop a table that does not exist is an error. Nevertheless, it is common in SQL script files to unconditionally try to drop each table before creating it, ignoring any error messages, so that the script works whether or not the table exists. (If you like, you can use the DROP TABLE IF EXISTS variant to avoid the error messages, but this is not standard SQL.)

If you need to modify a table that already exists, see Section 5.6 later in this chapter.

With the tools discussed so far you can create fully functional tables. The remainder of this chapter is concerned with adding features to the table definition to ensure data integrity, security, or convenience. If you are eager to fill your tables with data now you can skip ahead to Chapter 6 and read the rest of this chapter later.

5.2. Default Values

A column can be assigned a default value. When a new row is created and no values are specified for some of the columns, those columns will be filled with their respective default values. A data manipulation command can also request explicitly that a column be set to its default value, without having to know what that value is. (Details about data manipulation commands are in Chapter 6.)

If no default value is declared explicitly, the default value is the null value. This usually makes sense because a null value can be considered to represent unknown data.

In a table definition, default values are listed after the column data type. For example:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric DEFAULT 9.99
);
```

The default value can be an expression, which will be evaluated whenever the default value is inserted (*not* when the table is created). A common example is for a timestamp column to have a default of CURRENT_TIMESTAMP, so that it gets set to the time of row insertion. Another common example is generating a “serial number” for each row. In PostgreSQL this is typically done by something like:

```
CREATE TABLE products (
    product_no integer DEFAULT nextval('products_product_no_seq'),
    ...
);
```

where the `nextval()` function supplies successive values from a *sequence object* (see Section 9.16). This arrangement is sufficiently common that there's a special shorthand for it:

```
CREATE TABLE products (
    product_no SERIAL,
    ...
);
```

The `SERIAL` shorthand is discussed further in Section 8.1.4.

5.3. Generated Columns

A generated column is a special column that is always computed from other columns. Thus, it is for columns what a view is for tables. There are two kinds of generated columns: stored and virtual. A stored generated column is computed when it is written (inserted or updated) and occupies storage as if it were a normal column. A virtual generated column occupies no storage and is computed when it is read. Thus, a virtual generated column is similar to a view and a stored generated column is similar to a materialized view (except that it is always updated automatically). PostgreSQL currently implements only stored generated columns.

To create a generated column, use the `GENERATED ALWAYS AS` clause in `CREATE TABLE`, for example:

```
CREATE TABLE people (
    ...
    height_cm numeric,
    height_in numeric GENERATED ALWAYS AS (height_cm / 2.54) STORED
);
```

The keyword `STORED` must be specified to choose the stored kind of generated column. See `CREATE TABLE` for more details.

A generated column cannot be written to directly. In `INSERT` or `UPDATE` commands, a value cannot be specified for a generated column, but the keyword `DEFAULT` may be specified.

Consider the differences between a column with a default and a generated column. The column default is evaluated once when the row is first inserted if no other value was provided; a generated column is updated whenever the row changes and cannot be overridden. A column default may not refer to other columns of the table; a generation expression would normally do so. A column default can use volatile functions, for example `random()` or functions referring to the current time; this is not allowed for generated columns.

Several restrictions apply to the definition of generated columns and tables involving generated columns:

- The generation expression can only use immutable functions and cannot use subqueries or reference anything other than the current row in any way.
- A generation expression cannot reference another generated column.
- A generation expression cannot reference a system column, except `tableoid`.
- A generated column cannot have a column default or an identity definition.

- A generated column cannot be part of a partition key.
- Foreign tables can have generated columns. See CREATE FOREIGN TABLE for details.

Additional considerations apply to the use of generated columns.

- Generated columns maintain access privileges separately from their underlying base columns. So, it is possible to arrange it so that a particular role can read from a generated column but not from the underlying base columns.
- Generated columns are, conceptually, updated after BEFORE triggers have run. Therefore, changes made to base columns in a BEFORE trigger will be reflected in generated columns. But conversely, it is not allowed to access generated columns in BEFORE triggers.

5.4. Constraints

Data types are a way to limit the kind of data that can be stored in a table. For many applications, however, the constraint they provide is too coarse. For example, a column containing a product price should probably only accept positive values. But there is no standard data type that accepts only positive numbers. Another issue is that you might want to constrain column data with respect to other columns or rows. For example, in a table containing product information, there should be only one row for each product number.

To that end, SQL allows you to define constraints on columns and tables. Constraints give you as much control over the data in your tables as you wish. If a user attempts to store data in a column that would violate a constraint, an error is raised. This applies even if the value came from the default value definition.

5.4.1. Check Constraints

A check constraint is the most generic constraint type. It allows you to specify that the value in a certain column must satisfy a Boolean (truth-value) expression. For instance, to require positive product prices, you could use:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CHECK (price > 0)  
);
```

As you see, the constraint definition comes after the data type, just like default value definitions. Default values and constraints can be listed in any order. A check constraint consists of the key word CHECK followed by an expression in parentheses. The check constraint expression should involve the column thus constrained, otherwise the constraint would not make too much sense.

You can also give the constraint a separate name. This clarifies error messages and allows you to refer to the constraint when you need to change it. The syntax is:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CONSTRAINT positive_price CHECK (price > 0)  
);
```

So, to specify a named constraint, use the key word CONSTRAINT followed by an identifier followed by the constraint definition. (If you don't specify a constraint name in this way, the system chooses a name for you.)

A check constraint can also refer to several columns. Say you store a regular price and a discounted price, and you want to ensure that the discounted price is lower than the regular price:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CHECK (price > 0),  
    discounted_price numeric CHECK (discounted_price > 0),  
    CHECK (price > discounted_price)  
);
```

The first two constraints should look familiar. The third one uses a new syntax. It is not attached to a particular column, instead it appears as a separate item in the comma-separated column list. Column definitions and these constraint definitions can be listed in mixed order.

We say that the first two constraints are column constraints, whereas the third one is a table constraint because it is written separately from any one column definition. Column constraints can also be written as table constraints, while the reverse is not necessarily possible, since a column constraint is supposed to refer to only the column it is attached to. (PostgreSQL doesn't enforce that rule, but you should follow it if you want your table definitions to work with other database systems.) The above example could also be written as:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric,  
    CHECK (price > 0),  
    discounted_price numeric,  
    CHECK (discounted_price > 0),  
    CHECK (price > discounted_price)  
);
```

or even:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric CHECK (price > 0),  
    discounted_price numeric,  
    CHECK (discounted_price > 0 AND price > discounted_price)  
);
```

It's a matter of taste.

Names can be assigned to table constraints in the same way as column constraints:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric,  
    CHECK (price > 0),  
    discounted_price numeric,  
    CHECK (discounted_price > 0),  
    CONSTRAINT valid_discount CHECK (price > discounted_price)  
);
```

It should be noted that a check constraint is satisfied if the check expression evaluates to true or the null value. Since most expressions will evaluate to the null value if any operand is null, they will not prevent null values in the constrained columns. To ensure that a column does not contain null values, the not-null constraint described in the next section can be used.

Note

PostgreSQL does not support CHECK constraints that reference table data other than the new or updated row being checked. While a CHECK constraint that violates this rule may appear to work in simple tests, it cannot guarantee that the database will not reach a state in which the constraint condition is false (due to subsequent changes of the other row(s) involved). This would cause a database dump and reload to fail. The reload could fail even when the complete database state is consistent with the constraint, due to rows not being loaded in an order that will satisfy the constraint. If possible, use UNIQUE, EXCLUDE, or FOREIGN KEY constraints to express cross-row and cross-table restrictions.

If what you desire is a one-time check against other rows at row insertion, rather than a continuously-maintained consistency guarantee, a custom trigger can be used to implement that. (This approach avoids the dump/reload problem because pg_dump does not reinstall triggers until after reloading data, so that the check will not be enforced during a dump/reload.)

Note

PostgreSQL assumes that CHECK constraints' conditions are immutable, that is, they will always give the same result for the same input row. This assumption is what justifies examining CHECK constraints only when rows are inserted or updated, and not at other times. (The warning above about not referencing other table data is really a special case of this restriction.)

An example of a common way to break this assumption is to reference a user-defined function in a CHECK expression, and then change the behavior of that function. PostgreSQL does not disallow that, but it will not notice if there are rows in the table that now violate the CHECK constraint. That would cause a subsequent database dump and reload to fail. The recommended way to handle such a change is to drop the constraint (using ALTER TABLE), adjust the function definition, and re-add the constraint, thereby rechecking it against all table rows.

5.4.2. Not-Null Constraints

A not-null constraint simply specifies that a column must not assume the null value. A syntax example:

```
CREATE TABLE products (  
    product_no integer NOT NULL,  
    name text NOT NULL,  
    price numeric  
);
```

A not-null constraint is always written as a column constraint. A not-null constraint is functionally equivalent to creating a check constraint CHECK (*column_name* IS NOT NULL), but in PostgreSQL creating an explicit not-null constraint is more efficient. The drawback is that you cannot give explicit names to not-null constraints created this way.

Of course, a column can have more than one constraint. Just write the constraints one after another:

```
CREATE TABLE products (  
    product_no integer NOT NULL,  
    name text NOT NULL,  
    price numeric NOT NULL CHECK (price > 0)  
);
```

The order doesn't matter. It does not necessarily determine in which order the constraints are checked.

The NOT NULL constraint has an inverse: the NULL constraint. This does not mean that the column must be null, which would surely be useless. Instead, this simply selects the default behavior that the column might be null. The NULL constraint is not present in the SQL standard and should not be used in portable applications. (It was only added to PostgreSQL to be compatible with some other database systems.) Some users, however, like it because it makes it easy to toggle the constraint in a script file. For example, you could start with:

```
CREATE TABLE products (  
    product_no integer NULL,  
    name text NULL,  
    price numeric NULL  
);
```

and then insert the NOT key word where desired.

Tip

In most database designs the majority of columns should be marked not null.

5.4.3. Unique Constraints

Unique constraints ensure that the data contained in a column, or a group of columns, is unique among all the rows in the table. The syntax is:

```
CREATE TABLE products (  
    product_no integer UNIQUE,  
    name text,  
    price numeric  
);
```

when written as a column constraint, and:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric,  
    UNIQUE (product_no)  
);
```

when written as a table constraint.

To define a unique constraint for a group of columns, write it as a table constraint with the column names separated by commas:

```
CREATE TABLE example (  
    a integer,  
    b integer,  
    c integer,  
    UNIQUE (a, c)  
);
```

This specifies that the combination of values in the indicated columns is unique across the whole table, though any one of the columns need not be (and ordinarily isn't) unique.

You can assign your own name for a unique constraint, in the usual way:

```
CREATE TABLE products (  
    product_no integer CONSTRAINT must_be_different UNIQUE,  
    name text,  
    price numeric  
);
```

Adding a unique constraint will automatically create a unique B-tree index on the column or group of columns listed in the constraint. A uniqueness restriction covering only some rows cannot be written as a unique constraint, but it is possible to enforce such a restriction by creating a unique partial index.

In general, a unique constraint is violated if there is more than one row in the table where the values of all of the columns included in the constraint are equal. However, two null values are never considered equal in this comparison. That means even in the presence of a unique constraint it is possible to store duplicate rows that contain a null value in at least one of the constrained columns. This behavior conforms to the SQL standard, but we have heard that other SQL databases might not follow this rule. So be careful when developing applications that are intended to be portable.

5.4.4. Primary Keys

A primary key constraint indicates that a column, or group of columns, can be used as a unique identifier for rows in the table. This requires that the values be both unique and not null. So, the following two table definitions accept the same data:

```
CREATE TABLE products (  
    product_no integer UNIQUE NOT NULL,  
    name text,  
    price numeric  
);
```

```
CREATE TABLE products (  
    product_no integer PRIMARY KEY,  
    name text,  
    price numeric  
);
```

Primary keys can span more than one column; the syntax is similar to unique constraints:

```
CREATE TABLE example (  
    a integer,  
    b integer,  
    c integer,
```

```
    PRIMARY KEY (a, c)
);
```

Adding a primary key will automatically create a unique B-tree index on the column or group of columns listed in the primary key, and will force the column(s) to be marked NOT NULL.

A table can have at most one primary key. (There can be any number of unique and not-null constraints, which are functionally almost the same thing, but only one can be identified as the primary key.) Relational database theory dictates that every table must have a primary key. This rule is not enforced by PostgreSQL, but it is usually best to follow it.

Primary keys are useful both for documentation purposes and for client applications. For example, a GUI application that allows modifying row values probably needs to know the primary key of a table to be able to identify rows uniquely. There are also various ways in which the database system makes use of a primary key if one has been declared; for example, the primary key defines the default target column(s) for foreign keys referencing its table.

5.4.5. Foreign Keys

A foreign key constraint specifies that the values in a column (or a group of columns) must match the values appearing in some row of another table. We say this maintains the *referential integrity* between two related tables.

Say you have the product table that we have used several times already:

```
CREATE TABLE products (
    product_no integer PRIMARY KEY,
    name text,
    price numeric
);
```

Let's also assume you have a table storing orders of those products. We want to ensure that the orders table only contains orders of products that actually exist. So we define a foreign key constraint in the orders table that references the products table:

```
CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    product_no integer REFERENCES products (product_no),
    quantity integer
);
```

Now it is impossible to create orders with non-NULL product_no entries that do not appear in the products table.

We say that in this situation the orders table is the *referencing* table and the products table is the *referenced* table. Similarly, there are referencing and referenced columns.

You can also shorten the above command to:

```
CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    product_no integer REFERENCES products,
    quantity integer
);
```

because in absence of a column list the primary key of the referenced table is used as the referenced column(s).

A foreign key can also constrain and reference a group of columns. As usual, it then needs to be written in table constraint form. Here is a contrived syntax example:

```
CREATE TABLE t1 (  
  a integer PRIMARY KEY,  
  b integer,  
  c integer,  
  FOREIGN KEY (b, c) REFERENCES other_table (c1, c2)  
);
```

Of course, the number and type of the constrained columns need to match the number and type of the referenced columns.

You can assign your own name for a foreign key constraint, in the usual way.

A table can have more than one foreign key constraint. This is used to implement many-to-many relationships between tables. Say you have tables about products and orders, but now you want to allow one order to contain possibly many products (which the structure above did not allow). You could use this table structure:

```
CREATE TABLE products (  
  product_no integer PRIMARY KEY,  
  name text,  
  price numeric  
);  
  
CREATE TABLE orders (  
  order_id integer PRIMARY KEY,  
  shipping_address text,  
  ...  
);  
  
CREATE TABLE order_items (  
  product_no integer REFERENCES products,  
  order_id integer REFERENCES orders,  
  quantity integer,  
  PRIMARY KEY (product_no, order_id)  
);
```

Notice that the primary key overlaps with the foreign keys in the last table.

We know that the foreign keys disallow creation of orders that do not relate to any products. But what if a product is removed after an order is created that references it? SQL allows you to handle that as well. Intuitively, we have a few options:

- Disallow deleting a referenced product
- Delete the orders as well
- Something else?

To illustrate this, let's implement the following policy on the many-to-many relationship example above: when someone wants to remove a product that is still referenced by an order (via `order_items`), we disallow it. If someone removes an order, the order items are removed as well:

```
CREATE TABLE products (  
  product_no integer PRIMARY KEY,  
  name text,
```

```
        price numeric
    );

CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    shipping_address text,
    ...
);

CREATE TABLE order_items (
    product_no integer REFERENCES products ON DELETE RESTRICT,
    order_id integer REFERENCES orders ON DELETE CASCADE,
    quantity integer,
    PRIMARY KEY (product_no, order_id)
);
```

Restricting and cascading deletes are the two most common options. `RESTRICT` prevents deletion of a referenced row. `NO ACTION` means that if any referencing rows still exist when the constraint is checked, an error is raised; this is the default behavior if you do not specify anything. (The essential difference between these two choices is that `NO ACTION` allows the check to be deferred until later in the transaction, whereas `RESTRICT` does not.) `CASCADE` specifies that when a referenced row is deleted, row(s) referencing it should be automatically deleted as well. There are two other options: `SET NULL` and `SET DEFAULT`. These cause the referencing column(s) in the referencing row(s) to be set to nulls or their default values, respectively, when the referenced row is deleted. Note that these do not excuse you from observing any constraints. For example, if an action specifies `SET DEFAULT` but the default value would not satisfy the foreign key constraint, the operation will fail.

Analogous to `ON DELETE` there is also `ON UPDATE` which is invoked when a referenced column is changed (updated). The possible actions are the same. In this case, `CASCADE` means that the updated values of the referenced column(s) should be copied into the referencing row(s).

Normally, a referencing row need not satisfy the foreign key constraint if any of its referencing columns are null. If `MATCH FULL` is added to the foreign key declaration, a referencing row escapes satisfying the constraint only if all its referencing columns are null (so a mix of null and non-null values is guaranteed to fail a `MATCH FULL` constraint). If you don't want referencing rows to be able to avoid satisfying the foreign key constraint, declare the referencing column(s) as `NOT NULL`.

A foreign key must reference columns that either are a primary key or form a unique constraint. This means that the referenced columns always have an index (the one underlying the primary key or unique constraint); so checks on whether a referencing row has a match will be efficient. Since a `DELETE` of a row from the referenced table or an `UPDATE` of a referenced column will require a scan of the referencing table for rows matching the old value, it is often a good idea to index the referencing columns too. Because this is not always needed, and there are many choices available on how to index, declaration of a foreign key constraint does not automatically create an index on the referencing columns.

More information about updating and deleting data is in Chapter 6. Also see the description of foreign key constraint syntax in the reference documentation for `CREATE TABLE`.

5.4.6. Exclusion Constraints

Exclusion constraints ensure that if any two rows are compared on the specified columns or expressions using the specified operators, at least one of these operator comparisons will return false or null. The syntax is:

```
CREATE TABLE circles (
    c circle,
    EXCLUDE USING gist (c WITH &&)
```

);

See also `CREATE TABLE ... CONSTRAINT ... EXCLUDE` for details.

Adding an exclusion constraint will automatically create an index of the type specified in the constraint declaration.

5.5. System Columns

Every table has several *system columns* that are implicitly defined by the system. Therefore, these names cannot be used as names of user-defined columns. (Note that these restrictions are separate from whether the name is a key word or not; quoting a name will not allow you to escape these restrictions.) You do not really need to be concerned about these columns; just know they exist.

`tableoid`

The OID of the table containing this row. This column is particularly handy for queries that select from inheritance hierarchies (see Section 5.10), since without it, it's difficult to tell which individual table a row came from. The `tableoid` can be joined against the `oid` column of `pg_class` to obtain the table name.

`xmin`

The identity (transaction ID) of the inserting transaction for this row version. (A row version is an individual state of a row; each update of a row creates a new row version for the same logical row.)

`cmin`

The command identifier (starting at zero) within the inserting transaction.

`xmax`

The identity (transaction ID) of the deleting transaction, or zero for an undeleted row version. It is possible for this column to be nonzero in a visible row version. That usually indicates that the deleting transaction hasn't committed yet, or that an attempted deletion was rolled back.

`cmax`

The command identifier within the deleting transaction, or zero.

`ctid`

The physical location of the row version within its table. Note that although the `ctid` can be used to locate the row version very quickly, a row's `ctid` will change if it is updated or moved by `VACUUM FULL`. Therefore `ctid` is useless as a long-term row identifier. A primary key should be used to identify logical rows.

Transaction identifiers are also 32-bit quantities. In a long-lived database it is possible for transaction IDs to wrap around. This is not a fatal problem given appropriate maintenance procedures; see Chapter 24 for details. It is unwise, however, to depend on the uniqueness of transaction IDs over the long term (more than one billion transactions).

Command identifiers are also 32-bit quantities. This creates a hard limit of 2^{32} (4 billion) SQL commands within a single transaction. In practice this limit is not a problem — note that the limit is on the number of SQL commands, not the number of rows processed. Also, only commands that actually modify the database contents will consume a command identifier.

5.6. Modifying Tables

When you create a table and you realize that you made a mistake, or the requirements of the application change, you can drop the table and create it again. But this is not a convenient option if the table is already filled with data, or if the table is referenced by other database objects (for instance a foreign key constraint). Therefore PostgreSQL provides a family of commands to make modifications to existing tables. Note that this is conceptually distinct from altering the data contained in the table: here we are interested in altering the definition, or structure, of the table.

You can:

- Add columns
- Remove columns
- Add constraints
- Remove constraints
- Change default values
- Change column data types
- Rename columns
- Rename tables

All these actions are performed using the ALTER TABLE command, whose reference page contains details beyond those given here.

5.6.1. Adding a Column

To add a column, use a command like:

```
ALTER TABLE products ADD COLUMN description text;
```

The new column is initially filled with whatever default value is given (null if you don't specify a DEFAULT clause).

Tip

From PostgreSQL 11, adding a column with a constant default value no longer means that each row of the table needs to be updated when the ALTER TABLE statement is executed. Instead, the default value will be returned the next time the row is accessed, and applied when the table is rewritten, making the ALTER TABLE very fast even on large tables.

However, if the default value is volatile (e.g. clock_timestamp()) each row will need to be updated with the value calculated at the time ALTER TABLE is executed. To avoid a potentially lengthy update operation, particularly if you intend to fill the column with mostly nondefault values anyway, it may be preferable to add the column with no default, insert the correct values using UPDATE, and then add any desired default as described below.

You can also define constraints on the column at the same time, using the usual syntax:

```
ALTER TABLE products ADD COLUMN description text CHECK (description <> '');
```

In fact all the options that can be applied to a column description in CREATE TABLE can be used here. Keep in mind however that the default value must satisfy the given constraints, or the ADD will fail. Alternatively, you can add constraints later (see below) after you've filled in the new column correctly.

5.6.2. Removing a Column

To remove a column, use a command like:

```
ALTER TABLE products DROP COLUMN description;
```

Whatever data was in the column disappears. Table constraints involving the column are dropped, too. However, if the column is referenced by a foreign key constraint of another table, PostgreSQL will not silently drop that constraint. You can authorize dropping everything that depends on the column by adding `CASCADE`:

```
ALTER TABLE products DROP COLUMN description CASCADE;
```

See Section 5.14 for a description of the general mechanism behind this.

5.6.3. Adding a Constraint

To add a constraint, the table constraint syntax is used. For example:

```
ALTER TABLE products ADD CHECK (name <> '');  
ALTER TABLE products ADD CONSTRAINT some_name UNIQUE (product_no);  
ALTER TABLE products ADD FOREIGN KEY (product_group_id) REFERENCES  
product_groups;
```

To add a not-null constraint, which cannot be written as a table constraint, use this syntax:

```
ALTER TABLE products ALTER COLUMN product_no SET NOT NULL;
```

The constraint will be checked immediately, so the table data must satisfy the constraint before it can be added.

5.6.4. Removing a Constraint

To remove a constraint you need to know its name. If you gave it a name then that's easy. Otherwise the system assigned a generated name, which you need to find out. The `psql` command `\d table-name` can be helpful here; other interfaces might also provide a way to inspect table details. Then the command is:

```
ALTER TABLE products DROP CONSTRAINT some_name;
```

(If you are dealing with a generated constraint name like `$2`, don't forget that you'll need to double-quote it to make it a valid identifier.)

As with dropping a column, you need to add `CASCADE` if you want to drop a constraint that something else depends on. An example is that a foreign key constraint depends on a unique or primary key constraint on the referenced column(s).

This works the same for all constraint types except not-null constraints. To drop a not null constraint use:

```
ALTER TABLE products ALTER COLUMN product_no DROP NOT NULL;
```

(Recall that not-null constraints do not have names.)

5.6.5. Changing a Column's Default Value

To set a new default for a column, use a command like:

```
ALTER TABLE products ALTER COLUMN price SET DEFAULT 7.77;
```

Note that this doesn't affect any existing rows in the table, it just changes the default for future INSERT commands.

To remove any default value, use:

```
ALTER TABLE products ALTER COLUMN price DROP DEFAULT;
```

This is effectively the same as setting the default to null. As a consequence, it is not an error to drop a default where one hadn't been defined, because the default is implicitly the null value.

5.6.6. Changing a Column's Data Type

To convert a column to a different data type, use a command like:

```
ALTER TABLE products ALTER COLUMN price TYPE numeric(10,2);
```

This will succeed only if each existing entry in the column can be converted to the new type by an implicit cast. If a more complex conversion is needed, you can add a USING clause that specifies how to compute the new values from the old.

PostgreSQL will attempt to convert the column's default value (if any) to the new type, as well as any constraints that involve the column. But these conversions might fail, or might produce surprising results. It's often best to drop any constraints on the column before altering its type, and then add back suitably modified constraints afterwards.

5.6.7. Renaming a Column

To rename a column:

```
ALTER TABLE products RENAME COLUMN product_no TO product_number;
```

5.6.8. Renaming a Table

To rename a table:

```
ALTER TABLE products RENAME TO items;
```

5.7. Privileges

When an object is created, it is assigned an owner. The owner is normally the role that executed the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, *privileges* must be granted.

There are different kinds of privileges: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, TRIGGER, CREATE, CONNECT, TEMPORARY, EXECUTE, and USAGE. The privileges applicable to a particular object vary depending on the object's type (table, function, etc). More detail about the meanings of these privileges appears below. The following sections and chapters will also show you how these privileges are used.

The right to modify or destroy an object is always the privilege of the owner only.

An object can be assigned to a new owner with an ALTER command of the appropriate kind for the object, for example

```
ALTER TABLE table_name OWNER TO new_owner;
```

Superusers can always do this; ordinary roles can only do it if they are both the current owner of the object (or a member of the owning role) and a member of the new owning role.

To assign privileges, the GRANT command is used. For example, if `joe` is an existing role, and `accounts` is an existing table, the privilege to update the table can be granted with:

```
GRANT UPDATE ON accounts TO joe;
```

Writing ALL in place of a specific privilege grants all privileges that are relevant for the object type.

The special “role” name PUBLIC can be used to grant a privilege to every role on the system. Also, “group” roles can be set up to help manage privileges when there are many users of a database — for details see Chapter 21.

To revoke a privilege, use the fittingly named REVOKE command:

```
REVOKE ALL ON accounts FROM PUBLIC;
```

The special privileges of the object owner (i.e., the right to do DROP, GRANT, REVOKE, etc.) are always implicit in being the owner, and cannot be granted or revoked. But the object owner can choose to revoke their own ordinary privileges, for example to make a table read-only for themselves as well as others.

Ordinarily, only the object's owner (or a superuser) can grant or revoke privileges on an object. However, it is possible to grant a privilege “with grant option”, which gives the recipient the right to grant it in turn to others. If the grant option is subsequently revoked then all who received the privilege from that recipient (directly or through a chain of grants) will lose the privilege. For details see the GRANT and REVOKE reference pages.

The available privileges are:

SELECT

Allows SELECT from any column, or specific column(s), of a table, view, materialized view, or other table-like object. Also allows use of COPY TO. This privilege is also needed to reference existing column values in UPDATE or DELETE. For sequences, this privilege also allows use of the `currval` function. For large objects, this privilege allows the object to be read.

INSERT

Allows INSERT of a new row into a table, view, etc. Can be granted on specific column(s), in which case only those columns may be assigned to in the INSERT command (other columns will therefore receive default values). Also allows use of COPY FROM.

UPDATE

Allows UPDATE of any column, or specific column(s), of a table, view, etc. (In practice, any nontrivial UPDATE command will require SELECT privilege as well, since it must reference table columns to determine which rows to update, and/or to compute new values for columns.) SELECT ... FOR UPDATE and SELECT ... FOR SHARE also require this privilege on at least one column, in addition to the SELECT privilege. For sequences, this privilege allows use of the `nextval` and `setval` functions. For large objects, this privilege allows writing or truncating the object.

DELETE

Allows DELETE of a row from a table, view, etc. (In practice, any nontrivial DELETE command will require SELECT privilege as well, since it must reference table columns to determine which rows to delete.)

TRUNCATE

Allows TRUNCATE on a table, view, etc.

REFERENCES

Allows creation of a foreign key constraint referencing a table, or specific column(s) of a table.

TRIGGER

Allows creation of a trigger on a table, view, etc.

CREATE

For databases, allows new schemas and publications to be created within the database.

For schemas, allows new objects to be created within the schema. To rename an existing object, you must own the object *and* have this privilege for the containing schema.

For tablespaces, allows tables, indexes, and temporary files to be created within the tablespace, and allows databases to be created that have the tablespace as their default tablespace. (Note that revoking this privilege will not alter the placement of existing objects.)

CONNECT

Allows the grantee to connect to the database. This privilege is checked at connection startup (in addition to checking any restrictions imposed by `pg_hba.conf`).

TEMPORARY

Allows temporary tables to be created while using the database.

EXECUTE

Allows calling a function or procedure, including use of any operators that are implemented on top of the function. This is the only type of privilege that is applicable to functions and procedures.

USAGE

For procedural languages, allows use of the language for the creation of functions in that language. This is the only type of privilege that is applicable to procedural languages.

For schemas, allows access to objects contained in the schema (assuming that the objects' own privilege requirements are also met). Essentially this allows the grantee to “look up” objects within the schema. Without this permission, it is still possible to see the object names, e.g. by querying system catalogs. Also, after revoking this permission, existing sessions might have statements that have previously performed this lookup, so this is not a completely secure way to prevent object access.

For sequences, allows use of the `currval` and `nextval` functions.

For types and domains, allows use of the type or domain in the creation of tables, functions, and other schema objects. (Note that this privilege does not control all “usage” of the type, such as values of the type appearing in queries. It only prevents objects from being created that depend on the type. The main purpose of this privilege is controlling which users can create dependencies on a type, which could prevent the owner from changing the type later.)

For foreign-data wrappers, allows creation of new servers using the foreign-data wrapper.

For foreign servers, allows creation of foreign tables using the server. Grantees may also create, alter, or drop their own user mappings associated with that server.

The privileges required by other commands are listed on the reference page of the respective command.

PostgreSQL grants privileges on some types of objects to PUBLIC by default when the objects are created. No privileges are granted to PUBLIC by default on tables, table columns, sequences, foreign data wrappers, foreign servers, large objects, schemas, or tablespaces. For other types of objects, the default privileges granted to PUBLIC are as follows: CONNECT and TEMPORARY (create temporary tables) privileges for databases; EXECUTE privilege for functions and procedures; and USAGE privilege for languages and data types (including domains). The object owner can, of course, REVOKE both default and expressly granted privileges. (For maximum security, issue the REVOKE in the same transaction that creates the object; then there is no window in which another user can use the object.) Also, these default privilege settings can be overridden using the ALTER DEFAULT PRIVILEGES command.

Table 5.1 shows the one-letter abbreviations that are used for these privilege types in ACL (Access Control List) values. You will see these letters in the output of the psql commands listed below, or when looking at ACL columns of system catalogs.

Table 5.1. ACL Privilege Abbreviations

Privilege	Abbreviation	Applicable Object Types
SELECT	r (“read”)	LARGE OBJECT, SEQUENCE, TABLE (and table-like objects), table column
INSERT	a (“append”)	TABLE, table column
UPDATE	w (“write”)	LARGE OBJECT, SEQUENCE, TABLE, table column
DELETE	d	TABLE
TRUNCATE	D	TABLE
REFERENCES	x	TABLE, table column
TRIGGER	t	TABLE
CREATE	C	DATABASE, SCHEMA, TABLESPACE
CONNECT	c	DATABASE
TEMPORARY	T	DATABASE
EXECUTE	X	FUNCTION, PROCEDURE
USAGE	U	DOMAIN, FOREIGN DATA WRAPPER, FOREIGN SERVER, LANGUAGE, SCHEMA, SEQUENCE, TYPE

Table 5.2 summarizes the privileges available for each type of SQL object, using the abbreviations shown above. It also shows the psql command that can be used to examine privilege settings for each object type.

Table 5.2. Summary of Access Privileges

Object Type	All Privileges	Default PUBLIC Privileges	psql Command
DATABASE	CTc	Tc	\l

Object Type	All Privileges	Default PUBLIC Privileges	psql Command
DOMAIN	U	U	\dD+
FUNCTION or PROCEDURE	X	X	\df+
FOREIGN DATA WRAPPER	U	none	\dew+
FOREIGN SERVER	U	none	\des+
LANGUAGE	U	U	\dL+
LARGE OBJECT	rw	none	
SCHEMA	UC	none	\dn+
SEQUENCE	rwU	none	\dp
TABLE (and table-like objects)	arwdDxt	none	\dp
Table column	arwx	none	\dp
TABLESPACE	C	none	\db+
TYPE	U	U	\dT+

The privileges that have been granted for a particular object are displayed as a list of `aclitem` entries, where each `aclitem` describes the permissions of one grantee that have been granted by a particular grantor. For example, `calvin=r*w/hobbes` specifies that the role `calvin` has the privilege `SELECT (r)` with grant option (`*`) as well as the non-grantable privilege `UPDATE (w)`, both granted by the role `hobbes`. If `calvin` also has some privileges on the same object granted by a different grantor, those would appear as a separate `aclitem` entry. An empty grantee field in an `aclitem` stands for `PUBLIC`.

As an example, suppose that user `miriam` creates table `mytable` and does:

```
GRANT SELECT ON mytable TO PUBLIC;
GRANT SELECT, UPDATE, INSERT ON mytable TO admin;
GRANT SELECT (coll), UPDATE (coll) ON mytable TO miriam_rw;
```

Then `psql`'s `\dp` command would show:

```
=> \dp mytable
                                     Access privileges
 Schema | Name   | Type | Access privileges | Column
-----+-----+-----+-----+-----
 public | mytable | table | miriam=arwdDxt/miriam+ | coll:
      + |
 miriam |         |      | =r/miriam           + | miriam_rw=rw/
      |         |      | admin=arw/miriam   |
      |         |      |                     |
(1 row)
```

If the “Access privileges” column is empty for a given object, it means the object has default privileges (that is, its privileges entry in the relevant system catalog is null). Default privileges always include all privileges for the owner, and can include some privileges for `PUBLIC` depending on the object type, as explained above. The first `GRANT` or `REVOKE` on an object will instantiate the default privileges

(producing, for example, `miriam=arwdDxt/miriam`) and then modify them per the specified request. Similarly, entries are shown in “Column privileges” only for columns with nondefault privileges. (Note: for this purpose, “default privileges” always means the built-in default privileges for the object's type. An object whose privileges have been affected by an `ALTER DEFAULT PRIVILEGES` command will always be shown with an explicit privilege entry that includes the effects of the `ALTER`.)

Notice that the owner's implicit grant options are not marked in the access privileges display. A `*` will appear only when grant options have been explicitly granted to someone.

5.8. Row Security Policies

In addition to the SQL-standard privilege system available through `GRANT`, tables can have *row security policies* that restrict, on a per-user basis, which rows can be returned by normal queries or inserted, updated, or deleted by data modification commands. This feature is also known as *Row-Level Security*. By default, tables do not have any policies, so that if a user has access privileges to a table according to the SQL privilege system, all rows within it are equally available for querying or updating.

When row security is enabled on a table (with `ALTER TABLE ... ENABLE ROW LEVEL SECURITY`), all normal access to the table for selecting rows or modifying rows must be allowed by a row security policy. (However, the table's owner is typically not subject to row security policies.) If no policy exists for the table, a default-deny policy is used, meaning that no rows are visible or can be modified. Operations that apply to the whole table, such as `TRUNCATE` and `REFERENCES`, are not subject to row security.

Row security policies can be specific to commands, or to roles, or to both. A policy can be specified to apply to `ALL` commands, or to `SELECT`, `INSERT`, `UPDATE`, or `DELETE`. Multiple roles can be assigned to a given policy, and normal role membership and inheritance rules apply.

To specify which rows are visible or modifiable according to a policy, an expression is required that returns a Boolean result. This expression will be evaluated for each row prior to any conditions or functions coming from the user's query. (The only exceptions to this rule are `leakproof` functions, which are guaranteed to not leak information; the optimizer may choose to apply such functions ahead of the row-security check.) Rows for which the expression does not return `true` will not be processed. Separate expressions may be specified to provide independent control over the rows which are visible and the rows which are allowed to be modified. Policy expressions are run as part of the query and with the privileges of the user running the query, although security-definer functions can be used to access data not available to the calling user.

Superusers and roles with the `BYPASSRLS` attribute always bypass the row security system when accessing a table. Table owners normally bypass row security as well, though a table owner can choose to be subject to row security with `ALTER TABLE ... FORCE ROW LEVEL SECURITY`.

Enabling and disabling row security, as well as adding policies to a table, is always the privilege of the table owner only.

Policies are created using the `CREATE POLICY` command, altered using the `ALTER POLICY` command, and dropped using the `DROP POLICY` command. To enable and disable row security for a given table, use the `ALTER TABLE` command.

Each policy has a name and multiple policies can be defined for a table. As policies are table-specific, each policy for a table must have a unique name. Different tables may have policies with the same name.

When multiple policies apply to a given query, they are combined using either `OR` (for permissive policies, which are the default) or using `AND` (for restrictive policies). This is similar to the rule that a given role has the privileges of all roles that they are a member of. Permissive vs. restrictive policies are discussed further below.

As a simple example, here is how to create a policy on the `account` relation to allow only members of the `managers` role to access rows, and only rows of their accounts:

```
CREATE TABLE accounts (manager text, company text, contact_email
text);
```

```
ALTER TABLE accounts ENABLE ROW LEVEL SECURITY;
```

```
CREATE POLICY account_managers ON accounts TO managers
USING (manager = current_user);
```

The policy above implicitly provides a `WITH CHECK` clause identical to its `USING` clause, so that the constraint applies both to rows selected by a command (so a manager cannot `SELECT`, `UPDATE`, or `DELETE` existing rows belonging to a different manager) and to rows modified by a command (so rows belonging to a different manager cannot be created via `INSERT` or `UPDATE`).

If no role is specified, or the special user name `PUBLIC` is used, then the policy applies to all users on the system. To allow all users to access only their own row in a `users` table, a simple policy can be used:

```
CREATE POLICY user_policy ON users
USING (user_name = current_user);
```

This works similarly to the previous example.

To use a different policy for rows that are being added to the table compared to those rows that are visible, multiple policies can be combined. This pair of policies would allow all users to view all rows in the `users` table, but only modify their own:

```
CREATE POLICY user_sel_policy ON users
FOR SELECT
USING (true);
CREATE POLICY user_mod_policy ON users
USING (user_name = current_user);
```

In a `SELECT` command, these two policies are combined using `OR`, with the net effect being that all rows can be selected. In other command types, only the second policy applies, so that the effects are the same as before.

Row security can also be disabled with the `ALTER TABLE` command. Disabling row security does not remove any policies that are defined on the table; they are simply ignored. Then all rows in the table are visible and modifiable, subject to the standard SQL privileges system.

Below is a larger example of how this feature can be used in production environments. The table `passwd` emulates a Unix password file:

```
-- Simple passwd-file based example
CREATE TABLE passwd (
  user_name      text UNIQUE NOT NULL,
  pwhash         text,
  uid            int PRIMARY KEY,
  gid            int NOT NULL,
  real_name      text NOT NULL,
  home_phone     text,
  extra_info     text,
  home_dir       text NOT NULL,
  shell          text NOT NULL
);
```

```

CREATE ROLE admin; -- Administrator
CREATE ROLE bob; -- Normal user
CREATE ROLE alice; -- Normal user

-- Populate the table
INSERT INTO passwd VALUES
  ('admin','xxx',0,0,'Admin','111-222-3333',null,'/root','/bin/
dash');
INSERT INTO passwd VALUES
  ('bob','xxx',1,1,'Bob','123-456-7890',null,'/home/bob','/bin/
zsh');
INSERT INTO passwd VALUES
  ('alice','xxx',2,1,'Alice','098-765-4321',null,'/home/alice','/
bin/zsh');

-- Be sure to enable row level security on the table
ALTER TABLE passwd ENABLE ROW LEVEL SECURITY;

-- Create policies
-- Administrator can see all rows and add any rows
CREATE POLICY admin_all ON passwd TO admin USING (true) WITH CHECK
  (true);
-- Normal users can view all rows
CREATE POLICY all_view ON passwd FOR SELECT USING (true);
-- Normal users can update their own records, but
-- limit which shells a normal user is allowed to set
CREATE POLICY user_mod ON passwd FOR UPDATE
  USING (current_user = user_name)
  WITH CHECK (
    current_user = user_name AND
    shell IN ('/bin/bash','/bin/sh','/bin/dash','/bin/zsh','/bin/
tcsh')
  );

-- Allow admin all normal rights
GRANT SELECT, INSERT, UPDATE, DELETE ON passwd TO admin;
-- Users only get select access on public columns
GRANT SELECT
  (user_name, uid, gid, real_name, home_phone, extra_info,
  home_dir, shell)
  ON passwd TO public;
-- Allow users to update certain columns
GRANT UPDATE
  (pwhash, real_name, home_phone, extra_info, shell)
  ON passwd TO public;

```

As with any security settings, it's important to test and ensure that the system is behaving as expected. Using the example above, this demonstrates that the permission system is working properly.

```

-- admin can view all rows and fields
postgres=> set role admin;
SET
postgres=> table passwd;
 user_name | pwhash | uid | gid | real_name | home_phone |
 extra_info | home_dir | shell
-----+-----+-----+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+-----+-----+-----+

```

```

admin      | xxx      | 0 | 0 | Admin      | 111-222-3333 |
          | /root    | /bin/dash
bob        | xxx      | 1 | 1 | Bob        | 123-456-7890 |
          | /home/bob | /bin/zsh
alice      | xxx      | 2 | 1 | Alice      | 098-765-4321 |
          | /home/alice | /bin/zsh
(3 rows)

```

```

-- Test what Alice is able to do
postgres=> set role alice;
SET
postgres=> table passwd;
ERROR: permission denied for relation passwd
postgres=> select
  user_name,real_name,home_phone,extra_info,home_dir,shell from
  passwd;
 user_name | real_name | home_phone | extra_info | home_dir |
  shell
-----+-----+-----+-----+-----+
+-----+
admin      | Admin      | 111-222-3333 |          | /root
          | /bin/dash
bob        | Bob        | 123-456-7890 |          | /home/bob
          | /bin/zsh
alice      | Alice      | 098-765-4321 |          | /home/alice
          | /bin/zsh
(3 rows)

```

```

postgres=> update passwd set user_name = 'joe';
ERROR: permission denied for relation passwd
-- Alice is allowed to change her own real_name, but no others
postgres=> update passwd set real_name = 'Alice Doe';
UPDATE 1
postgres=> update passwd set real_name = 'John Doe' where user_name
  = 'admin';
UPDATE 0
postgres=> update passwd set shell = '/bin/xx';
ERROR: new row violates WITH CHECK OPTION for "passwd"
postgres=> delete from passwd;
ERROR: permission denied for relation passwd
postgres=> insert into passwd (user_name) values ('xxx');
ERROR: permission denied for relation passwd
-- Alice can change her own password; RLS silently prevents
  updating other rows
postgres=> update passwd set pwhash = 'abc';
UPDATE 1

```

All of the policies constructed thus far have been permissive policies, meaning that when multiple policies are applied they are combined using the “OR” Boolean operator. While permissive policies can be constructed to only allow access to rows in the intended cases, it can be simpler to combine permissive policies with restrictive policies (which the records must pass and which are combined using the “AND” Boolean operator). Building on the example above, we add a restrictive policy to require the administrator to be connected over a local Unix socket to access the records of the passwd table:

```

CREATE POLICY admin_local_only ON passwd AS RESTRICTIVE TO admin
  USING (pg_catalog.inet_client_addr() IS NULL);

```

We can then see that an administrator connecting over a network will not see any records, due to the restrictive policy:

```
=> SELECT current_user;
current_user
-----
admin
(1 row)

=> select inet_client_addr();
inet_client_addr
-----
127.0.0.1
(1 row)

=> SELECT current_user;
current_user
-----
admin
(1 row)

=> TABLE passwd;
user_name | pwhash | uid | gid | real_name | home_phone |
extra_info | home_dir | shell
-----+-----+-----+-----+-----+-----+
+-----+-----+-----+
(0 rows)

=> UPDATE passwd set pwhash = NULL;
UPDATE 0
```

Referential integrity checks, such as unique or primary key constraints and foreign key references, always bypass row security to ensure that data integrity is maintained. Care must be taken when developing schemas and row level policies to avoid “covert channel” leaks of information through such referential integrity checks.

In some contexts it is important to be sure that row security is not being applied. For example, when taking a backup, it could be disastrous if row security silently caused some rows to be omitted from the backup. In such a situation, you can set the `row_security` configuration parameter to `off`. This does not in itself bypass row security; what it does is throw an error if any query's results would get filtered by a policy. The reason for the error can then be investigated and fixed.

In the examples above, the policy expressions consider only the current values in the row to be accessed or updated. This is the simplest and best-performing case; when possible, it's best to design row security applications to work this way. If it is necessary to consult other rows or other tables to make a policy decision, that can be accomplished using sub-SELECTs, or functions that contain SELECTs, in the policy expressions. Be aware however that such accesses can create race conditions that could allow information leakage if care is not taken. As an example, consider the following table design:

```
-- definition of privilege groups
CREATE TABLE groups (group_id int PRIMARY KEY,
                    group_name text NOT NULL);

INSERT INTO groups VALUES
(1, 'low'),
(2, 'medium'),
(5, 'high');
```

```

GRANT ALL ON groups TO alice; -- alice is the administrator
GRANT SELECT ON groups TO public;

-- definition of users' privilege levels
CREATE TABLE users (user_name text PRIMARY KEY,
                    group_id int NOT NULL REFERENCES groups);

INSERT INTO users VALUES
    ('alice', 5),
    ('bob', 2),
    ('mallory', 2);

GRANT ALL ON users TO alice;
GRANT SELECT ON users TO public;

-- table holding the information to be protected
CREATE TABLE information (info text,
                        group_id int NOT NULL REFERENCES groups);

INSERT INTO information VALUES
    ('barely secret', 1),
    ('slightly secret', 2),
    ('very secret', 5);

ALTER TABLE information ENABLE ROW LEVEL SECURITY;

-- a row should be visible to/updatable by users whose security
group_id is
-- greater than or equal to the row's group_id
CREATE POLICY fp_s ON information FOR SELECT
    USING (group_id <= (SELECT group_id FROM users WHERE user_name =
    current_user));
CREATE POLICY fp_u ON information FOR UPDATE
    USING (group_id <= (SELECT group_id FROM users WHERE user_name =
    current_user));

-- we rely only on RLS to protect the information table
GRANT ALL ON information TO public;

```

Now suppose that alice wishes to change the “slightly secret” information, but decides that mallory should not be trusted with the new content of that row, so she does:

```

BEGIN;
UPDATE users SET group_id = 1 WHERE user_name = 'mallory';
UPDATE information SET info = 'secret from mallory' WHERE group_id
    = 2;
COMMIT;

```

That looks safe; there is no window wherein mallory should be able to see the “secret from mallory” string. However, there is a race condition here. If mallory is concurrently doing, say,

```

SELECT * FROM information WHERE group_id = 2 FOR UPDATE;

```

and her transaction is in READ COMMITTED mode, it is possible for her to see “secret from mallory”. That happens if her transaction reaches the information row just after alice's does. It blocks waiting for alice's transaction to commit, then fetches the updated row contents thanks to the FOR

UPDATE clause. However, it does *not* fetch an updated row for the implicit SELECT from `users`, because that sub-SELECT did not have `FOR UPDATE`; instead the `users` row is read with the snapshot taken at the start of the query. Therefore, the policy expression tests the old value of `mallery`'s privilege level and allows her to see the updated row.

There are several ways around this problem. One simple answer is to use `SELECT ... FOR SHARE` in sub-SELECTs in row security policies. However, that requires granting `UPDATE` privilege on the referenced table (here `users`) to the affected users, which might be undesirable. (But another row security policy could be applied to prevent them from actually exercising that privilege; or the sub-SELECT could be embedded into a security definer function.) Also, heavy concurrent use of row share locks on the referenced table could pose a performance problem, especially if updates of it are frequent. Another solution, practical if updates of the referenced table are infrequent, is to take an exclusive lock on the referenced table when updating it, so that no concurrent transactions could be examining old row values. Or one could just wait for all concurrent transactions to end after committing an update of the referenced table and before making changes that rely on the new security situation.

For additional details see `CREATE POLICY` and `ALTER TABLE`.

5.9. Schemas

A PostgreSQL database cluster contains one or more named databases. Users and groups of users are shared across the entire cluster, but no other data is shared across databases. Any given client connection to the server can access only the data in a single database, the one specified in the connection request.

Note

Users of a cluster do not necessarily have the privilege to access every database in the cluster. Sharing of user names means that there cannot be different users named, say, `joe` in two databases in the same cluster; but the system can be configured to allow `joe` access to only some of the databases.

A database contains one or more named *schemas*, which in turn contain tables. Schemas also contain other kinds of named objects, including data types, functions, and operators. The same object name can be used in different schemas without conflict; for example, both `schema1` and `myschema` can contain tables named `mytable`. Unlike databases, schemas are not rigidly separated: a user can access objects in any of the schemas in the database they are connected to, if they have privileges to do so.

There are several reasons why one might want to use schemas:

- To allow many users to use one database without interfering with each other.
- To organize database objects into logical groups to make them more manageable.
- Third-party applications can be put into separate schemas so they do not collide with the names of other objects.

Schemas are analogous to directories at the operating system level, except that schemas cannot be nested.

5.9.1. Creating a Schema

To create a schema, use the `CREATE SCHEMA` command. Give the schema a name of your choice. For example:

```
CREATE SCHEMA myschema;
```

To create or access objects in a schema, write a *qualified name* consisting of the schema name and table name separated by a dot:

schema.table

This works anywhere a table name is expected, including the table modification commands and the data access commands discussed in the following chapters. (For brevity we will speak of tables only, but the same ideas apply to other kinds of named objects, such as types and functions.)

Actually, the even more general syntax

database.schema.table

can be used too, but at present this is just for *pro forma* compliance with the SQL standard. If you write a database name, it must be the same as the database you are connected to.

So to create a table in the new schema, use:

```
CREATE TABLE myschema.mytable (  
    ...  
);
```

To drop a schema if it's empty (all objects in it have been dropped), use:

```
DROP SCHEMA myschema;
```

To drop a schema including all contained objects, use:

```
DROP SCHEMA myschema CASCADE;
```

See Section 5.14 for a description of the general mechanism behind this.

Often you will want to create a schema owned by someone else (since this is one of the ways to restrict the activities of your users to well-defined namespaces). The syntax for that is:

```
CREATE SCHEMA schema_name AUTHORIZATION user_name;
```

You can even omit the schema name, in which case the schema name will be the same as the user name. See Section 5.9.6 for how this can be useful.

Schema names beginning with `pg_` are reserved for system purposes and cannot be created by users.

5.9.2. The Public Schema

In the previous sections we created tables without specifying any schema names. By default such tables (and other objects) are automatically put into a schema named “public”. Every new database contains such a schema. Thus, the following are equivalent:

```
CREATE TABLE products ( ... );
```

and:

```
CREATE TABLE public.products ( ... );
```

5.9.3. The Schema Search Path

Qualified names are tedious to write, and it's often best not to wire a particular schema name into applications anyway. Therefore tables are often referred to by *unqualified names*, which consist of just the table name. The system determines which table is meant by following a *search path*, which is a list of schemas to look in. The first matching table in the search path is taken to be the one wanted. If there is no match in the search path, an error is reported, even if matching table names exist in other schemas in the database.

The ability to create like-named objects in different schemas complicates writing a query that references precisely the same objects every time. It also opens up the potential for users to change the behavior of other users' queries, maliciously or accidentally. Due to the prevalence of unqualified names in queries and their use in PostgreSQL internals, adding a schema to `search_path` effectively trusts all users having `CREATE` privilege on that schema. When you run an ordinary query, a malicious user able to create objects in a schema of your search path can take control and execute arbitrary SQL functions as though you executed them.

The first schema named in the search path is called the current schema. Aside from being the first schema searched, it is also the schema in which new tables will be created if the `CREATE TABLE` command does not specify a schema name.

To show the current search path, use the following command:

```
SHOW search_path;
```

In the default setup this returns:

```
search_path
-----
"$user", public
```

The first element specifies that a schema with the same name as the current user is to be searched. If no such schema exists, the entry is ignored. The second element refers to the public schema that we have seen already.

The first schema in the search path that exists is the default location for creating new objects. That is the reason that by default objects are created in the public schema. When objects are referenced in any other context without schema qualification (table modification, data modification, or query commands) the search path is traversed until a matching object is found. Therefore, in the default configuration, any unqualified access again can only refer to the public schema.

To put our new schema in the path, we use:

```
SET search_path TO myschema,public;
```

(We omit the `$user` here because we have no immediate need for it.) And then we can access the table without schema qualification:

```
DROP TABLE mytable;
```

Also, since `myschema` is the first element in the path, new objects would by default be created in it.

We could also have written:

```
SET search_path TO myschema;
```

Then we no longer have access to the public schema without explicit qualification. There is nothing special about the public schema except that it exists by default. It can be dropped, too.

See also Section 9.25 for other ways to manipulate the schema search path.

The search path works in the same way for data type names, function names, and operator names as it does for table names. Data type and function names can be qualified in exactly the same way as table names. If you need to write a qualified operator name in an expression, there is a special provision: you must write

```
OPERATOR(schema.operator)
```

This is needed to avoid syntactic ambiguity. An example is:

```
SELECT 3 OPERATOR(pg_catalog.+) 4;
```

In practice one usually relies on the search path for operators, so as not to have to write anything so ugly as that.

5.9.4. Schemas and Privileges

By default, users cannot access any objects in schemas they do not own. To allow that, the owner of the schema must grant the `USAGE` privilege on the schema. To allow users to make use of the objects in the schema, additional privileges might need to be granted, as appropriate for the object.

A user can also be allowed to create objects in someone else's schema. To allow that, the `CREATE` privilege on the schema needs to be granted. Note that by default, everyone has `CREATE` and `USAGE` privileges on the schema `public`. This allows all users that are able to connect to a given database to create objects in its `public` schema. Some usage patterns call for revoking that privilege:

```
REVOKE CREATE ON SCHEMA public FROM PUBLIC;
```

(The first “public” is the schema, the second “public” means “every user”. In the first sense it is an identifier, in the second sense it is a key word, hence the different capitalization; recall the guidelines from Section 4.1.1.)

5.9.5. The System Catalog Schema

In addition to `public` and user-created schemas, each database contains a `pg_catalog` schema, which contains the system tables and all the built-in data types, functions, and operators. `pg_catalog` is always effectively part of the search path. If it is not named explicitly in the path then it is implicitly searched *before* searching the path's schemas. This ensures that built-in names will always be findable. However, you can explicitly place `pg_catalog` at the end of your search path if you prefer to have user-defined names override built-in names.

Since system table names begin with `pg_`, it is best to avoid such names to ensure that you won't suffer a conflict if some future version defines a system table named the same as your table. (With the default search path, an unqualified reference to your table name would then be resolved as the system table instead.) System tables will continue to follow the convention of having names beginning with `pg_`, so that they will not conflict with unqualified user-table names so long as users avoid the `pg_` prefix.

5.9.6. Usage Patterns

Schemas can be used to organize your data in many ways. There are a few usage patterns easily supported by the default configuration, only one of which suffices when database users mistrust other database users:

- Constrain ordinary users to user-private schemas. To implement this, issue `REVOKE CREATE ON SCHEMA public FROM PUBLIC`, and create a schema for each user with the same name as that user. If affected users had logged in before this, consider auditing the public schema for objects named like objects in schema `pg_catalog`. Recall that the default search path starts with `$user`, which resolves to the user name. Therefore, if each user has a separate schema, they access their own schemas by default.
- Remove the public schema from each user's default search path using `ALTER ROLE user SET search_path = "$user"`. Everyone retains the ability to create objects in the public schema, but only qualified names will choose those objects. While qualified table references are fine, calls to functions in the public schema will be unsafe or unreliable. Also, a user holding the `CREATEROLE` privilege can undo this setting and issue arbitrary queries under the identity of users relying on the setting. If you create functions or extensions in the public schema or grant `CREATEROLE` to users not warranting this almost-superuser ability, use the first pattern instead.
- Remove the public schema from `search_path` in `postgresql.conf`. The ensuing user experience matches the previous pattern. In addition to that pattern's implications for functions and `CREATEROLE`, this trusts database owners like `CREATEROLE`. If you create functions or extensions in the public schema or assign the `CREATEROLE` privilege, `CREATEDB` privilege or individual database ownership to users not warranting almost-superuser access, use the first pattern instead.
- Keep the default. All users access the public schema implicitly. This simulates the situation where schemas are not available at all, giving a smooth transition from the non-schema-aware world. However, any user can issue arbitrary queries under the identity of any user not electing to protect itself individually. This pattern is acceptable only when the database has a single user or a few mutually-trusting users.

For any pattern, to install shared applications (tables to be used by everyone, additional functions provided by third parties, etc.), put them into separate schemas. Remember to grant appropriate privileges to allow the other users to access them. Users can then refer to these additional objects by qualifying the names with a schema name, or they can put the additional schemas into their search path, as they choose.

5.9.7. Portability

In the SQL standard, the notion of objects in the same schema being owned by different users does not exist. Moreover, some implementations do not allow you to create schemas that have a different name than their owner. In fact, the concepts of schema and user are nearly equivalent in a database system that implements only the basic schema support specified in the standard. Therefore, many users consider qualified names to really consist of `user_name.table_name`. This is how PostgreSQL will effectively behave if you create a per-user schema for every user.

Also, there is no concept of a `public` schema in the SQL standard. For maximum conformance to the standard, you should not use the `public` schema.

Of course, some SQL database systems might not implement schemas at all, or provide namespace support by allowing (possibly limited) cross-database access. If you need to work with those systems, then maximum portability would be achieved by not using schemas at all.

5.10. Inheritance

PostgreSQL implements table inheritance, which can be a useful tool for database designers. (SQL:1999 and later define a type inheritance feature, which differs in many respects from the features described here.)

Let's start with an example: suppose we are trying to build a data model for cities. Each state has many cities, but only one capital. We want to be able to quickly retrieve the capital city for any particular state. This can be done by creating two tables, one for state capitals and one for cities that are not

capitals. However, what happens when we want to ask for data about a city, regardless of whether it is a capital or not? The inheritance feature can help to resolve this problem. We define the `capitals` table so that it inherits from `cities`:

```
CREATE TABLE cities (
    name          text,
    population    float,
    altitude      int    -- in feet
);

CREATE TABLE capitals (
    state         char(2)
) INHERITS (cities);
```

In this case, the `capitals` table *inherits* all the columns of its parent table, `cities`. State capitals also have an extra column, `state`, that shows their state.

In PostgreSQL, a table can inherit from zero or more other tables, and a query can reference either all rows of a table or all rows of a table plus all of its descendant tables. The latter behavior is the default. For example, the following query finds the names of all cities, including state capitals, that are located at an altitude over 500 feet:

```
SELECT name, altitude
FROM cities
WHERE altitude > 500;
```

Given the sample data from the PostgreSQL tutorial (see Section 2.1), this returns:

name	altitude
Las Vegas	2174
Mariposa	1953
Madison	845

On the other hand, the following query finds all the cities that are not state capitals and are situated at an altitude over 500 feet:

```
SELECT name, altitude
FROM ONLY cities
WHERE altitude > 500;
```

name	altitude
Las Vegas	2174
Mariposa	1953

Here the `ONLY` keyword indicates that the query should apply only to `cities`, and not any tables below `cities` in the inheritance hierarchy. Many of the commands that we have already discussed — `SELECT`, `UPDATE` and `DELETE` — support the `ONLY` keyword.

You can also write the table name with a trailing `*` to explicitly specify that descendant tables are included:

```
SELECT name, altitude
```

```
FROM cities*
WHERE altitude > 500;
```

Writing `*` is not necessary, since this behavior is always the default. However, this syntax is still supported for compatibility with older releases where the default could be changed.

In some cases you might wish to know which table a particular row originated from. There is a system column called `tableoid` in each table which can tell you the originating table:

```
SELECT c.tableoid, c.name, c.altitude
FROM cities c
WHERE c.altitude > 500;
```

which returns:

tableoid	name	altitude
139793	Las Vegas	2174
139793	Mariposa	1953
139798	Madison	845

(If you try to reproduce this example, you will probably get different numeric OIDs.) By doing a join with `pg_class` you can see the actual table names:

```
SELECT p.relname, c.name, c.altitude
FROM cities c, pg_class p
WHERE c.altitude > 500 AND c.tableoid = p.oid;
```

which returns:

relname	name	altitude
cities	Las Vegas	2174
cities	Mariposa	1953
capitals	Madison	845

Another way to get the same effect is to use the `regclass` alias type, which will print the table OID symbolically:

```
SELECT c.tableoid::regclass, c.name, c.altitude
FROM cities c
WHERE c.altitude > 500;
```

Inheritance does not automatically propagate data from `INSERT` or `COPY` commands to other tables in the inheritance hierarchy. In our example, the following `INSERT` statement will fail:

```
INSERT INTO cities (name, population, altitude, state)
VALUES ('Albany', NULL, NULL, 'NY');
```

We might hope that the data would somehow be routed to the `capitals` table, but this does not happen: `INSERT` always inserts into exactly the table specified. In some cases it is possible to redirect the insertion using a rule (see Chapter 40). However that does not help for the above case because the `cities` table does not contain the column `state`, and so the command will be rejected before the rule can be applied.

All check constraints and not-null constraints on a parent table are automatically inherited by its children, unless explicitly specified otherwise with `NO INHERIT` clauses. Other types of constraints (unique, primary key, and foreign key constraints) are not inherited.

A table can inherit from more than one parent table, in which case it has the union of the columns defined by the parent tables. Any columns declared in the child table's definition are added to these. If the same column name appears in multiple parent tables, or in both a parent table and the child's definition, then these columns are “merged” so that there is only one such column in the child table. To be merged, columns must have the same data types, else an error is raised. Inheritable check constraints and not-null constraints are merged in a similar fashion. Thus, for example, a merged column will be marked not-null if any one of the column definitions it came from is marked not-null. Check constraints are merged if they have the same name, and the merge will fail if their conditions are different.

Table inheritance is typically established when the child table is created, using the `INHERITS` clause of the `CREATE TABLE` statement. Alternatively, a table which is already defined in a compatible way can have a new parent relationship added, using the `INHERIT` variant of `ALTER TABLE`. To do this the new child table must already include columns with the same names and types as the columns of the parent. It must also include check constraints with the same names and check expressions as those of the parent. Similarly an inheritance link can be removed from a child using the `NO INHERIT` variant of `ALTER TABLE`. Dynamically adding and removing inheritance links like this can be useful when the inheritance relationship is being used for table partitioning (see Section 5.11).

One convenient way to create a compatible table that will later be made a new child is to use the `LIKE` clause in `CREATE TABLE`. This creates a new table with the same columns as the source table. If there are any `CHECK` constraints defined on the source table, the `INCLUDING CONSTRAINTS` option to `LIKE` should be specified, as the new child must have constraints matching the parent to be considered compatible.

A parent table cannot be dropped while any of its children remain. Neither can columns or check constraints of child tables be dropped or altered if they are inherited from any parent tables. If you wish to remove a table and all of its descendants, one easy way is to drop the parent table with the `CASCADE` option (see Section 5.14).

`ALTER TABLE` will propagate any changes in column data definitions and check constraints down the inheritance hierarchy. Again, dropping columns that are depended on by other tables is only possible when using the `CASCADE` option. `ALTER TABLE` follows the same rules for duplicate column merging and rejection that apply during `CREATE TABLE`.

Inherited queries perform access permission checks on the parent table only. Thus, for example, granting `UPDATE` permission on the `cities` table implies permission to update rows in the `capitals` table as well, when they are accessed through `cities`. This preserves the appearance that the data is (also) in the parent table. But the `capitals` table could not be updated directly without an additional grant. In a similar way, the parent table's row security policies (see Section 5.8) are applied to rows coming from child tables during an inherited query. A child table's policies, if any, are applied only when it is the table explicitly named in the query; and in that case, any policies attached to its parent(s) are ignored.

Foreign tables (see Section 5.12) can also be part of inheritance hierarchies, either as parent or child tables, just as regular tables can be. If a foreign table is part of an inheritance hierarchy then any operations not supported by the foreign table are not supported on the whole hierarchy either.

5.10.1. Caveats

Note that not all SQL commands are able to work on inheritance hierarchies. Commands that are used for data querying, data modification, or schema modification (e.g., `SELECT`, `UPDATE`, `DELETE`, most variants of `ALTER TABLE`, but not `INSERT` or `ALTER TABLE . . . RENAME`) typically default to including child tables and support the `ONLY` notation to exclude them. Commands that do database maintenance and tuning (e.g., `REINDEX`, `VACUUM`) typically only work on individual, physical tables and do not support recursing over inheritance hierarchies. The respective behavior of each individual command is documented in its reference page (SQL Commands).

A serious limitation of the inheritance feature is that indexes (including unique constraints) and foreign key constraints only apply to single tables, not to their inheritance children. This is true on both the referencing and referenced sides of a foreign key constraint. Thus, in the terms of the above example:

- If we declared `cities.name` to be `UNIQUE` or a `PRIMARY KEY`, this would not stop the `capitals` table from having rows with names duplicating rows in `cities`. And those duplicate rows would by default show up in queries from `cities`. In fact, by default `capitals` would have no unique constraint at all, and so could contain multiple rows with the same name. You could add a unique constraint to `capitals`, but this would not prevent duplication compared to `cities`.
- Similarly, if we were to specify that `cities.name` `REFERENCES` some other table, this constraint would not automatically propagate to `capitals`. In this case you could work around it by manually adding the same `REFERENCES` constraint to `capitals`.
- Specifying that another table's column `REFERENCES cities(name)` would allow the other table to contain city names, but not capital names. There is no good workaround for this case.

Some functionality not implemented for inheritance hierarchies is implemented for declarative partitioning. Considerable care is needed in deciding whether partitioning with legacy inheritance is useful for your application.

5.11. Table Partitioning

PostgreSQL supports basic table partitioning. This section describes why and how to implement partitioning as part of your database design.

5.11.1. Overview

Partitioning refers to splitting what is logically one large table into smaller physical pieces. Partitioning can provide several benefits:

- Query performance can be improved dramatically in certain situations, particularly when most of the heavily accessed rows of the table are in a single partition or a small number of partitions. The partitioning substitutes for leading columns of indexes, reducing index size and making it more likely that the heavily-used parts of the indexes fit in memory.
- When queries or updates access a large percentage of a single partition, performance can be improved by taking advantage of sequential scan of that partition instead of using an index and random access reads scattered across the whole table.
- Bulk loads and deletes can be accomplished by adding or removing partitions, if that requirement is planned into the partitioning design. Doing `ALTER TABLE DETACH PARTITION` or dropping an individual partition using `DROP TABLE` is far faster than a bulk operation. These commands also entirely avoid the `VACUUM` overhead caused by a bulk `DELETE`.
- Seldom-used data can be migrated to cheaper and slower storage media.

The benefits will normally be worthwhile only when a table would otherwise be very large. The exact point at which a table will benefit from partitioning depends on the application, although a rule of thumb is that the size of the table should exceed the physical memory of the database server.

PostgreSQL offers built-in support for the following forms of partitioning:

Range Partitioning

The table is partitioned into “ranges” defined by a key column or set of columns, with no overlap between the ranges of values assigned to different partitions. For example, one might partition by date ranges, or by ranges of identifiers for particular business objects.

List Partitioning

The table is partitioned by explicitly listing which key values appear in each partition.

Hash Partitioning

The table is partitioned by specifying a modulus and a remainder for each partition. Each partition will hold the rows for which the hash value of the partition key divided by the specified modulus will produce the specified remainder.

If your application needs to use other forms of partitioning not listed above, alternative methods such as inheritance and `UNION ALL` views can be used instead. Such methods offer flexibility but do not have some of the performance benefits of built-in declarative partitioning.

5.11.2. Declarative Partitioning

PostgreSQL offers a way to specify how to divide a table into pieces called partitions. The table that is divided is referred to as a *partitioned table*. The specification consists of the *partitioning method* and a list of columns or expressions to be used as the *partition key*.

All rows inserted into a partitioned table will be routed to one of the *partitions* based on the value of the partition key. Each partition has a subset of the data defined by its *partition bounds*. The currently supported partitioning methods are range, list, and hash.

Partitions may themselves be defined as partitioned tables, using what is called *sub-partitioning*. Partitions may have their own indexes, constraints and default values, distinct from those of other partitions. See `CREATE TABLE` for more details on creating partitioned tables and partitions.

It is not possible to turn a regular table into a partitioned table or vice versa. However, it is possible to add a regular or partitioned table containing data as a partition of a partitioned table, or remove a partition from a partitioned table turning it into a standalone table; see `ALTER TABLE` to learn more about the `ATTACH PARTITION` and `DETACH PARTITION` sub-commands.

Individual partitions are linked to the partitioned table with inheritance behind-the-scenes; however, it is not possible to use some of the generic features of inheritance (discussed below) with declaratively partitioned tables or their partitions. For example, a partition cannot have any parents other than the partitioned table it is a partition of, nor can a regular table inherit from a partitioned table making the latter its parent. That means partitioned tables and their partitions do not participate in inheritance with regular tables. Since a partition hierarchy consisting of the partitioned table and its partitions is still an inheritance hierarchy, all the normal rules of inheritance apply as described in Section 5.10 with some exceptions, most notably:

- Both `CHECK` and `NOT NULL` constraints of a partitioned table are always inherited by all its partitions. `CHECK` constraints that are marked `NO INHERIT` are not allowed to be created on partitioned tables.
- Using `ONLY` to add or drop a constraint on only the partitioned table is supported as long as there are no partitions. Once partitions exist, using `ONLY` will result in an error as adding or dropping constraints on only the partitioned table, when partitions exist, is not supported. Instead, constraints on the partitions themselves can be added and (if they are not present in the parent table) dropped.
- As a partitioned table does not have any data directly, attempts to use `TRUNCATE ONLY` on a partitioned table will always return an error.
- Partitions cannot have columns that are not present in the parent. It is not possible to specify columns when creating partitions with `CREATE TABLE`, nor is it possible to add columns to partitions after-the-fact using `ALTER TABLE`. Tables may be added as a partition with `ALTER TABLE . . . ATTACH PARTITION` only if their columns exactly match the parent.

- You cannot drop the `NOT NULL` constraint on a partition's column if the constraint is present in the parent table.

Partitions can also be foreign tables, although they have some limitations that normal tables do not; see `CREATE FOREIGN TABLE` for more information.

Updating the partition key of a row might cause it to be moved into a different partition where this row satisfies the partition bounds.

5.11.2.1. Example

Suppose we are constructing a database for a large ice cream company. The company measures peak temperatures every day as well as ice cream sales in each region. Conceptually, we want a table like:

```
CREATE TABLE measurement (  
    city_id          int not null,  
    logdate          date not null,  
    peaktemp        int,  
    unitsales       int  
);
```

We know that most queries will access just the last week's, month's or quarter's data, since the main use of this table will be to prepare online reports for management. To reduce the amount of old data that needs to be stored, we decide to only keep the most recent 3 years worth of data. At the beginning of each month we will remove the oldest month's data. In this situation we can use partitioning to help us meet all of our different requirements for the measurements table.

To use declarative partitioning in this case, use the following steps:

1. Create `measurement` table as a partitioned table by specifying the `PARTITION BY` clause, which includes the partitioning method (`RANGE` in this case) and the list of column(s) to use as the partition key.

```
CREATE TABLE measurement (  
    city_id          int not null,  
    logdate          date not null,  
    peaktemp        int,  
    unitsales       int  
) PARTITION BY RANGE (logdate);
```

- You may decide to use multiple columns in the partition key for range partitioning, if desired. Of course, this will often result in a larger number of partitions, each of which is individually smaller. On the other hand, using fewer columns may lead to a coarser-grained partitioning criteria with smaller number of partitions. A query accessing the partitioned table will have to scan fewer partitions if the conditions involve some or all of these columns. For example, consider a table range partitioned using columns `lastname` and `firstname` (in that order) as the partition key.
2. Create partitions. Each partition's definition must specify the bounds that correspond to the partitioning method and partition key of the parent. Note that specifying bounds such that the new partition's values will overlap with those in one or more existing partitions will cause an error. Inserting data into the parent table that does not map to one of the existing partitions will cause an error; an appropriate partition must be added manually.

Partitions thus created are in every way normal PostgreSQL tables (or, possibly, foreign tables). It is possible to specify a tablespace and storage parameters for each partition separately.

It is not necessary to create table constraints describing partition boundary condition for partitions. Instead, partition constraints are generated implicitly from the partition bound specification whenever there is need to refer to them.

```

CREATE TABLE measurement_y2006m02 PARTITION OF measurement
  FOR VALUES FROM ('2006-02-01') TO ('2006-03-01');

CREATE TABLE measurement_y2006m03 PARTITION OF measurement
  FOR VALUES FROM ('2006-03-01') TO ('2006-04-01');

...

CREATE TABLE measurement_y2007m11 PARTITION OF measurement
  FOR VALUES FROM ('2007-11-01') TO ('2007-12-01');

CREATE TABLE measurement_y2007m12 PARTITION OF measurement
  FOR VALUES FROM ('2007-12-01') TO ('2008-01-01')
  TABLESPACE fasttablespace;

CREATE TABLE measurement_y2008m01 PARTITION OF measurement
  FOR VALUES FROM ('2008-01-01') TO ('2008-02-01')
  WITH (parallel_workers = 4)
  TABLESPACE fasttablespace;

```

To implement sub-partitioning, specify the `PARTITION BY` clause in the commands used to create individual partitions, for example:

```

CREATE TABLE measurement_y2006m02 PARTITION OF measurement
  FOR VALUES FROM ('2006-02-01') TO ('2006-03-01')
  PARTITION BY RANGE (peaktemp);

```

After creating partitions of `measurement_y2006m02`, any data inserted into `measurement` that is mapped to `measurement_y2006m02` (or data that is directly inserted into `measurement_y2006m02`, provided it satisfies its partition constraint) will be further redirected to one of its partitions based on the `peaktemp` column. The partition key specified may overlap with the parent's partition key, although care should be taken when specifying the bounds of a sub-partition such that the set of data it accepts constitutes a subset of what the partition's own bounds allows; the system does not try to check whether that's really the case.

3. Create an index on the key column(s), as well as any other indexes you might want, on the partitioned table. (The key index is not strictly necessary, but in most scenarios it is helpful.) This automatically creates one index on each partition, and any partitions you create or attach later will also contain the index.

```

CREATE INDEX ON measurement (logdate);

```

4. Ensure that the `enable_partition_pruning` configuration parameter is not disabled in `postgresql.conf`. If it is, queries will not be optimized as desired.

In the above example we would be creating a new partition each month, so it might be wise to write a script that generates the required DDL automatically.

5.11.2.2. Partition Maintenance

Normally the set of partitions established when initially defining the table are not intended to remain static. It is common to want to remove old partitions of data and periodically add new partitions for new data. One of the most important advantages of partitioning is precisely that it allows this otherwise painful task to be executed nearly instantaneously by manipulating the partition structure, rather than physically moving large amounts of data around.

The simplest option for removing old data is to drop the partition that is no longer necessary:

```
DROP TABLE measurement_y2006m02;
```

This can very quickly delete millions of records because it doesn't have to individually delete every record. Note however that the above command requires taking an `ACCESS EXCLUSIVE` lock on the parent table.

Another option that is often preferable is to remove the partition from the partitioned table but retain access to it as a table in its own right:

```
ALTER TABLE measurement DETACH PARTITION measurement_y2006m02;
```

This allows further operations to be performed on the data before it is dropped. For example, this is often a useful time to back up the data using `COPY`, `pg_dump`, or similar tools. It might also be a useful time to aggregate data into smaller formats, perform other data manipulations, or run reports.

Similarly we can add a new partition to handle new data. We can create an empty partition in the partitioned table just as the original partitions were created above:

```
CREATE TABLE measurement_y2008m02 PARTITION OF measurement
    FOR VALUES FROM ('2008-02-01') TO ('2008-03-01')
    TABLESPACE fasttablespace;
```

As an alternative, it is sometimes more convenient to create the new table outside the partition structure, and make it a proper partition later. This allows the data to be loaded, checked, and transformed prior to it appearing in the partitioned table:

```
CREATE TABLE measurement_y2008m02
    (LIKE measurement INCLUDING DEFAULTS INCLUDING CONSTRAINTS)
    TABLESPACE fasttablespace;
```

```
ALTER TABLE measurement_y2008m02 ADD CONSTRAINT y2008m02
    CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE
    '2008-03-01' );
```

```
\copy measurement_y2008m02 from 'measurement_y2008m02'
-- possibly some other data preparation work
```

```
ALTER TABLE measurement ATTACH PARTITION measurement_y2008m02
    FOR VALUES FROM ('2008-02-01') TO ('2008-03-01' );
```

Before running the `ATTACH PARTITION` command, it is recommended to create a `CHECK` constraint on the table to be attached matching the desired partition constraint. That way, the system will be able to skip the scan to validate the implicit partition constraint. Without the `CHECK` constraint, the table will be scanned to validate the partition constraint while holding an `ACCESS EXCLUSIVE` lock on that partition and a `SHARE UPDATE EXCLUSIVE` lock on the parent table. It may be desired to drop the redundant `CHECK` constraint after `ATTACH PARTITION` is finished.

As explained above, it is possible to create indexes on partitioned tables and they are applied automatically to the entire hierarchy. This is very convenient, as not only the existing partitions will become indexed, but also any partitions that are created in the future will. One limitation is that it's not possible to use the `CONCURRENTLY` qualifier when creating such a partitioned index. To overcome long lock times, it is possible to use `CREATE INDEX ON ONLY` the partitioned table; such an index is marked invalid, and the partitions do not get the index applied automatically. The indexes on partitions can be created separately using `CONCURRENTLY`, and later *attached* to the index on the parent using `ALTER INDEX . . ATTACH PARTITION`. Once indexes for all partitions are attached to the parent index, the parent index is marked valid automatically. Example:

```
CREATE INDEX measurement_usls_idx ON ONLY measurement (unitsales);

CREATE INDEX measurement_usls_200602_idx
  ON measurement_y2006m02 (unitsales);
ALTER INDEX measurement_usls_idx
  ATTACH PARTITION measurement_usls_200602_idx;
...

```

This technique can be used with `UNIQUE` and `PRIMARY KEY` constraints too; the indexes are created implicitly when the constraint is created. Example:

```
ALTER TABLE ONLY measurement ADD UNIQUE (city_id, logdate);

ALTER TABLE measurement_y2006m02 ADD UNIQUE (city_id, logdate);
ALTER INDEX measurement_city_id_logdate_key
  ATTACH PARTITION measurement_y2006m02_city_id_logdate_key;
...

```

5.11.2.3. Limitations

The following limitations apply to partitioned tables:

- There is no way to create an exclusion constraint spanning all partitions; it is only possible to constrain each leaf partition individually.
- Unique constraints on partitioned tables must include all the partition key columns. This limitation exists because PostgreSQL can only enforce uniqueness in each partition individually.
- `BEFORE ROW` triggers, if necessary, must be defined on individual partitions, not the partitioned table.
- Mixing temporary and permanent relations in the same partition tree is not allowed. Hence, if the partitioned table is permanent, so must be its partitions and likewise if the partitioned table is temporary. When using temporary relations, all members of the partition tree have to be from the same session.

5.11.3. Implementation Using Inheritance

While the built-in declarative partitioning is suitable for most common use cases, there are some circumstances where a more flexible approach may be useful. Partitioning can be implemented using table inheritance, which allows for several features not supported by declarative partitioning, such as:

- For declarative partitioning, partitions must have exactly the same set of columns as the partitioned table, whereas with table inheritance, child tables may have extra columns not present in the parent.
- Table inheritance allows for multiple inheritance.
- Declarative partitioning only supports range, list and hash partitioning, whereas table inheritance allows data to be divided in a manner of the user's choosing. (Note, however, that if constraint exclusion is unable to prune child tables effectively, query performance might be poor.)
- Some operations require a stronger lock when using declarative partitioning than when using table inheritance. For example, adding or removing a partition to or from a partitioned table requires taking an `ACCESS EXCLUSIVE` lock on the parent table, whereas a `SHARE UPDATE EXCLUSIVE` lock is enough in the case of regular inheritance.

5.11.3.1. Example

We use the same measurement table we used above. To implement partitioning using inheritance, use the following steps:

1. Create the “master” table, from which all of the “child” tables will inherit. This table will contain no data. Do not define any check constraints on this table, unless you intend them to be applied equally to all child tables. There is no point in defining any indexes or unique constraints on it, either. For our example, the master table is the measurement table as originally defined.
2. Create several “child” tables that each inherit from the master table. Normally, these tables will not add any columns to the set inherited from the master. Just as with declarative partitioning, these tables are in every way normal PostgreSQL tables (or foreign tables).

```
CREATE TABLE measurement_y2006m02 () INHERITS (measurement);
CREATE TABLE measurement_y2006m03 () INHERITS (measurement);
...
CREATE TABLE measurement_y2007m11 () INHERITS (measurement);
CREATE TABLE measurement_y2007m12 () INHERITS (measurement);
CREATE TABLE measurement_y2008m01 () INHERITS (measurement);
```

3. Add non-overlapping table constraints to the child tables to define the allowed key values in each.

Typical examples would be:

```
CHECK ( x = 1 )
CHECK ( county IN ( 'Oxfordshire', 'Buckinghamshire',
  'Warwickshire' ))
CHECK ( outletID >= 100 AND outletID < 200 )
```

Ensure that the constraints guarantee that there is no overlap between the key values permitted in different child tables. A common mistake is to set up range constraints like:

```
CHECK ( outletID BETWEEN 100 AND 200 )
CHECK ( outletID BETWEEN 200 AND 300 )
```

This is wrong since it is not clear which child table the key value 200 belongs in.

It would be better to instead create child tables as follows:

```
CREATE TABLE measurement_y2006m02 (
  CHECK ( logdate >= DATE '2006-02-01' AND logdate < DATE
  '2006-03-01' )
) INHERITS (measurement);

CREATE TABLE measurement_y2006m03 (
  CHECK ( logdate >= DATE '2006-03-01' AND logdate < DATE
  '2006-04-01' )
) INHERITS (measurement);

...
CREATE TABLE measurement_y2007m11 (
  CHECK ( logdate >= DATE '2007-11-01' AND logdate < DATE
  '2007-12-01' )
) INHERITS (measurement);

CREATE TABLE measurement_y2007m12 (
```

```

    CHECK ( logdate >= DATE '2007-12-01' AND logdate < DATE
'2008-01-01' )
) INHERITS (measurement);

```

```

CREATE TABLE measurement_y2008m01 (
    CHECK ( logdate >= DATE '2008-01-01' AND logdate < DATE
'2008-02-01' )
) INHERITS (measurement);

```

4. For each child table, create an index on the key column(s), as well as any other indexes you might want.

```

CREATE INDEX measurement_y2006m02_logdate ON measurement_y2006m02
(logdate);
CREATE INDEX measurement_y2006m03_logdate ON measurement_y2006m03
(logdate);
CREATE INDEX measurement_y2007m11_logdate ON measurement_y2007m11
(logdate);
CREATE INDEX measurement_y2007m12_logdate ON measurement_y2007m12
(logdate);
CREATE INDEX measurement_y2008m01_logdate ON measurement_y2008m01
(logdate);

```

5. We want our application to be able to say `INSERT INTO measurement ...` and have the data be redirected into the appropriate child table. We can arrange that by attaching a suitable trigger function to the master table. If data will be added only to the latest child, we can use a very simple trigger function:

```

CREATE OR REPLACE FUNCTION measurement_insert_trigger()
RETURNS TRIGGER AS $$
BEGIN
    INSERT INTO measurement_y2008m01 VALUES (NEW.*);
    RETURN NULL;
END;
$$
LANGUAGE plpgsql;

```

After creating the function, we create a trigger which calls the trigger function:

```

CREATE TRIGGER insert_measurement_trigger
BEFORE INSERT ON measurement
FOR EACH ROW EXECUTE FUNCTION measurement_insert_trigger();

```

We must redefine the trigger function each month so that it always points to the current child table. The trigger definition does not need to be updated, however.

We might want to insert data and have the server automatically locate the child table into which the row should be added. We could do this with a more complex trigger function, for example:

```

CREATE OR REPLACE FUNCTION measurement_insert_trigger()
RETURNS TRIGGER AS $$
BEGIN
    IF ( NEW.logdate >= DATE '2006-02-01' AND
NEW.logdate < DATE '2006-03-01' ) THEN
        INSERT INTO measurement_y2006m02 VALUES (NEW.*);
    ELSIF ( NEW.logdate >= DATE '2006-03-01' AND
NEW.logdate < DATE '2006-04-01' ) THEN

```

```

        INSERT INTO measurement_y2006m03 VALUES (NEW.*);
    ...
    ELSIF ( NEW.logdate >= DATE '2008-01-01' AND
           NEW.logdate < DATE '2008-02-01' ) THEN
        INSERT INTO measurement_y2008m01 VALUES (NEW.*);
    ELSE
        RAISE EXCEPTION 'Date out of range. Fix the
measurement_insert_trigger() function!';
    END IF;
    RETURN NULL;
END;
$$
LANGUAGE plpgsql;

```

The trigger definition is the same as before. Note that each IF test must exactly match the CHECK constraint for its child table.

While this function is more complex than the single-month case, it doesn't need to be updated as often, since branches can be added in advance of being needed.

Note

In practice, it might be best to check the newest child first, if most inserts go into that child. For simplicity, we have shown the trigger's tests in the same order as in other parts of this example.

A different approach to redirecting inserts into the appropriate child table is to set up rules, instead of a trigger, on the master table. For example:

```

CREATE RULE measurement_insert_y2006m02 AS
ON INSERT TO measurement WHERE
    ( logdate >= DATE '2006-02-01' AND logdate < DATE
      '2006-03-01' )
DO INSTEAD
    INSERT INTO measurement_y2006m02 VALUES (NEW.*);
...
CREATE RULE measurement_insert_y2008m01 AS
ON INSERT TO measurement WHERE
    ( logdate >= DATE '2008-01-01' AND logdate < DATE
      '2008-02-01' )
DO INSTEAD
    INSERT INTO measurement_y2008m01 VALUES (NEW.*);

```

A rule has significantly more overhead than a trigger, but the overhead is paid once per query rather than once per row, so this method might be advantageous for bulk-insert situations. In most cases, however, the trigger method will offer better performance.

Be aware that COPY ignores rules. If you want to use COPY to insert data, you'll need to copy into the correct child table rather than directly into the master. COPY does fire triggers, so you can use it normally if you use the trigger approach.

Another disadvantage of the rule approach is that there is no simple way to force an error if the set of rules doesn't cover the insertion date; the data will silently go into the master table instead.

6. Ensure that the `constraint_exclusion` configuration parameter is not disabled in `postgres.conf`; otherwise child tables may be accessed unnecessarily.

As we can see, a complex table hierarchy could require a substantial amount of DDL. In the above example we would be creating a new child table each month, so it might be wise to write a script that generates the required DDL automatically.

5.11.3.2. Maintenance for Inheritance Partitioning

To remove old data quickly, simply drop the child table that is no longer necessary:

```
DROP TABLE measurement_y2006m02;
```

To remove the child table from the inheritance hierarchy table but retain access to it as a table in its own right:

```
ALTER TABLE measurement_y2006m02 NO INHERIT measurement;
```

To add a new child table to handle new data, create an empty child table just as the original children were created above:

```
CREATE TABLE measurement_y2008m02 (
    CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE
    '2008-03-01' )
) INHERITS (measurement);
```

Alternatively, one may want to create and populate the new child table before adding it to the table hierarchy. This could allow data to be loaded, checked, and transformed before being made visible to queries on the parent table.

```
CREATE TABLE measurement_y2008m02
    (LIKE measurement INCLUDING DEFAULTS INCLUDING CONSTRAINTS);
ALTER TABLE measurement_y2008m02 ADD CONSTRAINT y2008m02
    CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE
    '2008-03-01' );
\copy measurement_y2008m02 from 'measurement_y2008m02'
-- possibly some other data preparation work
ALTER TABLE measurement_y2008m02 INHERIT measurement;
```

5.11.3.3. Caveats

The following caveats apply to partitioning implemented using inheritance:

- There is no automatic way to verify that all of the CHECK constraints are mutually exclusive. It is safer to create code that generates child tables and creates and/or modifies associated objects than to write each by hand.
- Indexes and foreign key constraints apply to single tables and not to their inheritance children, hence they have some caveats to be aware of.
- The schemes shown here assume that the values of a row's key column(s) never change, or at least do not change enough to require it to move to another partition. An UPDATE that attempts to do that will fail because of the CHECK constraints. If you need to handle such cases, you can put suitable update triggers on the child tables, but it makes management of the structure much more complicated.
- If you are using manual VACUUM or ANALYZE commands, don't forget that you need to run them on each child table individually. A command like:

```
ANALYZE measurement;
```

will only process the master table.

- INSERT statements with ON CONFLICT clauses are unlikely to work as expected, as the ON CONFLICT action is only taken in case of unique violations on the specified target relation, not its child relations.
- Triggers or rules will be needed to route rows to the desired child table, unless the application is explicitly aware of the partitioning scheme. Triggers may be complicated to write, and will be much slower than the tuple routing performed internally by declarative partitioning.

5.11.4. Partition Pruning

Partition pruning is a query optimization technique that improves performance for declaratively partitioned tables. As an example:

```
SET enable_partition_pruning = on;           -- the default
SELECT count(*) FROM measurement WHERE logdate >= DATE
      '2008-01-01';
```

Without partition pruning, the above query would scan each of the partitions of the measurement table. With partition pruning enabled, the planner will examine the definition of each partition and prove that the partition need not be scanned because it could not contain any rows meeting the query's WHERE clause. When the planner can prove this, it excludes (*prunes*) the partition from the query plan.

By using the EXPLAIN command and the enable_partition_pruning configuration parameter, it's possible to show the difference between a plan for which partitions have been pruned and one for which they have not. A typical unoptimized plan for this type of table setup is:

```
SET enable_partition_pruning = off;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE
      '2008-01-01';
```

QUERY PLAN

```
-----
Aggregate  (cost=188.76..188.77 rows=1 width=8)
  -> Append  (cost=0.00..181.05 rows=3085 width=0)
    -> Seq Scan on measurement_y2006m02  (cost=0.00..33.12
rows=617 width=0)
          Filter: (logdate >= '2008-01-01'::date)
    -> Seq Scan on measurement_y2006m03  (cost=0.00..33.12
rows=617 width=0)
          Filter: (logdate >= '2008-01-01'::date)
...
    -> Seq Scan on measurement_y2007m11  (cost=0.00..33.12
rows=617 width=0)
          Filter: (logdate >= '2008-01-01'::date)
    -> Seq Scan on measurement_y2007m12  (cost=0.00..33.12
rows=617 width=0)
          Filter: (logdate >= '2008-01-01'::date)
    -> Seq Scan on measurement_y2008m01  (cost=0.00..33.12
rows=617 width=0)
          Filter: (logdate >= '2008-01-01'::date)
```

Some or all of the partitions might use index scans instead of full-table sequential scans, but the point here is that there is no need to scan the older partitions at all to answer this query. When we enable partition pruning, we get a significantly cheaper plan that will deliver the same answer:

```
SET enable_partition_pruning = on;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE
'2008-01-01';
```

QUERY PLAN

```
-----
Aggregate  (cost=37.75..37.76 rows=1 width=8)
  -> Seq Scan on measurement_y2008m01  (cost=0.00..33.12 rows=617
width=0)
    Filter: (logdate >= '2008-01-01'::date)
```

Note that partition pruning is driven only by the constraints defined implicitly by the partition keys, not by the presence of indexes. Therefore it isn't necessary to define indexes on the key columns. Whether an index needs to be created for a given partition depends on whether you expect that queries that scan the partition will generally scan a large part of the partition or just a small part. An index will be helpful in the latter case but not the former.

Partition pruning can be performed not only during the planning of a given query, but also during its execution. This is useful as it can allow more partitions to be pruned when clauses contain expressions whose values are not known at query planning time, for example, parameters defined in a `PREPARE` statement, using a value obtained from a subquery, or using a parameterized value on the inner side of a nested loop join. Partition pruning during execution can be performed at any of the following times:

- During initialization of the query plan. Partition pruning can be performed here for parameter values which are known during the initialization phase of execution. Partitions which are pruned during this stage will not show up in the query's `EXPLAIN` or `EXPLAIN ANALYZE`. It is possible to determine the number of partitions which were removed during this phase by observing the “Subplans Removed” property in the `EXPLAIN` output.
- During actual execution of the query plan. Partition pruning may also be performed here to remove partitions using values which are only known during actual query execution. This includes values from subqueries and values from execution-time parameters such as those from parameterized nested loop joins. Since the value of these parameters may change many times during the execution of the query, partition pruning is performed whenever one of the execution parameters being used by partition pruning changes. Determining if partitions were pruned during this phase requires careful inspection of the `loops` property in the `EXPLAIN ANALYZE` output. Subplans corresponding to different partitions may have different values for it depending on how many times each of them was pruned during execution. Some may be shown as `(never executed)` if they were pruned every time.

Partition pruning can be disabled using the `enable_partition_pruning` setting.

Note

Execution-time partition pruning currently only occurs for the `Append` and `MergeAppend` node types. It is not yet implemented for the `ModifyTable` node type, but that is likely to be changed in a future release of PostgreSQL.

5.11.5. Partitioning and Constraint Exclusion

Constraint exclusion is a query optimization technique similar to partition pruning. While it is primarily used for partitioning implemented using the legacy inheritance method, it can be used for other purposes, including with declarative partitioning.

Constraint exclusion works in a very similar way to partition pruning, except that it uses each table's `CHECK` constraints — which gives it its name — whereas partition pruning uses the table's partition

bounds, which exist only in the case of declarative partitioning. Another difference is that constraint exclusion is only applied at plan time; there is no attempt to remove partitions at execution time.

The fact that constraint exclusion uses CHECK constraints, which makes it slow compared to partition pruning, can sometimes be used as an advantage: because constraints can be defined even on declaratively-partitioned tables, in addition to their internal partition bounds, constraint exclusion may be able to elide additional partitions from the query plan.

The default (and recommended) setting of `constraint_exclusion` is neither `on` nor `off`, but an intermediate setting called `partition`, which causes the technique to be applied only to queries that are likely to be working on inheritance partitioned tables. The `on` setting causes the planner to examine CHECK constraints in all queries, even simple ones that are unlikely to benefit.

The following caveats apply to constraint exclusion:

- Constraint exclusion is only applied during query planning, unlike partition pruning, which can also be applied during query execution.
- Constraint exclusion only works when the query's WHERE clause contains constants (or externally supplied parameters). For example, a comparison against a non-immutable function such as `CURRENT_TIMESTAMP` cannot be optimized, since the planner cannot know which child table the function's value might fall into at run time.
- Keep the partitioning constraints simple, else the planner may not be able to prove that child tables might not need to be visited. Use simple equality conditions for list partitioning, or simple range tests for range partitioning, as illustrated in the preceding examples. A good rule of thumb is that partitioning constraints should contain only comparisons of the partitioning column(s) to constants using B-tree-indexable operators, because only B-tree-indexable column(s) are allowed in the partition key.
- All constraints on all children of the parent table are examined during constraint exclusion, so large numbers of children are likely to increase query planning time considerably. So the legacy inheritance based partitioning will work well with up to perhaps a hundred child tables; don't try to use many thousands of children.

5.11.6. Declarative Partitioning Best Practices

The choice of how to partition a table should be made carefully as the performance of query planning and execution can be negatively affected by poor design.

One of the most critical design decisions will be the column or columns by which you partition your data. Often the best choice will be to partition by the column or set of columns which most commonly appear in WHERE clauses of queries being executed on the partitioned table. WHERE clause items that match and are compatible with the partition key can be used to prune unneeded partitions. However, you may be forced into making other decisions by requirements for the PRIMARY KEY or a UNIQUE constraint. Removal of unwanted data is also a factor to consider when planning your partitioning strategy. An entire partition can be detached fairly quickly, so it may be beneficial to design the partition strategy in such a way that all data to be removed at once is located in a single partition.

Choosing the target number of partitions that the table should be divided into is also a critical decision to make. Not having enough partitions may mean that indexes remain too large and that data locality remains poor which could result in low cache hit ratios. However, dividing the table into too many partitions can also cause issues. Too many partitions can mean longer query planning times and higher memory consumption during both query planning and execution. When choosing how to partition your table, it's also important to consider what changes may occur in the future. For example, if you choose to have one partition per customer and you currently have a small number of large customers, consider the implications if in several years you instead find yourself with a large number of small customers. In this case, it may be better to choose to partition by HASH and choose a reasonable number of partitions rather than trying to partition by LIST and hoping that the number of customers does not increase beyond what it is practical to partition the data by.

Sub-partitioning can be useful to further divide partitions that are expected to become larger than other partitions, although excessive sub-partitioning can easily lead to large numbers of partitions and can cause the same problems mentioned in the preceding paragraph.

It is also important to consider the overhead of partitioning during query planning and execution. The query planner is generally able to handle partition hierarchies with up to a few thousand partitions fairly well, provided that typical queries allow the query planner to prune all but a small number of partitions. Planning times become longer and memory consumption becomes higher when more partitions remain after the planner performs partition pruning. This is particularly true for the `UPDATE` and `DELETE` commands. Another reason to be concerned about having a large number of partitions is that the server's memory consumption may grow significantly over a period of time, especially if many sessions touch large numbers of partitions. That's because each partition requires its metadata to be loaded into the local memory of each session that touches it.

With data warehouse type workloads, it can make sense to use a larger number of partitions than with an OLTP type workload. Generally, in data warehouses, query planning time is less of a concern as the majority of processing time is spent during query execution. With either of these two types of workload, it is important to make the right decisions early, as re-partitioning large quantities of data can be painfully slow. Simulations of the intended workload are often beneficial for optimizing the partitioning strategy. Never assume that more partitions are better than fewer partitions and vice-versa.

5.12. Foreign Data

PostgreSQL implements portions of the SQL/MED specification, allowing you to access data that resides outside PostgreSQL using regular SQL queries. Such data is referred to as *foreign data*. (Note that this usage is not to be confused with foreign keys, which are a type of constraint within the database.)

Foreign data is accessed with help from a *foreign data wrapper*. A foreign data wrapper is a library that can communicate with an external data source, hiding the details of connecting to the data source and obtaining data from it. There are some foreign data wrappers available as `contrib` modules; see Appendix F. Other kinds of foreign data wrappers might be found as third party products. If none of the existing foreign data wrappers suit your needs, you can write your own; see Chapter 56.

To access foreign data, you need to create a *foreign server* object, which defines how to connect to a particular external data source according to the set of options used by its supporting foreign data wrapper. Then you need to create one or more *foreign tables*, which define the structure of the remote data. A foreign table can be used in queries just like a normal table, but a foreign table has no storage in the PostgreSQL server. Whenever it is used, PostgreSQL asks the foreign data wrapper to fetch data from the external source, or transmit data to the external source in the case of update commands.

Accessing remote data may require authenticating to the external data source. This information can be provided by a *user mapping*, which can provide additional data such as user names and passwords based on the current PostgreSQL role.

For additional information, see `CREATE FOREIGN DATA WRAPPER`, `CREATE SERVER`, `CREATE USER MAPPING`, `CREATE FOREIGN TABLE`, and `IMPORT FOREIGN SCHEMA`.

5.13. Other Database Objects

Tables are the central objects in a relational database structure, because they hold your data. But they are not the only objects that exist in a database. Many other kinds of objects can be created to make the use and management of the data more efficient or convenient. They are not discussed in this chapter, but we give you a list here so that you are aware of what is possible:

- Views
- Functions, procedures, and operators

- Data types and domains
- Triggers and rewrite rules

Detailed information on these topics appears in Part V.

5.14. Dependency Tracking

When you create complex database structures involving many tables with foreign key constraints, views, triggers, functions, etc. you implicitly create a net of dependencies between the objects. For instance, a table with a foreign key constraint depends on the table it references.

To ensure the integrity of the entire database structure, PostgreSQL makes sure that you cannot drop objects that other objects still depend on. For example, attempting to drop the `products` table we considered in Section 5.4.5, with the `orders` table depending on it, would result in an error message like this:

```
DROP TABLE products;
```

```
ERROR:  cannot drop table products because other objects depend on
it
DETAIL:  constraint orders_product_no_fkey on table orders depends
on table products
HINT:   Use DROP ... CASCADE to drop the dependent objects too.
```

The error message contains a useful hint: if you do not want to bother deleting all the dependent objects individually, you can run:

```
DROP TABLE products CASCADE;
```

and all the dependent objects will be removed, as will any objects that depend on them, recursively. In this case, it doesn't remove the `orders` table, it only removes the foreign key constraint. It stops there because nothing depends on the foreign key constraint. (If you want to check what `DROP ... CASCADE` will do, run `DROP` without `CASCADE` and read the `DETAIL` output.)

Almost all `DROP` commands in PostgreSQL support specifying `CASCADE`. Of course, the nature of the possible dependencies varies with the type of the object. You can also write `RESTRICT` instead of `CASCADE` to get the default behavior, which is to prevent dropping objects that any other objects depend on.

Note

According to the SQL standard, specifying either `RESTRICT` or `CASCADE` is required in a `DROP` command. No database system actually enforces that rule, but whether the default behavior is `RESTRICT` or `CASCADE` varies across systems.

If a `DROP` command lists multiple objects, `CASCADE` is only required when there are dependencies outside the specified group. For example, when saying `DROP TABLE tab1, tab2` the existence of a foreign key referencing `tab1` from `tab2` would not mean that `CASCADE` is needed to succeed.

For user-defined functions, PostgreSQL tracks dependencies associated with a function's externally-visible properties, such as its argument and result types, but *not* dependencies that could only be known by examining the function body. As an example, consider this situation:

```
CREATE TYPE rainbow AS ENUM ('red', 'orange', 'yellow',
                             'green', 'blue', 'purple');

CREATE TABLE my_colors (color rainbow, note text);

CREATE FUNCTION get_color_note (rainbow) RETURNS text AS
  'SELECT note FROM my_colors WHERE color = $1'
  LANGUAGE SQL;
```

(See Section 37.5 for an explanation of SQL-language functions.) PostgreSQL will be aware that the `get_color_note` function depends on the `rainbow` type: dropping the type would force dropping the function, because its argument type would no longer be defined. But PostgreSQL will not consider `get_color_note` to depend on the `my_colors` table, and so will not drop the function if the table is dropped. While there are disadvantages to this approach, there are also benefits. The function is still valid in some sense if the table is missing, though executing it would cause an error; creating a new table of the same name would allow the function to work again.

Chapter 6. Data Manipulation

The previous chapter discussed how to create tables and other structures to hold your data. Now it is time to fill the tables with data. This chapter covers how to insert, update, and delete table data. The chapter after this will finally explain how to extract your long-lost data from the database.

6.1. Inserting Data

When a table is created, it contains no data. The first thing to do before a database can be of much use is to insert data. Data is conceptually inserted one row at a time. Of course you can also insert more than one row, but there is no way to insert less than one row. Even if you know only some column values, a complete row must be created.

To create a new row, use the `INSERT` command. The command requires the table name and column values. For example, consider the `products` table from Chapter 5:

```
CREATE TABLE products (  
    product_no integer,  
    name text,  
    price numeric  
);
```

An example command to insert a row would be:

```
INSERT INTO products VALUES (1, 'Cheese', 9.99);
```

The data values are listed in the order in which the columns appear in the table, separated by commas. Usually, the data values will be literals (constants), but scalar expressions are also allowed.

The above syntax has the drawback that you need to know the order of the columns in the table. To avoid this you can also list the columns explicitly. For example, both of the following commands have the same effect as the one above:

```
INSERT INTO products (product_no, name, price) VALUES (1, 'Cheese',  
9.99);  
INSERT INTO products (name, price, product_no) VALUES ('Cheese',  
9.99, 1);
```

Many users consider it good practice to always list the column names.

If you don't have values for all the columns, you can omit some of them. In that case, the columns will be filled with their default values. For example:

```
INSERT INTO products (product_no, name) VALUES (1, 'Cheese');  
INSERT INTO products VALUES (1, 'Cheese');
```

The second form is a PostgreSQL extension. It fills the columns from the left with as many values as are given, and the rest will be defaulted.

For clarity, you can also request default values explicitly, for individual columns or for the entire row:

```
INSERT INTO products (product_no, name, price) VALUES (1, 'Cheese',  
DEFAULT);
```

```
INSERT INTO products DEFAULT VALUES;
```

You can insert multiple rows in a single command:

```
INSERT INTO products (product_no, name, price) VALUES
  (1, 'Cheese', 9.99),
  (2, 'Bread', 1.99),
  (3, 'Milk', 2.99);
```

It is also possible to insert the result of a query (which might be no rows, one row, or many rows):

```
INSERT INTO products (product_no, name, price)
  SELECT product_no, name, price FROM new_products
  WHERE release_date = 'today';
```

This provides the full power of the SQL query mechanism (Chapter 7) for computing the rows to be inserted.

Tip

When inserting a lot of data at the same time, consider using the COPY command. It is not as flexible as the INSERT command, but is more efficient. Refer to Section 14.4 for more information on improving bulk loading performance.

6.2. Updating Data

The modification of data that is already in the database is referred to as updating. You can update individual rows, all the rows in a table, or a subset of all rows. Each column can be updated separately; the other columns are not affected.

To update existing rows, use the UPDATE command. This requires three pieces of information:

1. The name of the table and column to update
2. The new value of the column
3. Which row(s) to update

Recall from Chapter 5 that SQL does not, in general, provide a unique identifier for rows. Therefore it is not always possible to directly specify which row to update. Instead, you specify which conditions a row must meet in order to be updated. Only if you have a primary key in the table (independent of whether you declared it or not) can you reliably address individual rows by choosing a condition that matches the primary key. Graphical database access tools rely on this fact to allow you to update rows individually.

For example, this command updates all products that have a price of 5 to have a price of 10:

```
UPDATE products SET price = 10 WHERE price = 5;
```

This might cause zero, one, or many rows to be updated. It is not an error to attempt an update that does not match any rows.

Let's look at that command in detail. First is the key word UPDATE followed by the table name. As usual, the table name can be schema-qualified, otherwise it is looked up in the path. Next is the key word SET followed by the column name, an equal sign, and the new column value. The new column value can be any scalar expression, not just a constant. For example, if you want to raise the price of all products by 10% you could use:

```
UPDATE products SET price = price * 1.10;
```

As you see, the expression for the new value can refer to the existing value(s) in the row. We also left out the `WHERE` clause. If it is omitted, it means that all rows in the table are updated. If it is present, only those rows that match the `WHERE` condition are updated. Note that the equals sign in the `SET` clause is an assignment while the one in the `WHERE` clause is a comparison, but this does not create any ambiguity. Of course, the `WHERE` condition does not have to be an equality test. Many other operators are available (see Chapter 9). But the expression needs to evaluate to a Boolean result.

You can update more than one column in an `UPDATE` command by listing more than one assignment in the `SET` clause. For example:

```
UPDATE mytable SET a = 5, b = 3, c = 1 WHERE a > 0;
```

6.3. Deleting Data

So far we have explained how to add data to tables and how to change data. What remains is to discuss how to remove data that is no longer needed. Just as adding data is only possible in whole rows, you can only remove entire rows from a table. In the previous section we explained that SQL does not provide a way to directly address individual rows. Therefore, removing rows can only be done by specifying conditions that the rows to be removed have to match. If you have a primary key in the table then you can specify the exact row. But you can also remove groups of rows matching a condition, or you can remove all rows in the table at once.

You use the `DELETE` command to remove rows; the syntax is very similar to the `UPDATE` command. For instance, to remove all rows from the `products` table that have a price of 10, use:

```
DELETE FROM products WHERE price = 10;
```

If you simply write:

```
DELETE FROM products;
```

then all rows in the table will be deleted! Caveat programmer.

6.4. Returning Data From Modified Rows

Sometimes it is useful to obtain data from modified rows while they are being manipulated. The `INSERT`, `UPDATE`, and `DELETE` commands all have an optional `RETURNING` clause that supports this. Use of `RETURNING` avoids performing an extra database query to collect the data, and is especially valuable when it would otherwise be difficult to identify the modified rows reliably.

The allowed contents of a `RETURNING` clause are the same as a `SELECT` command's output list (see Section 7.3). It can contain column names of the command's target table, or value expressions using those columns. A common shorthand is `RETURNING *`, which selects all columns of the target table in order.

In an `INSERT`, the data available to `RETURNING` is the row as it was inserted. This is not so useful in trivial inserts, since it would just repeat the data provided by the client. But it can be very handy when relying on computed default values. For example, when using a `serial` column to provide unique identifiers, `RETURNING` can return the ID assigned to a new row:

```
CREATE TABLE users (firstname text, lastname text, id serial  
primary key);
```

```
INSERT INTO users (firstname, lastname) VALUES ('Joe', 'Cool')
RETURNING id;
```

The RETURNING clause is also very useful with INSERT ... SELECT.

In an UPDATE, the data available to RETURNING is the new content of the modified row. For example:

```
UPDATE products SET price = price * 1.10
WHERE price <= 99.99
RETURNING name, price AS new_price;
```

In a DELETE, the data available to RETURNING is the content of the deleted row. For example:

```
DELETE FROM products
WHERE obsolescence_date = 'today'
RETURNING *;
```

If there are triggers (Chapter 38) on the target table, the data available to RETURNING is the row as modified by the triggers. Thus, inspecting columns computed by triggers is another common use-case for RETURNING.

Chapter 7. Queries

The previous chapters explained how to create tables, how to fill them with data, and how to manipulate that data. Now we finally discuss how to retrieve the data from the database.

7.1. Overview

The process of retrieving or the command to retrieve data from a database is called a *query*. In SQL the `SELECT` command is used to specify queries. The general syntax of the `SELECT` command is

```
[WITH with_queries] SELECT select_list FROM table_expression
[sort_specification]
```

The following sections describe the details of the select list, the table expression, and the sort specification. `WITH` queries are treated last since they are an advanced feature.

A simple kind of query has the form:

```
SELECT * FROM table1;
```

Assuming that there is a table called `table1`, this command would retrieve all rows and all user-defined columns from `table1`. (The method of retrieval depends on the client application. For example, the `psql` program will display an ASCII-art table on the screen, while client libraries will offer functions to extract individual values from the query result.) The select list specification `*` means all columns that the table expression happens to provide. A select list can also select a subset of the available columns or make calculations using the columns. For example, if `table1` has columns named `a`, `b`, and `c` (and perhaps others) you can make the following query:

```
SELECT a, b + c FROM table1;
```

(assuming that `b` and `c` are of a numerical data type). See Section 7.3 for more details.

`FROM table1` is a simple kind of table expression: it reads just one table. In general, table expressions can be complex constructs of base tables, joins, and subqueries. But you can also omit the table expression entirely and use the `SELECT` command as a calculator:

```
SELECT 3 * 4;
```

This is more useful if the expressions in the select list return varying results. For example, you could call a function this way:

```
SELECT random();
```

7.2. Table Expressions

A *table expression* computes a table. The table expression contains a `FROM` clause that is optionally followed by `WHERE`, `GROUP BY`, and `HAVING` clauses. Trivial table expressions simply refer to a table on disk, a so-called base table, but more complex expressions can be used to modify or combine base tables in various ways.

The optional `WHERE`, `GROUP BY`, and `HAVING` clauses in the table expression specify a pipeline of successive transformations performed on the table derived in the `FROM` clause. All these transforma-

tions produce a virtual table that provides the rows that are passed to the select list to compute the output rows of the query.

7.2.1. The FROM Clause

The FROM Clause derives a table from one or more other tables given in a comma-separated table reference list.

```
FROM table_reference [, table_reference [, ...]]
```

A table reference can be a table name (possibly schema-qualified), or a derived table such as a subquery, a JOIN construct, or complex combinations of these. If more than one table reference is listed in the FROM clause, the tables are cross-joined (that is, the Cartesian product of their rows is formed; see below). The result of the FROM list is an intermediate virtual table that can then be subject to transformations by the WHERE, GROUP BY, and HAVING clauses and is finally the result of the overall table expression.

When a table reference names a table that is the parent of a table inheritance hierarchy, the table reference produces rows of not only that table but all of its descendant tables, unless the key word ONLY precedes the table name. However, the reference produces only the columns that appear in the named table — any columns added in subtables are ignored.

Instead of writing ONLY before the table name, you can write * after the table name to explicitly specify that descendant tables are included. There is no real reason to use this syntax any more, because searching descendant tables is now always the default behavior. However, it is supported for compatibility with older releases.

7.2.1.1. Joined Tables

A joined table is a table derived from two other (real or derived) tables according to the rules of the particular join type. Inner, outer, and cross-joins are available. The general syntax of a joined table is

```
T1 join_type T2 [ join_condition ]
```

Joins of all types can be chained together, or nested: either or both *T1* and *T2* can be joined tables. Parentheses can be used around JOIN clauses to control the join order. In the absence of parentheses, JOIN clauses nest left-to-right.

Join Types

Cross join

```
T1 CROSS JOIN T2
```

For every possible combination of rows from *T1* and *T2* (i.e., a Cartesian product), the joined table will contain a row consisting of all columns in *T1* followed by all columns in *T2*. If the tables have N and M rows respectively, the joined table will have N * M rows.

FROM *T1* CROSS JOIN *T2* is equivalent to FROM *T1* INNER JOIN *T2* ON TRUE (see below). It is also equivalent to FROM *T1*, *T2*.

Note

This latter equivalence does not hold exactly when more than two tables appear, because JOIN binds more tightly than comma. For example FROM *T1* CROSS JOIN *T2* INNER JOIN *T3* ON *condition* is not the same as FROM

T1, *T2* INNER JOIN *T3* ON *condition* because the *condition* can reference *T1* in the first case but not the second.

Qualified joins

```
T1 { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2
  ON boolean_expression
T1 { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2 USING
  ( join column list )
T1 NATURAL { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2
```

The words INNER and OUTER are optional in all forms. INNER is the default; LEFT, RIGHT, and FULL imply an outer join.

The *join condition* is specified in the ON or USING clause, or implicitly by the word NATURAL. The join condition determines which rows from the two source tables are considered to “match”, as explained in detail below.

The possible types of qualified join are:

INNER JOIN

For each row R1 of T1, the joined table has a row for each row in T2 that satisfies the join condition with R1.

LEFT OUTER JOIN

First, an inner join is performed. Then, for each row in T1 that does not satisfy the join condition with any row in T2, a joined row is added with null values in columns of T2. Thus, the joined table always has at least one row for each row in T1.

RIGHT OUTER JOIN

First, an inner join is performed. Then, for each row in T2 that does not satisfy the join condition with any row in T1, a joined row is added with null values in columns of T1. This is the converse of a left join: the result table will always have a row for each row in T2.

FULL OUTER JOIN

First, an inner join is performed. Then, for each row in T1 that does not satisfy the join condition with any row in T2, a joined row is added with null values in columns of T2. Also, for each row of T2 that does not satisfy the join condition with any row in T1, a joined row with null values in the columns of T1 is added.

The ON clause is the most general kind of join condition: it takes a Boolean value expression of the same kind as is used in a WHERE clause. A pair of rows from *T1* and *T2* match if the ON expression evaluates to true.

The USING clause is a shorthand that allows you to take advantage of the specific situation where both sides of the join use the same name for the joining column(s). It takes a comma-separated list of the shared column names and forms a join condition that includes an equality comparison for each one. For example, joining *T1* and *T2* with USING (*a*, *b*) produces the join condition ON *T1.a* = *T2.a* AND *T1.b* = *T2.b*.

Furthermore, the output of JOIN USING suppresses redundant columns: there is no need to print both of the matched columns, since they must have equal values. While JOIN ON produces all columns from *T1* followed by all columns from *T2*, JOIN USING produces one output column for each of the listed column pairs (in the listed order), followed by any remaining columns from *T1*, followed by any remaining columns from *T2*.

Finally, `NATURAL` is a shorthand form of `USING`: it forms a `USING` list consisting of all column names that appear in both input tables. As with `USING`, these columns appear only once in the output table. If there are no common column names, `NATURAL JOIN` behaves like `JOIN . . . ON TRUE`, producing a cross-product join.

Note

`USING` is reasonably safe from column changes in the joined relations since only the listed columns are combined. `NATURAL` is considerably more risky since any schema changes to either relation that cause a new matching column name to be present will cause the join to combine that new column as well.

To put this together, assume we have tables `t1`:

num	name
1	a
2	b
3	c

and `t2`:

num	value
1	xxx
3	YYY
5	zzz

then we get the following results for the various joins:

```
=> SELECT * FROM t1 CROSS JOIN t2;
```

num	name	num	value
1	a	1	xxx
1	a	3	YYY
1	a	5	zzz
2	b	1	xxx
2	b	3	YYY
2	b	5	zzz
3	c	1	xxx
3	c	3	YYY
3	c	5	zzz

(9 rows)

```
=> SELECT * FROM t1 INNER JOIN t2 ON t1.num = t2.num;
```

num	name	num	value
1	a	1	xxx
3	c	3	YYY

(2 rows)

```
=> SELECT * FROM t1 INNER JOIN t2 USING (num);
```

num	name	value
1	a	xxx

```

 3 | c      | YYY
(2 rows)

```

```
=> SELECT * FROM t1 NATURAL INNER JOIN t2;
```

```

 num | name | value
-----+-----+-----
  1 | a    | xxx
  3 | c    | YYY
(2 rows)

```

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num;
```

```

 num | name | num | value
-----+-----+-----+-----
  1 | a    |    1 | xxx
  2 | b    |    |
  3 | c    |    3 | YYY
(3 rows)

```

```
=> SELECT * FROM t1 LEFT JOIN t2 USING (num);
```

```

 num | name | value
-----+-----+-----
  1 | a    | xxx
  2 | b    |
  3 | c    | YYY
(3 rows)

```

```
=> SELECT * FROM t1 RIGHT JOIN t2 ON t1.num = t2.num;
```

```

 num | name | num | value
-----+-----+-----+-----
  1 | a    |    1 | xxx
  3 | c    |    3 | YYY
    |      |    5 | zzz
(3 rows)

```

```
=> SELECT * FROM t1 FULL JOIN t2 ON t1.num = t2.num;
```

```

 num | name | num | value
-----+-----+-----+-----
  1 | a    |    1 | xxx
  2 | b    |    |
  3 | c    |    3 | YYY
    |      |    5 | zzz
(4 rows)

```

The join condition specified with ON can also contain conditions that do not relate directly to the join. This can prove useful for some queries but needs to be thought out carefully. For example:

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num AND t2.value = 'xxx';
```

```

 num | name | num | value
-----+-----+-----+-----
  1 | a    |    1 | xxx
  2 | b    |    |
  3 | c    |    |
(3 rows)

```

Notice that placing the restriction in the WHERE clause produces a different result:

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num WHERE t2.value
   = 'xxx';
   num | name | num | value
-----+-----+-----+-----
    1 | a    |    1 | xxx
(1 row)
```

This is because a restriction placed in the ON clause is processed *before* the join, while a restriction placed in the WHERE clause is processed *after* the join. That does not matter with inner joins, but it matters a lot with outer joins.

7.2.1.2. Table and Column Aliases

A temporary name can be given to tables and complex table references to be used for references to the derived table in the rest of the query. This is called a *table alias*.

To create a table alias, write

```
FROM table_reference AS alias
```

or

```
FROM table_reference alias
```

The AS key word is optional noise. *alias* can be any identifier.

A typical application of table aliases is to assign short identifiers to long table names to keep the join clauses readable. For example:

```
SELECT * FROM some_very_long_table_name s JOIN
   another_fairly_long_name a ON s.id = a.num;
```

The alias becomes the new name of the table reference so far as the current query is concerned — it is not allowed to refer to the table by the original name elsewhere in the query. Thus, this is not valid:

```
SELECT * FROM my_table AS m WHERE my_table.a > 5;    -- wrong
```

Table aliases are mainly for notational convenience, but it is necessary to use them when joining a table to itself, e.g.:

```
SELECT * FROM people AS mother JOIN people AS child ON mother.id =
   child.mother_id;
```

Additionally, an alias is required if the table reference is a subquery (see Section 7.2.1.3).

Parentheses are used to resolve ambiguities. In the following example, the first statement assigns the alias *b* to the second instance of *my_table*, but the second statement assigns the alias to the result of the join:

```
SELECT * FROM my_table AS a CROSS JOIN my_table AS b ...
SELECT * FROM (my_table AS a CROSS JOIN my_table) AS b ...
```

Another form of table aliasing gives temporary names to the columns of the table, as well as the table itself:

```
FROM table_reference [AS] alias ( column1 [, column2 [, ...]] )
```

If fewer column aliases are specified than the actual table has columns, the remaining columns are not renamed. This syntax is especially useful for self-joins or subqueries.

When an alias is applied to the output of a JOIN clause, the alias hides the original name(s) within the JOIN. For example:

```
SELECT a.* FROM my_table AS a JOIN your_table AS b ON ...
```

is valid SQL, but:

```
SELECT a.* FROM (my_table AS a JOIN your_table AS b ON ...) AS c
```

is not valid; the table alias *a* is not visible outside the alias *c*.

7.2.1.3. Subqueries

Subqueries specifying a derived table must be enclosed in parentheses and *must* be assigned a table alias name (as in Section 7.2.1.2). For example:

```
FROM (SELECT * FROM table1) AS alias_name
```

This example is equivalent to `FROM table1 AS alias_name`. More interesting cases, which cannot be reduced to a plain join, arise when the subquery involves grouping or aggregation.

A subquery can also be a VALUES list:

```
FROM (VALUES ('anne', 'smith'), ('bob', 'jones'), ('joe', 'blow'))
      AS names(first, last)
```

Again, a table alias is required. Assigning alias names to the columns of the VALUES list is optional, but is good practice. For more information see Section 7.7.

7.2.1.4. Table Functions

Table functions are functions that produce a set of rows, made up of either base data types (scalar types) or composite data types (table rows). They are used like a table, view, or subquery in the FROM clause of a query. Columns returned by table functions can be included in SELECT, JOIN, or WHERE clauses in the same manner as columns of a table, view, or subquery.

Table functions may also be combined using the ROWS FROM syntax, with the results returned in parallel columns; the number of result rows in this case is that of the largest function result, with smaller results padded with null values to match.

```
function_call [WITH ORDINALITY] [[AS] table_alias [(column_alias
  [, ... ])] ]
ROWS FROM( function_call [, ... ] ) [WITH ORDINALITY]
  [[AS] table_alias [(column_alias [, ... ])] ]
```

If the WITH ORDINALITY clause is specified, an additional column of type `bigint` will be added to the function result columns. This column numbers the rows of the function result set, starting from 1. (This is a generalization of the SQL-standard syntax for `UNNEST ... WITH ORDINALITY`.)

By default, the ordinal column is called `ordinality`, but a different column name can be assigned to it using an `AS` clause.

The special table function `UNNEST` may be called with any number of array parameters, and it returns a corresponding number of columns, as if `UNNEST` (Section 9.18) had been called on each parameter separately and combined using the `ROWS FROM` construct.

```
UNNEST( array_expression [, ... ] ) [WITH ORDINALITY]
  [[AS] table_alias [(column_alias [, ... ])]]
```

If no `table_alias` is specified, the function name is used as the table name; in the case of a `ROWS FROM()` construct, the first function's name is used.

If column aliases are not supplied, then for a function returning a base data type, the column name is also the same as the function name. For a function returning a composite type, the result columns get the names of the individual attributes of the type.

Some examples:

```
CREATE TABLE foo (fooid int, foosubid int, fooname text);
```

```
CREATE FUNCTION getfoo(int) RETURNS SETOF foo AS $$
  SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;
```

```
SELECT * FROM getfoo(1) AS t1;
```

```
SELECT * FROM foo
  WHERE foosubid IN (
    SELECT foosubid
    FROM getfoo(foo.fooid) z
    WHERE z.fooid = foo.fooid
  );
```

```
CREATE VIEW vw_getfoo AS SELECT * FROM getfoo(1);
```

```
SELECT * FROM vw_getfoo;
```

In some cases it is useful to define table functions that can return different column sets depending on how they are invoked. To support this, the table function can be declared as returning the pseudo-type `record`. When such a function is used in a query, the expected row structure must be specified in the query itself, so that the system can know how to parse and plan the query. This syntax looks like:

```
function_call [AS] alias (column_definition [, ... ])
function_call AS [alias] (column_definition [, ... ])
ROWS FROM( ... function_call AS (column_definition [, ... ])
  [, ... ] )
```

When not using the `ROWS FROM()` syntax, the `column_definition` list replaces the column alias list that could otherwise be attached to the `FROM` item; the names in the column definitions serve as column aliases. When using the `ROWS FROM()` syntax, a `column_definition` list can be attached to each member function separately; or if there is only one member function and no `WITH ORDINALITY` clause, a `column_definition` list can be written in place of a column alias list following `ROWS FROM()`.

Consider this example:

```
SELECT *
  FROM dblink('dbname=mydb', 'SELECT proname, prosrc FROM
pg_proc')
  AS t1(proname name, prosrc text)
  WHERE proname LIKE 'bytea%';
```

The `dblink` function (part of the `dblink` module) executes a remote query. It is declared to return `record` since it might be used for any kind of query. The actual column set must be specified in the calling query so that the parser knows, for example, what `*` should expand to.

7.2.1.5. LATERAL Subqueries

Subqueries appearing in `FROM` can be preceded by the key word `LATERAL`. This allows them to reference columns provided by preceding `FROM` items. (Without `LATERAL`, each subquery is evaluated independently and so cannot cross-reference any other `FROM` item.)

Table functions appearing in `FROM` can also be preceded by the key word `LATERAL`, but for functions the key word is optional; the function's arguments can contain references to columns provided by preceding `FROM` items in any case.

A `LATERAL` item can appear at top level in the `FROM` list, or within a `JOIN` tree. In the latter case it can also refer to any items that are on the left-hand side of a `JOIN` that it is on the right-hand side of.

When a `FROM` item contains `LATERAL` cross-references, evaluation proceeds as follows: for each row of the `FROM` item providing the cross-referenced column(s), or set of rows of multiple `FROM` items providing the columns, the `LATERAL` item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

A trivial example of `LATERAL` is

```
SELECT * FROM foo, LATERAL (SELECT * FROM bar WHERE bar.id =
foo.bar_id) ss;
```

This is not especially useful since it has exactly the same result as the more conventional

```
SELECT * FROM foo, bar WHERE bar.id = foo.bar_id;
```

`LATERAL` is primarily useful when the cross-referenced column is necessary for computing the row(s) to be joined. A common application is providing an argument value for a set-returning function. For example, supposing that `vertices(polygon)` returns the set of vertices of a polygon, we could identify close-together vertices of polygons stored in a table with:

```
SELECT p1.id, p2.id, v1, v2
FROM polygons p1, polygons p2,
  LATERAL vertices(p1.poly) v1,
  LATERAL vertices(p2.poly) v2
WHERE (v1 <-> v2) < 10 AND p1.id != p2.id;
```

This query could also be written

```
SELECT p1.id, p2.id, v1, v2
FROM polygons p1 CROSS JOIN LATERAL vertices(p1.poly) v1,
  polygons p2 CROSS JOIN LATERAL vertices(p2.poly) v2
WHERE (v1 <-> v2) < 10 AND p1.id != p2.id;
```

or in several other equivalent formulations. (As already mentioned, the `LATERAL` key word is unnecessary in this example, but we use it for clarity.)

It is often particularly handy to `LEFT JOIN` to a `LATERAL` subquery, so that source rows will appear in the result even if the `LATERAL` subquery produces no rows for them. For example, if `get_product_names()` returns the names of products made by a manufacturer, but some manufacturers in our table currently produce no products, we could find out which ones those are like this:

```
SELECT m.name
FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id)
  pname ON true
WHERE pname IS NULL;
```

7.2.2. The WHERE Clause

The syntax of the `WHERE` Clause is

```
WHERE search_condition
```

where *search_condition* is any value expression (see Section 4.2) that returns a value of type `boolean`.

After the processing of the `FROM` clause is done, each row of the derived virtual table is checked against the search condition. If the result of the condition is true, the row is kept in the output table, otherwise (i.e., if the result is false or null) it is discarded. The search condition typically references at least one column of the table generated in the `FROM` clause; this is not required, but otherwise the `WHERE` clause will be fairly useless.

Note

The join condition of an inner join can be written either in the `WHERE` clause or in the `JOIN` clause. For example, these table expressions are equivalent:

```
FROM a, b WHERE a.id = b.id AND b.val > 5
```

and:

```
FROM a INNER JOIN b ON (a.id = b.id) WHERE b.val > 5
```

or perhaps even:

```
FROM a NATURAL JOIN b WHERE b.val > 5
```

Which one of these you use is mainly a matter of style. The `JOIN` syntax in the `FROM` clause is probably not as portable to other SQL database management systems, even though it is in the SQL standard. For outer joins there is no choice: they must be done in the `FROM` clause. The `ON` or `USING` clause of an outer join is *not* equivalent to a `WHERE` condition, because it results in the addition of rows (for unmatched input rows) as well as the removal of rows in the final result.

Here are some examples of `WHERE` clauses:

```

SELECT ... FROM fdt WHERE c1 > 5

SELECT ... FROM fdt WHERE c1 IN (1, 2, 3)

SELECT ... FROM fdt WHERE c1 IN (SELECT c1 FROM t2)

SELECT ... FROM fdt WHERE c1 IN (SELECT c3 FROM t2 WHERE c2 =
    fdt.c1 + 10)

SELECT ... FROM fdt WHERE c1 BETWEEN (SELECT c3 FROM t2 WHERE c2 =
    fdt.c1 + 10) AND 100

SELECT ... FROM fdt WHERE EXISTS (SELECT c1 FROM t2 WHERE c2 >
    fdt.c1)

```

`fdt` is the table derived in the `FROM` clause. Rows that do not meet the search condition of the `WHERE` clause are eliminated from `fdt`. Notice the use of scalar subqueries as value expressions. Just like any other query, the subqueries can employ complex table expressions. Notice also how `fdt` is referenced in the subqueries. Qualifying `c1` as `fdt.c1` is only necessary if `c1` is also the name of a column in the derived input table of the subquery. But qualifying the column name adds clarity even when it is not needed. This example shows how the column naming scope of an outer query extends into its inner queries.

7.2.3. The GROUP BY and HAVING Clauses

After passing the `WHERE` filter, the derived input table might be subject to grouping, using the `GROUP BY` clause, and elimination of group rows using the `HAVING` clause.

```

SELECT select_list
    FROM ...
    [WHERE ...]
    GROUP BY grouping_column_reference
    [, grouping_column_reference]...

```

The `GROUP BY` Clause is used to group together those rows in a table that have the same values in all the columns listed. The order in which the columns are listed does not matter. The effect is to combine each set of rows having common values into one group row that represents all rows in the group. This is done to eliminate redundancy in the output and/or compute aggregates that apply to these groups. For instance:

```

=> SELECT * FROM test1;
  x | y
---+---
  a | 3
  c | 2
  b | 5
  a | 1
(4 rows)

=> SELECT x FROM test1 GROUP BY x;
  x
---
  a
  b
  c
(3 rows)

```

In the second query, we could not have written `SELECT * FROM test1 GROUP BY x`, because there is no single value for the column `y` that could be associated with each group. The grouped-by columns can be referenced in the select list since they have a single value in each group.

In general, if a table is grouped, columns that are not listed in `GROUP BY` cannot be referenced except in aggregate expressions. An example with aggregate expressions is:

```
=> SELECT x, sum(y) FROM test1 GROUP BY x;
 x | sum
---+-----
 a |    4
 b |    5
 c |    2
(3 rows)
```

Here `sum` is an aggregate function that computes a single value over the entire group. More information about the available aggregate functions can be found in Section 9.20.

Tip

Grouping without aggregate expressions effectively calculates the set of distinct values in a column. This can also be achieved using the `DISTINCT` clause (see Section 7.3.3).

Here is another example: it calculates the total sales for each product (rather than the total sales of all products):

```
SELECT product_id, p.name, (sum(s.units) * p.price) AS sales
FROM products p LEFT JOIN sales s USING (product_id)
GROUP BY product_id, p.name, p.price;
```

In this example, the columns `product_id`, `p.name`, and `p.price` must be in the `GROUP BY` clause since they are referenced in the query select list (but see below). The column `s.units` does not have to be in the `GROUP BY` list since it is only used in an aggregate expression (`sum(...)`), which represents the sales of a product. For each product, the query returns a summary row about all sales of the product.

If the `products` table is set up so that, say, `product_id` is the primary key, then it would be enough to group by `product_id` in the above example, since name and price would be *functionally dependent* on the product ID, and so there would be no ambiguity about which name and price value to return for each product ID group.

In strict SQL, `GROUP BY` can only group by columns of the source table but PostgreSQL extends this to also allow `GROUP BY` to group by columns in the select list. Grouping by value expressions instead of simple column names is also allowed.

If a table has been grouped using `GROUP BY`, but only certain groups are of interest, the `HAVING` clause can be used, much like a `WHERE` clause, to eliminate groups from the result. The syntax is:

```
SELECT select_list FROM ... [WHERE ...] GROUP BY ...
HAVING boolean_expression
```

Expressions in the `HAVING` clause can refer both to grouped expressions and to ungrouped expressions (which necessarily involve an aggregate function).

Example:

```
=> SELECT x, sum(y) FROM test1 GROUP BY x HAVING sum(y) > 3;
```

```
x | sum
---+-----
a | 4
b | 5
(2 rows)
```

```
=> SELECT x, sum(y) FROM test1 GROUP BY x HAVING x < 'c';
```

```
x | sum
---+-----
a | 4
b | 5
(2 rows)
```

Again, a more realistic example:

```
SELECT product_id, p.name, (sum(s.units) * (p.price - p.cost)) AS
profit
FROM products p LEFT JOIN sales s USING (product_id)
WHERE s.date > CURRENT_DATE - INTERVAL '4 weeks'
GROUP BY product_id, p.name, p.price, p.cost
HAVING sum(p.price * s.units) > 5000;
```

In the example above, the WHERE clause is selecting rows by a column that is not grouped (the expression is only true for sales during the last four weeks), while the HAVING clause restricts the output to groups with total gross sales over 5000. Note that the aggregate expressions do not necessarily need to be the same in all parts of the query.

If a query contains aggregate function calls, but no GROUP BY clause, grouping still occurs: the result is a single group row (or perhaps no rows at all, if the single row is then eliminated by HAVING). The same is true if it contains a HAVING clause, even without any aggregate function calls or GROUP BY clause.

7.2.4. GROUPING SETS, CUBE, and ROLLUP

More complex grouping operations than those described above are possible using the concept of *grouping sets*. The data selected by the FROM and WHERE clauses is grouped separately by each specified grouping set, aggregates computed for each group just as for simple GROUP BY clauses, and then the results returned. For example:

```
=> SELECT * FROM items_sold;
```

```
brand | size | sales
-----+-----+-----
Foo   | L    | 10
Foo   | M    | 20
Bar   | M    | 15
Bar   | L    | 5
(4 rows)
```

```
=> SELECT brand, size, sum(sales) FROM items_sold GROUP BY GROUPING
SETS ((brand), (size), ());
```

```
brand | size | sum
-----+-----+-----
```

```

Foo | | 30
Bar | | 20
    | L | 15
    | M | 35
    |   | 50
(5 rows)

```

Each sublist of `GROUPING SETS` may specify zero or more columns or expressions and is interpreted the same way as though it were directly in the `GROUP BY` clause. An empty grouping set means that all rows are aggregated down to a single group (which is output even if no input rows were present), as described above for the case of aggregate functions with no `GROUP BY` clause.

References to the grouping columns or expressions are replaced by null values in result rows for grouping sets in which those columns do not appear. To distinguish which grouping a particular output row resulted from, see Table 9.59.

A shorthand notation is provided for specifying two common types of grouping set. A clause of the form

```
ROLLUP ( e1, e2, e3, ... )
```

represents the given list of expressions and all prefixes of the list including the empty list; thus it is equivalent to

```

GROUPING SETS (
    ( e1, e2, e3, ... ),
    ...
    ( e1, e2 ),
    ( e1 ),
    ( )
)

```

This is commonly used for analysis over hierarchical data; e.g. total salary by department, division, and company-wide total.

A clause of the form

```
CUBE ( e1, e2, ... )
```

represents the given list and all of its possible subsets (i.e. the power set). Thus

```
CUBE ( a, b, c )
```

is equivalent to

```

GROUPING SETS (
    ( a, b, c ),
    ( a, b   ),
    ( a,   c ),
    ( a     ),
    (   b, c ),
    (   b   ),
    (     c ),
    (     )
)

```

The individual elements of a CUBE or ROLLUP clause may be either individual expressions, or sublists of elements in parentheses. In the latter case, the sublists are treated as single units for the purposes of generating the individual grouping sets. For example:

```
CUBE ( (a, b), (c, d) )
```

is equivalent to

```
GROUPING SETS (
  ( a, b, c, d ),
  ( a, b      ),
  (          c, d ),
  (          )
)
```

and

```
ROLLUP ( a, (b, c), d )
```

is equivalent to

```
GROUPING SETS (
  ( a, b, c, d ),
  ( a, b, c      ),
  ( a            ),
  (            )
)
```

The CUBE and ROLLUP constructs can be used either directly in the GROUP BY clause, or nested inside a GROUPING SETS clause. If one GROUPING SETS clause is nested inside another, the effect is the same as if all the elements of the inner clause had been written directly in the outer clause.

If multiple grouping items are specified in a single GROUP BY clause, then the final list of grouping sets is the cross product of the individual items. For example:

```
GROUP BY a, CUBE (b, c), GROUPING SETS ((d), (e))
```

is equivalent to

```
GROUP BY GROUPING SETS (
  (a, b, c, d), (a, b, c, e),
  (a, b, d),   (a, b, e),
  (a, c, d),   (a, c, e),
  (a, d),      (a, e)
)
```

Note

The construct (a, b) is normally recognized in expressions as a row constructor. Within the GROUP BY clause, this does not apply at the top levels of expressions, and (a, b) is parsed as a list of expressions as described above. If for some reason you need a row constructor in a grouping expression, use ROW(a, b).

7.2.5. Window Function Processing

If the query contains any window functions (see Section 3.5, Section 9.21 and Section 4.2.8), these functions are evaluated after any grouping, aggregation, and `HAVING` filtering is performed. That is, if the query uses any aggregates, `GROUP BY`, or `HAVING`, then the rows seen by the window functions are the group rows instead of the original table rows from `FROM/WHERE`.

When multiple window functions are used, all the window functions having syntactically equivalent `PARTITION BY` and `ORDER BY` clauses in their window definitions are guaranteed to be evaluated in a single pass over the data. Therefore they will see the same sort ordering, even if the `ORDER BY` does not uniquely determine an ordering. However, no guarantees are made about the evaluation of functions having different `PARTITION BY` or `ORDER BY` specifications. (In such cases a sort step is typically required between the passes of window function evaluations, and the sort is not guaranteed to preserve ordering of rows that its `ORDER BY` sees as equivalent.)

Currently, window functions always require presorted data, and so the query output will be ordered according to one or another of the window functions' `PARTITION BY/ORDER BY` clauses. It is not recommended to rely on this, however. Use an explicit top-level `ORDER BY` clause if you want to be sure the results are sorted in a particular way.

7.3. Select Lists

As shown in the previous section, the table expression in the `SELECT` command constructs an intermediate virtual table by possibly combining tables, views, eliminating rows, grouping, etc. This table is finally passed on to processing by the *select list*. The select list determines which *columns* of the intermediate table are actually output.

7.3.1. Select-List Items

The simplest kind of select list is `*` which emits all columns that the table expression produces. Otherwise, a select list is a comma-separated list of value expressions (as defined in Section 4.2). For instance, it could be a list of column names:

```
SELECT a, b, c FROM ...
```

The columns names `a`, `b`, and `c` are either the actual names of the columns of tables referenced in the `FROM` clause, or the aliases given to them as explained in Section 7.2.1.2. The name space available in the select list is the same as in the `WHERE` clause, unless grouping is used, in which case it is the same as in the `HAVING` clause.

If more than one table has a column of the same name, the table name must also be given, as in:

```
SELECT tbl1.a, tbl2.a, tbl1.b FROM ...
```

When working with multiple tables, it can also be useful to ask for all the columns of a particular table:

```
SELECT tbl1.*, tbl2.a FROM ...
```

See Section 8.16.5 for more about the `table_name.*` notation.

If an arbitrary value expression is used in the select list, it conceptually adds a new virtual column to the returned table. The value expression is evaluated once for each result row, with the row's values substituted for any column references. But the expressions in the select list do not have to reference any columns in the table expression of the `FROM` clause; they can be constant arithmetic expressions, for instance.

7.3.2. Column Labels

The entries in the select list can be assigned names for subsequent processing, such as for use in an `ORDER BY` clause or for display by the client application. For example:

```
SELECT a AS value, b + c AS sum FROM ...
```

If no output column name is specified using `AS`, the system assigns a default column name. For simple column references, this is the name of the referenced column. For function calls, this is the name of the function. For complex expressions, the system will generate a generic name.

The `AS` keyword is optional, but only if the new column name does not match any PostgreSQL keyword (see Appendix C). To avoid an accidental match to a keyword, you can double-quote the column name. For example, `VALUE` is a keyword, so this does not work:

```
SELECT a value, b + c AS sum FROM ...
```

but this does:

```
SELECT a "value", b + c AS sum FROM ...
```

For protection against possible future keyword additions, it is recommended that you always either write `AS` or double-quote the output column name.

Note

The naming of output columns here is different from that done in the `FROM` clause (see Section 7.2.1.2). It is possible to rename the same column twice, but the name assigned in the select list is the one that will be passed on.

7.3.3. DISTINCT

After the select list has been processed, the result table can optionally be subject to the elimination of duplicate rows. The `DISTINCT` key word is written directly after `SELECT` to specify this:

```
SELECT DISTINCT select_list ...
```

(Instead of `DISTINCT` the key word `ALL` can be used to specify the default behavior of retaining all rows.)

Obviously, two rows are considered distinct if they differ in at least one column value. Null values are considered equal in this comparison.

Alternatively, an arbitrary expression can determine what rows are to be considered distinct:

```
SELECT DISTINCT ON (expression [, expression ...]) select_list ...
```

Here *expression* is an arbitrary value expression that is evaluated for all rows. A set of rows for which all the expressions are equal are considered duplicates, and only the first row of the set is kept in the output. Note that the “first row” of a set is unpredictable unless the query is sorted on enough columns to guarantee a unique ordering of the rows arriving at the `DISTINCT` filter. (`DISTINCT ON` processing occurs after `ORDER BY` sorting.)

The `DISTINCT ON` clause is not part of the SQL standard and is sometimes considered bad style because of the potentially indeterminate nature of its results. With judicious use of `GROUP BY` and subqueries in `FROM`, this construct can be avoided, but it is often the most convenient alternative.

7.4. Combining Queries

The results of two queries can be combined using the set operations union, intersection, and difference. The syntax is

```
query1 UNION [ALL] query2
query1 INTERSECT [ALL] query2
query1 EXCEPT [ALL] query2
```

`query1` and `query2` are queries that can use any of the features discussed up to this point. Set operations can also be nested and chained, for example

```
query1 UNION query2 UNION query3
```

which is executed as:

```
(query1 UNION query2) UNION query3
```

`UNION` effectively appends the result of `query2` to the result of `query1` (although there is no guarantee that this is the order in which the rows are actually returned). Furthermore, it eliminates duplicate rows from its result, in the same way as `DISTINCT`, unless `UNION ALL` is used.

`INTERSECT` returns all rows that are both in the result of `query1` and in the result of `query2`. Duplicate rows are eliminated unless `INTERSECT ALL` is used.

`EXCEPT` returns all rows that are in the result of `query1` but not in the result of `query2`. (This is sometimes called the *difference* between two queries.) Again, duplicates are eliminated unless `EXCEPT ALL` is used.

In order to calculate the union, intersection, or difference of two queries, the two queries must be “union compatible”, which means that they return the same number of columns and the corresponding columns have compatible data types, as described in Section 10.5.

7.5. Sorting Rows

After a query has produced an output table (after the select list has been processed) it can optionally be sorted. If sorting is not chosen, the rows will be returned in an unspecified order. The actual order in that case will depend on the scan and join plan types and the order on disk, but it must not be relied on. A particular output ordering can only be guaranteed if the sort step is explicitly chosen.

The `ORDER BY` clause specifies the sort order:

```
SELECT select_list
      FROM table_expression
      ORDER BY sort_expression1 [ASC | DESC] [NULLS { FIRST | LAST }]
             [, sort_expression2 [ASC | DESC] [NULLS { FIRST |
LAST }]] ...]
```

The sort expression(s) can be any expression that would be valid in the query's select list. An example is:

```
SELECT a, b FROM table1 ORDER BY a + b, c;
```

When more than one expression is specified, the later values are used to sort rows that are equal according to the earlier values. Each expression can be followed by an optional ASC or DESC keyword to set the sort direction to ascending or descending. ASC order is the default. Ascending order puts smaller values first, where “smaller” is defined in terms of the < operator. Similarly, descending order is determined with the > operator.¹

The NULLS FIRST and NULLS LAST options can be used to determine whether nulls appear before or after non-null values in the sort ordering. By default, null values sort as if larger than any non-null value; that is, NULLS FIRST is the default for DESC order, and NULLS LAST otherwise.

Note that the ordering options are considered independently for each sort column. For example ORDER BY x, y DESC means ORDER BY x ASC, y DESC, which is not the same as ORDER BY x DESC, y DESC.

A *sort_expression* can also be the column label or number of an output column, as in:

```
SELECT a + b AS sum, c FROM table1 ORDER BY sum;
SELECT a, max(b) FROM table1 GROUP BY a ORDER BY 1;
```

both of which sort by the first output column. Note that an output column name has to stand alone, that is, it cannot be used in an expression — for example, this is *not* correct:

```
SELECT a + b AS sum, c FROM table1 ORDER BY sum + c;      --
wrong
```

This restriction is made to reduce ambiguity. There is still ambiguity if an ORDER BY item is a simple name that could match either an output column name or a column from the table expression. The output column is used in such cases. This would only cause confusion if you use AS to rename an output column to match some other table column's name.

ORDER BY can be applied to the result of a UNION, INTERSECT, or EXCEPT combination, but in this case it is only permitted to sort by output column names or numbers, not by expressions.

7.6. LIMIT and OFFSET

LIMIT and OFFSET allow you to retrieve just a portion of the rows that are generated by the rest of the query:

```
SELECT select_list
   FROM table_expression
   [ ORDER BY ... ]
   [ LIMIT { number | ALL } ] [ OFFSET number ]
```

If a limit count is given, no more than that many rows will be returned (but possibly fewer, if the query itself yields fewer rows). LIMIT ALL is the same as omitting the LIMIT clause, as is LIMIT with a NULL argument.

OFFSET says to skip that many rows before beginning to return rows. OFFSET 0 is the same as omitting the OFFSET clause, as is OFFSET with a NULL argument.

If both OFFSET and LIMIT appear, then OFFSET rows are skipped before starting to count the LIMIT rows that are returned.

¹ Actually, PostgreSQL uses the *default B-tree operator class* for the expression's data type to determine the sort ordering for ASC and DESC. Conventionally, data types will be set up so that the < and > operators correspond to this sort ordering, but a user-defined data type's designer could choose to do something different.

When using `LIMIT`, it is important to use an `ORDER BY` clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows. You might be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? The ordering is unknown, unless you specified `ORDER BY`.

The query optimizer takes `LIMIT` into account when generating query plans, so you are very likely to get different plans (yielding different row orders) depending on what you give for `LIMIT` and `OFFSET`. Thus, using different `LIMIT/OFFSET` values to select different subsets of a query result *will give inconsistent results* unless you enforce a predictable result ordering with `ORDER BY`. This is not a bug; it is an inherent consequence of the fact that `SQL` does not promise to deliver the results of a query in any particular order unless `ORDER BY` is used to constrain the order.

The rows skipped by an `OFFSET` clause still have to be computed inside the server; therefore a large `OFFSET` might be inefficient.

7.7. VALUES Lists

`VALUES` provides a way to generate a “constant table” that can be used in a query without having to actually create and populate a table on-disk. The syntax is

```
VALUES ( expression [, ...] ) [, ...]
```

Each parenthesized list of expressions generates a row in the table. The lists must all have the same number of elements (i.e., the number of columns in the table), and corresponding entries in each list must have compatible data types. The actual data type assigned to each column of the result is determined using the same rules as for `UNION` (see Section 10.5).

As an example:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

will return a table of two columns and three rows. It's effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

By default, PostgreSQL assigns the names `column1`, `column2`, etc. to the columns of a `VALUES` table. The column names are not specified by the `SQL` standard and different database systems do it differently, so it's usually better to override the default names with a table alias list, like this:

```
=> SELECT * FROM (VALUES (1, 'one'), (2, 'two'), (3, 'three')) AS t
   (num,letter);
 num | letter
-----+-----
   1 | one
   2 | two
   3 | three
(3 rows)
```

Syntactically, `VALUES` followed by expression lists is treated as equivalent to:

```
SELECT select_list FROM table_expression
```

and can appear anywhere a SELECT can. For example, you can use it as part of a UNION, or attach a *sort_specification* (ORDER BY, LIMIT, and/or OFFSET) to it. VALUES is most commonly used as the data source in an INSERT command, and next most commonly as a subquery.

For more information see VALUES.

7.8. WITH Queries (Common Table Expressions)

WITH provides a way to write auxiliary statements for use in a larger query. These statements, which are often referred to as Common Table Expressions or CTEs, can be thought of as defining temporary tables that exist just for one query. Each auxiliary statement in a WITH clause can be a SELECT, INSERT, UPDATE, or DELETE; and the WITH clause itself is attached to a primary statement that can also be a SELECT, INSERT, UPDATE, or DELETE.

7.8.1. SELECT in WITH

The basic value of SELECT in WITH is to break down complicated queries into simpler parts. An example is:

```
WITH regional_sales AS (
    SELECT region, SUM(amount) AS total_sales
    FROM orders
    GROUP BY region
), top_regions AS (
    SELECT region
    FROM regional_sales
    WHERE total_sales > (SELECT SUM(total_sales)/10 FROM
    regional_sales)
)
SELECT region,
    product,
    SUM(quantity) AS product_units,
    SUM(amount) AS product_sales
FROM orders
WHERE region IN (SELECT region FROM top_regions)
GROUP BY region, product;
```

which displays per-product sales totals in only the top sales regions. The WITH clause defines two auxiliary statements named *regional_sales* and *top_regions*, where the output of *regional_sales* is used in *top_regions* and the output of *top_regions* is used in the primary SELECT query. This example could have been written without WITH, but we'd have needed two levels of nested sub-SELECTs. It's a bit easier to follow this way.

The optional RECURSIVE modifier changes WITH from a mere syntactic convenience into a feature that accomplishes things not otherwise possible in standard SQL. Using RECURSIVE, a WITH query can refer to its own output. A very simple example is this query to sum the integers from 1 through 100:

```
WITH RECURSIVE t(n) AS (
    VALUES (1)
    UNION ALL
    SELECT n+1 FROM t WHERE n < 100
)
```

```
SELECT sum(n) FROM t;
```

The general form of a recursive WITH query is always a *non-recursive term*, then UNION (or UNION ALL), then a *recursive term*, where only the recursive term can contain a reference to the query's own output. Such a query is executed as follows:

Recursive Query Evaluation

1. Evaluate the non-recursive term. For UNION (but not UNION ALL), discard duplicate rows. Include all remaining rows in the result of the recursive query, and also place them in a temporary *working table*.
2. So long as the working table is not empty, repeat these steps:
 - a. Evaluate the recursive term, substituting the current contents of the working table for the recursive self-reference. For UNION (but not UNION ALL), discard duplicate rows and rows that duplicate any previous result row. Include all remaining rows in the result of the recursive query, and also place them in a temporary *intermediate table*.
 - b. Replace the contents of the working table with the contents of the intermediate table, then empty the intermediate table.

Note

Strictly speaking, this process is iteration not recursion, but RECURSIVE is the terminology chosen by the SQL standards committee.

In the example above, the working table has just a single row in each step, and it takes on the values from 1 through 100 in successive steps. In the 100th step, there is no output because of the WHERE clause, and so the query terminates.

Recursive queries are typically used to deal with hierarchical or tree-structured data. A useful example is this query to find all the direct and indirect sub-parts of a product, given only a table that shows immediate inclusions:

```
WITH RECURSIVE included_parts(sub_part, part, quantity) AS (
  SELECT sub_part, part, quantity FROM parts WHERE part =
  'our_product'
  UNION ALL
  SELECT p.sub_part, p.part, p.quantity
  FROM included_parts pr, parts p
  WHERE p.part = pr.sub_part
)
SELECT sub_part, SUM(quantity) as total_quantity
FROM included_parts
GROUP BY sub_part
```

When working with recursive queries it is important to be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. Sometimes, using UNION instead of UNION ALL can accomplish this by discarding rows that duplicate previous output rows. However, often a cycle does not involve output rows that are completely duplicate: it may be necessary to check just one or a few fields to see if the same point has been reached before. The standard method for handling such situations is to compute an array of the already-visited values. For example, consider the following query that searches a table graph using a link field:

```
WITH RECURSIVE search_graph(id, link, data, depth) AS (
```

```

SELECT g.id, g.link, g.data, 1
FROM graph g
UNION ALL
SELECT g.id, g.link, g.data, sg.depth + 1
FROM graph g, search_graph sg
WHERE g.id = sg.link
)
SELECT * FROM search_graph;

```

This query will loop if the link relationships contain cycles. Because we require a “depth” output, just changing UNION ALL to UNION would not eliminate the looping. Instead we need to recognize whether we have reached the same row again while following a particular path of links. We add two columns path and cycle to the loop-prone query:

```

WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS
(
    SELECT g.id, g.link, g.data, 1,
        ARRAY[g.id],
        false
    FROM graph g
    UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1,
        path || g.id,
        g.id = ANY(path)
    FROM graph g, search_graph sg
    WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;

```

Aside from preventing cycles, the array value is often useful in its own right as representing the “path” taken to reach any particular row.

In the general case where more than one field needs to be checked to recognize a cycle, use an array of rows. For example, if we needed to compare fields f1 and f2:

```

WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS
(
    SELECT g.id, g.link, g.data, 1,
        ARRAY[ROW(g.f1, g.f2)],
        false
    FROM graph g
    UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1,
        path || ROW(g.f1, g.f2),
        ROW(g.f1, g.f2) = ANY(path)
    FROM graph g, search_graph sg
    WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;

```

Tip

Omit the ROW() syntax in the common case where only one field needs to be checked to recognize a cycle. This allows a simple array rather than a composite-type array to be used, gaining efficiency.

Tip

The recursive query evaluation algorithm produces its output in breadth-first search order. You can display the results in depth-first search order by making the outer query ORDER BY a “path” column constructed in this way.

A helpful trick for testing queries when you are not certain if they might loop is to place a LIMIT in the parent query. For example, this query would loop forever without the LIMIT:

```
WITH RECURSIVE t(n) AS (
  SELECT 1
  UNION ALL
  SELECT n+1 FROM t
)
SELECT n FROM t LIMIT 100;
```

This works because PostgreSQL's implementation evaluates only as many rows of a WITH query as are actually fetched by the parent query. Using this trick in production is not recommended, because other systems might work differently. Also, it usually won't work if you make the outer query sort the recursive query's results or join them to some other table, because in such cases the outer query will usually try to fetch all of the WITH query's output anyway.

A useful property of WITH queries is that they are normally evaluated only once per execution of the parent query, even if they are referred to more than once by the parent query or sibling WITH queries. Thus, expensive calculations that are needed in multiple places can be placed within a WITH query to avoid redundant work. Another possible application is to prevent unwanted multiple evaluations of functions with side-effects. However, the other side of this coin is that the optimizer is not able to push restrictions from the parent query down into a multiply-referenced WITH query, since that might affect all uses of the WITH query's output when it should affect only one. The multiply-referenced WITH query will be evaluated as written, without suppression of rows that the parent query might discard afterwards. (But, as mentioned above, evaluation might stop early if the reference(s) to the query demand only a limited number of rows.)

However, if a WITH query is non-recursive and side-effect-free (that is, it is a SELECT containing no volatile functions) then it can be folded into the parent query, allowing joint optimization of the two query levels. By default, this happens if the parent query references the WITH query just once, but not if it references the WITH query more than once. You can override that decision by specifying MATERIALIZED to force separate calculation of the WITH query, or by specifying NOT MATERIALIZED to force it to be merged into the parent query. The latter choice risks duplicate computation of the WITH query, but it can still give a net savings if each usage of the WITH query needs only a small part of the WITH query's full output.

A simple example of these rules is

```
WITH w AS (
  SELECT * FROM big_table
)
SELECT * FROM w WHERE key = 123;
```

This WITH query will be folded, producing the same execution plan as

```
SELECT * FROM big_table WHERE key = 123;
```

In particular, if there's an index on key, it will probably be used to fetch just the rows having key = 123. On the other hand, in

```
WITH w AS (
    SELECT * FROM big_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.key = w2.ref
WHERE w2.key = 123;
```

the WITH query will be materialized, producing a temporary copy of `big_table` that is then joined with itself — without benefit of any index. This query will be executed much more efficiently if written as

```
WITH w AS NOT MATERIALIZED (
    SELECT * FROM big_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.key = w2.ref
WHERE w2.key = 123;
```

so that the parent query's restrictions can be applied directly to scans of `big_table`.

An example where `NOT MATERIALIZED` could be undesirable is

```
WITH w AS (
    SELECT key, very_expensive_function(val) as f FROM some_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.f = w2.f;
```

Here, materialization of the WITH query ensures that `very_expensive_function` is evaluated only once per table row, not twice.

The examples above only show WITH being used with SELECT, but it can be attached in the same way to INSERT, UPDATE, or DELETE. In each case it effectively provides temporary table(s) that can be referred to in the main command.

7.8.2. Data-Modifying Statements in WITH

You can use data-modifying statements (INSERT, UPDATE, or DELETE) in WITH. This allows you to perform several different operations in the same query. An example is:

```
WITH moved_rows AS (
    DELETE FROM products
    WHERE
        "date" >= '2010-10-01' AND
        "date" < '2010-11-01'
    RETURNING *
)
INSERT INTO products_log
SELECT * FROM moved_rows;
```

This query effectively moves rows from `products` to `products_log`. The DELETE in WITH deletes the specified rows from `products`, returning their contents by means of its RETURNING clause; and then the primary query reads that output and inserts it into `products_log`.

A fine point of the above example is that the WITH clause is attached to the INSERT, not the sub-SELECT within the INSERT. This is necessary because data-modifying statements are only allowed in WITH clauses that are attached to the top-level statement. However, normal WITH visibility rules apply, so it is possible to refer to the WITH statement's output from the sub-SELECT.

Data-modifying statements in `WITH` usually have `RETURNING` clauses (see Section 6.4), as shown in the example above. It is the output of the `RETURNING` clause, *not* the target table of the data-modifying statement, that forms the temporary table that can be referred to by the rest of the query. If a data-modifying statement in `WITH` lacks a `RETURNING` clause, then it forms no temporary table and cannot be referred to in the rest of the query. Such a statement will be executed nonetheless. A not-particularly-useful example is:

```
WITH t AS (
    DELETE FROM foo
)
DELETE FROM bar;
```

This example would remove all rows from tables `foo` and `bar`. The number of affected rows reported to the client would only include rows removed from `bar`.

Recursive self-references in data-modifying statements are not allowed. In some cases it is possible to work around this limitation by referring to the output of a recursive `WITH`, for example:

```
WITH RECURSIVE included_parts(sub_part, part) AS (
    SELECT sub_part, part FROM parts WHERE part = 'our_product'
    UNION ALL
    SELECT p.sub_part, p.part
    FROM included_parts pr, parts p
    WHERE p.part = pr.sub_part
)
DELETE FROM parts
WHERE part IN (SELECT part FROM included_parts);
```

This query would remove all direct and indirect subparts of a product.

Data-modifying statements in `WITH` are executed exactly once, and always to completion, independently of whether the primary query reads all (or indeed any) of their output. Notice that this is different from the rule for `SELECT` in `WITH`: as stated in the previous section, execution of a `SELECT` is carried only as far as the primary query demands its output.

The sub-statements in `WITH` are executed concurrently with each other and with the main query. Therefore, when using data-modifying statements in `WITH`, the order in which the specified updates actually happen is unpredictable. All the statements are executed with the same *snapshot* (see Chapter 13), so they cannot “see” one another's effects on the target tables. This alleviates the effects of the unpredictability of the actual order of row updates, and means that `RETURNING` data is the only way to communicate changes between different `WITH` sub-statements and the main query. An example of this is that in

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM products;
```

the outer `SELECT` would return the original prices before the action of the `UPDATE`, while in

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM t;
```

the outer `SELECT` would return the updated data.

Trying to update the same row twice in a single statement is not supported. Only one of the modifications takes place, but it is not easy (and sometimes not possible) to reliably predict which one. This also applies to deleting a row that was already updated in the same statement: only the update is performed. Therefore you should generally avoid trying to modify a single row twice in a single statement. In particular avoid writing `WITH` sub-statements that could affect the same rows changed by the main statement or a sibling sub-statement. The effects of such a statement will not be predictable.

At present, any table used as the target of a data-modifying statement in `WITH` must not have a conditional rule, nor an `ALSO` rule, nor an `INSTEAD` rule that expands to multiple statements.

Chapter 8. Data Types

PostgreSQL has a rich set of native data types available to users. Users can add new types to PostgreSQL using the CREATE TYPE command.

Table 8.1 shows all the built-in general-purpose data types. Most of the alternative names listed in the “Aliases” column are the names used internally by PostgreSQL for historical reasons. In addition, some internally used or deprecated types are available, but are not listed here.

Table 8.1. Data Types

Name	Aliases	Description
bigint	int8	signed eight-byte integer
bigserial	serial8	autoincrementing eight-byte integer
bit [(n)]		fixed-length bit string
bit varying [(n)]	varbit [(n)]	variable-length bit string
boolean	bool	logical Boolean (true/false)
box		rectangular box on a plane
bytea		binary data (“byte array”)
character [(n)]	char [(n)]	fixed-length character string
character varying [(n)]	varchar [(n)]	variable-length character string
cidr		IPv4 or IPv6 network address
circle		circle on a plane
date		calendar date (year, month, day)
double precision	float8	double precision floating-point number (8 bytes)
inet		IPv4 or IPv6 host address
integer	int, int4	signed four-byte integer
interval [fields] [(p)]		time span
json		textual JSON data
jsonb		binary JSON data, decomposed
line		infinite line on a plane
lseg		line segment on a plane
macaddr		MAC (Media Access Control) address
macaddr8		MAC (Media Access Control) address (EUI-64 format)
money		currency amount
numeric [(p, s)]	decimal [(p, s)]	exact numeric of selectable precision
path		geometric path on a plane
pg_lsn		PostgreSQL Log Sequence Number
point		geometric point on a plane

Name	Aliases	Description
<code>polygon</code>		closed geometric path on a plane
<code>real</code>	<code>float4</code>	single precision floating-point number (4 bytes)
<code>smallint</code>	<code>int2</code>	signed two-byte integer
<code>smallserial</code>	<code>serial2</code>	autoincrementing two-byte integer
<code>serial</code>	<code>serial4</code>	autoincrementing four-byte integer
<code>text</code>		variable-length character string
<code>time [(p)] [without time zone]</code>		time of day (no time zone)
<code>time [(p)] with time zone</code>	<code>timetz</code>	time of day, including time zone
<code>timestamp [(p)] [without time zone]</code>		date and time (no time zone)
<code>timestamp [(p)] with time zone</code>	<code>timestamptz</code>	date and time, including time zone
<code>tsquery</code>		text search query
<code>tsvector</code>		text search document
<code>txid_snapshot</code>		user-level transaction ID snapshot
<code>uuid</code>		universally unique identifier
<code>xml</code>		XML data

Compatibility

The following types (or spellings thereof) are specified by SQL: `bigint`, `bit`, `bit varying`, `boolean`, `char`, `character varying`, `character`, `varchar`, `date`, `double precision`, `integer`, `interval`, `numeric`, `decimal`, `real`, `smallint`, `time` (with or without time zone), `timestamp` (with or without time zone), `xml`.

Each data type has an external representation determined by its input and output functions. Many of the built-in types have obvious external formats. However, several types are either unique to PostgreSQL, such as geometric paths, or have several possible formats, such as the date and time types. Some of the input and output functions are not invertible, i.e., the result of an output function might lose accuracy when compared to the original input.

8.1. Numeric Types

Numeric types consist of two-, four-, and eight-byte integers, four- and eight-byte floating-point numbers, and selectable-precision decimals. Table 8.2 lists the available types.

Table 8.2. Numeric Types

Name	Storage Size	Description	Range
<code>smallint</code>	2 bytes	small-range integer	-32768 to +32767

Name	Storage Size	Description	Range
<code>integer</code>	4 bytes	typical choice for integer	-2147483648 to +2147483647
<code>bigint</code>	8 bytes	large-range integer	-9223372036854775808 to +9223372036854775807
<code>decimal</code>	variable	user-specified precision, exact	up to 131072 digits before the decimal point; up to 16383 digits after the decimal point
<code>numeric</code>	variable	user-specified precision, exact	up to 131072 digits before the decimal point; up to 16383 digits after the decimal point
<code>real</code>	4 bytes	variable-precision, inexact	6 decimal digits precision
<code>double precision</code>	8 bytes	variable-precision, inexact	15 decimal digits precision
<code>smallserial</code>	2 bytes	small autoincrementing integer	1 to 32767
<code>serial</code>	4 bytes	autoincrementing integer	1 to 2147483647
<code>bigserial</code>	8 bytes	large autoincrementing integer	1 to 9223372036854775807

The syntax of constants for the numeric types is described in Section 4.1.2. The numeric types have a full set of corresponding arithmetic operators and functions. Refer to Chapter 9 for more information. The following sections describe the types in detail.

8.1.1. Integer Types

The types `smallint`, `integer`, and `bigint` store whole numbers, that is, numbers without fractional components, of various ranges. Attempts to store values outside of the allowed range will result in an error.

The type `integer` is the common choice, as it offers the best balance between range, storage size, and performance. The `smallint` type is generally only used if disk space is at a premium. The `bigint` type is designed to be used when the range of the `integer` type is insufficient.

SQL only specifies the integer types `integer` (or `int`), `smallint`, and `bigint`. The type names `int2`, `int4`, and `int8` are extensions, which are also used by some other SQL database systems.

8.1.2. Arbitrary Precision Numbers

The type `numeric` can store numbers with a very large number of digits. It is especially recommended for storing monetary amounts and other quantities where exactness is required. Calculations with `numeric` values yield exact results where possible, e.g. addition, subtraction, multiplication. However, calculations on `numeric` values are very slow compared to the integer types, or to the floating-point types described in the next section.

We use the following terms below: The *precision* of a `numeric` is the total count of significant digits in the whole number, that is, the number of digits to both sides of the decimal point. The *scale* of a `numeric` is the count of decimal digits in the fractional part, to the right of the decimal point. So the number 23.5141 has a precision of 6 and a scale of 4. Integers can be considered to have a scale of zero.

Both the maximum precision and the maximum scale of a `numeric` column can be configured. To declare a column of type `numeric` use the syntax:

```
NUMERIC(precision, scale)
```

The precision must be positive, the scale zero or positive. Alternatively:

```
NUMERIC(precision)
```

selects a scale of 0. Specifying:

```
NUMERIC
```

without any precision or scale creates a column in which numeric values of any precision and scale can be stored, up to the implementation limit on precision. A column of this kind will not coerce input values to any particular scale, whereas `numeric` columns with a declared scale will coerce input values to that scale. (The SQL standard requires a default scale of 0, i.e., coercion to integer precision. We find this a bit useless. If you're concerned about portability, always specify the precision and scale explicitly.)

Note

The maximum allowed precision when explicitly specified in the type declaration is 1000; `NUMERIC` without a specified precision is subject to the limits described in Table 8.2.

If the scale of a value to be stored is greater than the declared scale of the column, the system will round the value to the specified number of fractional digits. Then, if the number of digits to the left of the decimal point exceeds the declared precision minus the declared scale, an error is raised.

Numeric values are physically stored without any extra leading or trailing zeroes. Thus, the declared precision and scale of a column are maximums, not fixed allocations. (In this sense the `numeric` type is more akin to `varchar(n)` than to `char(n)`.) The actual storage requirement is two bytes for each group of four decimal digits, plus three to eight bytes overhead.

In addition to ordinary numeric values, the `numeric` type allows the special value `NaN`, meaning “not-a-number”. Any operation on `NaN` yields another `NaN`. When writing this value as a constant in an SQL command, you must put quotes around it, for example `UPDATE table SET x = 'NaN'`. On input, the string `NaN` is recognized in a case-insensitive manner.

Note

In most implementations of the “not-a-number” concept, `NaN` is not considered equal to any other numeric value (including `NaN`). In order to allow `numeric` values to be sorted and used in tree-based indexes, PostgreSQL treats `NaN` values as equal, and greater than all non-`NaN` values.

The types `decimal` and `numeric` are equivalent. Both types are part of the SQL standard.

When rounding values, the `numeric` type rounds ties away from zero, while (on most machines) the `real` and `double precision` types round ties to the nearest even number. For example:

```

SELECT x,
       round(x::numeric) AS num_round,
       round(x::double precision) AS dbl_round
FROM generate_series(-3.5, 3.5, 1) as x;
 x   | num_round | dbl_round
-----+-----+-----
-3.5 |         -4 |        -4
-2.5 |         -3 |        -2
-1.5 |         -2 |        -2
-0.5 |         -1 |         0
 0.5 |          1 |          0
 1.5 |          2 |          2
 2.5 |          3 |          2
 3.5 |          4 |          4
(8 rows)

```

8.1.3. Floating-Point Types

The data types `real` and `double precision` are inexact, variable-precision numeric types. On all currently supported platforms, these types are implementations of IEEE Standard 754 for Binary Floating-Point Arithmetic (single and double precision, respectively), to the extent that the underlying processor, operating system, and compiler support it.

Inexact means that some values cannot be converted exactly to the internal format and are stored as approximations, so that storing and retrieving a value might show slight discrepancies. Managing these errors and how they propagate through calculations is the subject of an entire branch of mathematics and computer science and will not be discussed here, except for the following points:

- If you require exact storage and calculations (such as for monetary amounts), use the `numeric` type instead.
- If you want to do complicated calculations with these types for anything important, especially if you rely on certain behavior in boundary cases (infinity, underflow), you should evaluate the implementation carefully.
- Comparing two floating-point values for equality might not always work as expected.

On all currently supported platforms, the `real` type has a range of around $1\text{E}-37$ to $1\text{E}+37$ with a precision of at least 6 decimal digits. The `double precision` type has a range of around $1\text{E}-307$ to $1\text{E}+308$ with a precision of at least 15 digits. Values that are too large or too small will cause an error. Rounding might take place if the precision of an input number is too high. Numbers too close to zero that are not representable as distinct from zero will cause an underflow error.

By default, floating point values are output in text form in their shortest precise decimal representation; the decimal value produced is closer to the true stored binary value than to any other value representable in the same binary precision. (However, the output value is currently never *exactly* midway between two representable values, in order to avoid a widespread bug where input routines do not properly respect the round-to-even rule.) This value will use at most 17 significant decimal digits for `float8` values, and at most 9 digits for `float4` values.

Note

This shortest-precise output format is much faster to generate than the historical rounded format.

For compatibility with output generated by older versions of PostgreSQL, and to allow the output precision to be reduced, the `extra_float_digits` parameter can be used to select rounded decimal output

instead. Setting a value of 0 restores the previous default of rounding the value to 6 (for `float4`) or 15 (for `float8`) significant decimal digits. Setting a negative value reduces the number of digits further; for example -2 would round output to 4 or 13 digits respectively.

Any value of `extra_float_digits` greater than 0 selects the shortest-precise format.

Note

Applications that wanted precise values have historically had to set `extra_float_digits` to 3 to obtain them. For maximum compatibility between versions, they should continue to do so.

In addition to ordinary numeric values, the floating-point types have several special values:

Infinity
-Infinity
NaN

These represent the IEEE 754 special values “infinity”, “negative infinity”, and “not-a-number”, respectively. When writing these values as constants in an SQL command, you must put quotes around them, for example `UPDATE table SET x = '-Infinity'`. On input, these strings are recognized in a case-insensitive manner.

Note

IEEE754 specifies that NaN should not compare equal to any other floating-point value (including NaN). In order to allow floating-point values to be sorted and used in tree-based indexes, PostgreSQL treats NaN values as equal, and greater than all non-NaN values.

PostgreSQL also supports the SQL-standard notations `float` and `float(p)` for specifying inexact numeric types. Here, *p* specifies the minimum acceptable precision in *binary* digits. PostgreSQL accepts `float(1)` to `float(24)` as selecting the `real` type, while `float(25)` to `float(53)` select `double precision`. Values of *p* outside the allowed range draw an error. `float` with no precision specified is taken to mean `double precision`.

8.1.4. Serial Types

Note

This section describes a PostgreSQL-specific way to create an autoincrementing column. Another way is to use the SQL-standard identity column feature, described at `CREATE TABLE`.

The data types `smallserial`, `serial` and `bigserial` are not true types, but merely a notational convenience for creating unique identifier columns (similar to the `AUTO_INCREMENT` property supported by some other databases). In the current implementation, specifying:

```
CREATE TABLE tablename (
    colname SERIAL
);
```

is equivalent to specifying:

```
CREATE SEQUENCE tablename_colname_seq AS integer;
CREATE TABLE tablename (
    colname integer NOT NULL DEFAULT
    nextval('tablename_colname_seq')
);
ALTER SEQUENCE tablename_colname_seq OWNED BY tablename.colname;
```

Thus, we have created an integer column and arranged for its default values to be assigned from a sequence generator. A NOT NULL constraint is applied to ensure that a null value cannot be inserted. (In most cases you would also want to attach a UNIQUE or PRIMARY KEY constraint to prevent duplicate values from being inserted by accident, but this is not automatic.) Lastly, the sequence is marked as “owned by” the column, so that it will be dropped if the column or table is dropped.

Note

Because `smallserial`, `serial` and `bigserial` are implemented using sequences, there may be “holes” or gaps in the sequence of values which appears in the column, even if no rows are ever deleted. A value allocated from the sequence is still “used up” even if a row containing that value is never successfully inserted into the table column. This may happen, for example, if the inserting transaction rolls back. See `nextval()` in Section 9.16 for details.

To insert the next value of the sequence into the `serial` column, specify that the `serial` column should be assigned its default value. This can be done either by excluding the column from the list of columns in the `INSERT` statement, or through the use of the `DEFAULT` key word.

The type names `serial` and `serial4` are equivalent: both create `integer` columns. The type names `bigserial` and `serial8` work the same way, except that they create a `bigint` column. `bigserial` should be used if you anticipate the use of more than 2^{31} identifiers over the lifetime of the table. The type names `smallserial` and `serial2` also work the same way, except that they create a `smallint` column.

The sequence created for a `serial` column is automatically dropped when the owning column is dropped. You can drop the sequence without dropping the column, but this will force removal of the column default expression.

8.2. Monetary Types

The `money` type stores a currency amount with a fixed fractional precision; see Table 8.3. The fractional precision is determined by the database's `lc_monetary` setting. The range shown in the table assumes there are two fractional digits. Input is accepted in a variety of formats, including integer and floating-point literals, as well as typical currency formatting, such as '\$1,000.00'. Output is generally in the latter form but depends on the locale.

Table 8.3. Monetary Types

Name	Storage Size	Description	Range
money	8 bytes	currency amount	-92233720368547758.08 to +92233720368547758.07

Since the output of this data type is locale-sensitive, it might not work to load money data into a database that has a different setting of `lc_monetary`. To avoid problems, before restoring a dump

into a new database make sure `lc_monetary` has the same or equivalent value as in the database that was dumped.

Values of the `numeric`, `int`, and `bigint` data types can be cast to `money`. Conversion from the `real` and `double precision` data types can be done by casting to `numeric` first, for example:

```
SELECT '12.34'::float8::numeric::money;
```

However, this is not recommended. Floating point numbers should not be used to handle money due to the potential for rounding errors.

A `money` value can be cast to `numeric` without loss of precision. Conversion to other types could potentially lose precision, and must also be done in two stages:

```
SELECT '52093.89'::money::numeric::float8;
```

Division of a `money` value by an integer value is performed with truncation of the fractional part towards zero. To get a rounded result, divide by a floating-point value, or cast the `money` value to `numeric` before dividing and back to `money` afterwards. (The latter is preferable to avoid risking precision loss.) When a `money` value is divided by another `money` value, the result is `double precision` (i.e., a pure number, not `money`); the currency units cancel each other out in the division.

8.3. Character Types

Table 8.4. Character Types

Name	Description
<code>character varying(n)</code> , <code>varchar(n)</code>	variable-length with limit
<code>character(n)</code> , <code>char(n)</code>	fixed-length, blank padded
<code>text</code>	variable unlimited length

Table 8.4 shows the general-purpose character types available in PostgreSQL.

SQL defines two primary character types: `character varying(n)` and `character(n)`, where n is a positive integer. Both of these types can store strings up to n characters (not bytes) in length. An attempt to store a longer string into a column of these types will result in an error, unless the excess characters are all spaces, in which case the string will be truncated to the maximum length. (This somewhat bizarre exception is required by the SQL standard.) If the string to be stored is shorter than the declared length, values of type `character` will be space-padded; values of type `character varying` will simply store the shorter string.

If one explicitly casts a value to `character varying(n)` or `character(n)`, then an over-length value will be truncated to n characters without raising an error. (This too is required by the SQL standard.)

The notations `varchar(n)` and `char(n)` are aliases for `character varying(n)` and `character(n)`, respectively. `character` without length specifier is equivalent to `character(1)`. If `character varying` is used without length specifier, the type accepts strings of any size. The latter is a PostgreSQL extension.

In addition, PostgreSQL provides the `text` type, which stores strings of any length. Although the type `text` is not in the SQL standard, several other SQL database management systems have it as well.

Values of type `character` are physically padded with spaces to the specified width n , and are stored and displayed that way. However, trailing spaces are treated as semantically insignificant and disregarded when comparing two values of type `character`. In collations where whitespace is signifi-

cant, this behavior can produce unexpected results; for example `SELECT 'a '::CHAR(2) col-
late "C" < E'a\n'::CHAR(2)` returns true, even though C locale would consider a space
to be greater than a newline. Trailing spaces are removed when converting a character value to
one of the other string types. Note that trailing spaces *are* semantically significant in character
varying and text values, and when using pattern matching, that is LIKE and regular expressions.

The storage requirement for a short string (up to 126 bytes) is 1 byte plus the actual string, which
includes the space padding in the case of character. Longer strings have 4 bytes of overhead instead
of 1. Long strings are compressed by the system automatically, so the physical requirement on disk
might be less. Very long values are also stored in background tables so that they do not interfere with
rapid access to shorter column values. In any case, the longest possible character string that can be
stored is about 1 GB. (The maximum value that will be allowed for *n* in the data type declaration is less
than that. It wouldn't be useful to change this because with multibyte character encodings the number
of characters and bytes can be quite different. If you desire to store long strings with no specific upper
limit, use text or character varying without a length specifier, rather than making up an
arbitrary length limit.)

Tip

There is no performance difference among these three types, apart from increased stor-
age space when using the blank-padded type, and a few extra CPU cycles to check the
length when storing into a length-constrained column. While character(*n*) has
performance advantages in some other database systems, there is no such advantage
in PostgreSQL; in fact character(*n*) is usually the slowest of the three because
of its additional storage costs. In most situations text or character varying
should be used instead.

Refer to Section 4.1.2.1 for information about the syntax of string literals, and to Chapter 9 for infor-
mation about available operators and functions. The database character set determines the character
set used to store textual values; for more information on character set support, refer to Section 23.3.

Example 8.1. Using the Character Types

```
CREATE TABLE test1 (a character(4));
INSERT INTO test1 VALUES ('ok');
SELECT a, char_length(a) FROM test1; -- 1
```

a	char_length
ok	2

```
CREATE TABLE test2 (b varchar(5));
INSERT INTO test2 VALUES ('ok');
INSERT INTO test2 VALUES ('good ');
INSERT INTO test2 VALUES ('too long');
ERROR: value too long for type character varying(5)
INSERT INTO test2 VALUES ('too long'::varchar(5)); -- explicit
truncation
SELECT b, char_length(b) FROM test2;
```

b	char_length
ok	2
good	5

too 1 | 5

❶ The `char_length` function is discussed in Section 9.4.

There are two other fixed-length character types in PostgreSQL, shown in Table 8.5. The `name` type exists *only* for the storage of identifiers in the internal system catalogs and is not intended for use by the general user. Its length is currently defined as 64 bytes (63 usable characters plus terminator) but should be referenced using the constant `NAMEDATALEN` in C source code. The length is set at compile time (and is therefore adjustable for special uses); the default maximum length might change in a future release. The type `"char"` (note the quotes) is different from `char(1)` in that it only uses one byte of storage. It is internally used in the system catalogs as a simplistic enumeration type.

Table 8.5. Special Character Types

Name	Storage Size	Description
<code>"char"</code>	1 byte	single-byte internal type
<code>name</code>	64 bytes	internal type for object names

8.4. Binary Data Types

The `bytea` data type allows storage of binary strings; see Table 8.6.

Table 8.6. Binary Data Types

Name	Storage Size	Description
<code>bytea</code>	1 or 4 bytes plus the actual binary string	variable-length binary string

A binary string is a sequence of octets (or bytes). Binary strings are distinguished from character strings in two ways. First, binary strings specifically allow storing octets of value zero and other “non-printable” octets (usually, octets outside the decimal range 32 to 126). Character strings disallow zero octets, and also disallow any other octet values and sequences of octet values that are invalid according to the database’s selected character set encoding. Second, operations on binary strings process the actual bytes, whereas the processing of character strings depends on locale settings. In short, binary strings are appropriate for storing data that the programmer thinks of as “raw bytes”, whereas character strings are appropriate for storing text.

The `bytea` type supports two formats for input and output: “hex” format and PostgreSQL’s historical “escape” format. Both of these are always accepted on input. The output format depends on the configuration parameter `bytea_output`; the default is hex. (Note that the hex format was introduced in PostgreSQL 9.0; earlier versions and some tools don’t understand it.)

The SQL standard defines a different binary string type, called `BLOB` or `BINARY LARGE OBJECT`. The input format is different from `bytea`, but the provided functions and operators are mostly the same.

8.4.1. bytea Hex Format

The “hex” format encodes binary data as 2 hexadecimal digits per byte, most significant nibble first. The entire string is preceded by the sequence `\x` (to distinguish it from the escape format). In some contexts, the initial backslash may need to be escaped by doubling it (see Section 4.1.2.1). For input, the hexadecimal digits can be either upper or lower case, and whitespace is permitted between digit pairs (but not within a digit pair nor in the starting `\x` sequence). The hex format is compatible with a wide range of external applications and protocols, and it tends to be faster to convert than the escape format, so its use is preferred.

Example:

```
SELECT '\xDEADBEEF';
```

8.4.2. bytea Escape Format

The “escape” format is the traditional PostgreSQL format for the `bytea` type. It takes the approach of representing a binary string as a sequence of ASCII characters, while converting those bytes that cannot be represented as an ASCII character into special escape sequences. If, from the point of view of the application, representing bytes as characters makes sense, then this representation can be convenient. But in practice it is usually confusing because it fuzzes up the distinction between binary strings and character strings, and also the particular escape mechanism that was chosen is somewhat unwieldy. Therefore, this format should probably be avoided for most new applications.

When entering `bytea` values in escape format, octets of certain values *must* be escaped, while all octet values *can* be escaped. In general, to escape an octet, convert it into its three-digit octal value and precede it by a backslash. Backslash itself (octet decimal value 92) can alternatively be represented by double backslashes. Table 8.7 shows the characters that must be escaped, and gives the alternative escape sequences where applicable.

Table 8.7. bytea Literal Escaped Octets

Decimal Value	Octet	Description	Escaped Input Representation	Example	Hex Representation
0		zero octet	'\000'	SELECT '\000'::bytea;	\x00
39		single quote	'' or '\047'	SELECT ''::bytea;	\x27
92		backslash	'\\' or '\134'	SELECT '\\':bytea;	\x5c
0 to 31 and 127 to 255		“non-printable” octets	'\xxx' (octal value)	SELECT '\001'::bytea;	\x01

The requirement to escape *non-printable* octets varies depending on locale settings. In some instances you can get away with leaving them unescaped.

The reason that single quotes must be doubled, as shown in Table 8.7, is that this is true for any string literal in a SQL command. The generic string-literal parser consumes the outermost single quotes and reduces any pair of single quotes to one data character. What the `bytea` input function sees is just one single quote, which it treats as a plain data character. However, the `bytea` input function treats backslashes as special, and the other behaviors shown in Table 8.7 are implemented by that function.

In some contexts, backslashes must be doubled compared to what is shown above, because the generic string-literal parser will also reduce pairs of backslashes to one data character; see Section 4.1.2.1.

`Bytea` octets are output in hex format by default. If you change `bytea_output` to `escape`, “non-printable” octets are converted to their equivalent three-digit octal value and preceded by one backslash. Most “printable” octets are output by their standard representation in the client character set, e.g.:

```
SET bytea_output = 'escape';

SELECT 'abc \153\154\155 \052\251\124'::bytea;
       bytea
-----
```

```
abc klm *\251T
```

The octet with decimal value 92 (backslash) is doubled in the output. Details are in Table 8.8.

Table 8.8. `bytea` Output Escaped Octets

Decimal Value	Octet	Description	Escaped Output Representation	Example	Output Result
92		backslash	\\	SELECT '\134'::bytea;	\\
0 to 31 and 127 to 255		“non-printable” octets	\xxx (octal value)	SELECT '\001'::bytea;	\001
32 to 126		“printable” octets	client character set representation	SELECT '\176'::bytea;	~

Depending on the front end to PostgreSQL you use, you might have additional work to do in terms of escaping and unescaping `bytea` strings. For example, you might also have to escape line feeds and carriage returns if your interface automatically translates these.

8.5. Date/Time Types

PostgreSQL supports the full set of SQL date and time types, shown in Table 8.9. The operations available on these data types are described in Section 9.9. Dates are counted according to the Gregorian calendar, even in years before that calendar was introduced (see Section B.5 for more information).

Table 8.9. Date/Time Types

Name	Storage Size	Description	Low Value	High Value	Resolution
timestamp [(p)] [without time zone]	8 bytes	both date and time (no time zone)	4713 BC	294276 AD	1 microsecond
timestamp [(p)] with time zone	8 bytes	both date and time, with time zone	4713 BC	294276 AD	1 microsecond
date	4 bytes	date (no time of day)	4713 BC	5874897 AD	1 day
time [(p)] [without time zone]	8 bytes	time of day (no date)	00:00:00	24:00:00	1 microsecond
time [(p)] with time zone	12 bytes	time of day (no date), with time zone	00:00:00+1459	24:00:00-1459	1 microsecond
interval [fields] [(p)]	16 bytes	time interval	-178000000 years	178000000 years	1 microsecond

Note

The SQL standard requires that writing just `timestamp` be equivalent to `timestamp without time zone`, and PostgreSQL honors that behavior. `time-`

`stamp tz` is accepted as an abbreviation for `timestamp with time zone`; this is a PostgreSQL extension.

`time`, `timestamp`, and `interval` accept an optional precision value p which specifies the number of fractional digits retained in the seconds field. By default, there is no explicit bound on precision. The allowed range of p is from 0 to 6.

The `interval` type has an additional option, which is to restrict the set of stored fields by writing one of these phrases:

```
YEAR
MONTH
DAY
HOUR
MINUTE
SECOND
YEAR TO MONTH
DAY TO HOUR
DAY TO MINUTE
DAY TO SECOND
HOUR TO MINUTE
HOUR TO SECOND
MINUTE TO SECOND
```

Note that if both *fields* and p are specified, the *fields* must include `SECOND`, since the precision applies only to the seconds.

The type `time with time zone` is defined by the SQL standard, but the definition exhibits properties which lead to questionable usefulness. In most cases, a combination of `date`, `time`, `timestamp without time zone`, and `timestamp with time zone` should provide a complete range of date/time functionality required by any application.

8.5.1. Date/Time Input

Date and time input is accepted in almost any reasonable format, including ISO 8601, SQL-compatible, traditional POSTGRES, and others. For some formats, ordering of day, month, and year in date input is ambiguous and there is support for specifying the expected ordering of these fields. Set the `DateStyle` parameter to `MDY` to select month-day-year interpretation, `DMY` to select day-month-year interpretation, or `YMD` to select year-month-day interpretation.

PostgreSQL is more flexible in handling date/time input than the SQL standard requires. See Appendix B for the exact parsing rules of date/time input and for the recognized text fields including months, days of the week, and time zones.

Remember that any date or time literal input needs to be enclosed in single quotes, like text strings. Refer to Section 4.1.2.7 for more information. SQL requires the following syntax

```
type [ (p) ] 'value'
```

where p is an optional precision specification giving the number of fractional digits in the seconds field. Precision can be specified for `time`, `timestamp`, and `interval` types, and can range from 0 to 6. If no precision is specified in a constant specification, it defaults to the precision of the literal value (but not more than 6 digits).

8.5.1.1. Dates

Table 8.10 shows some possible inputs for the `date` type.

Table 8.10. Date Input

Example	Description
1999-01-08	ISO 8601; January 8 in any mode (recommended format)
January 8, 1999	unambiguous in any <code>datestyle</code> input mode
1/8/1999	January 8 in MDY mode; August 1 in DMY mode
1/18/1999	January 18 in MDY mode; rejected in other modes
01/02/03	January 2, 2003 in MDY mode; February 1, 2003 in DMY mode; February 3, 2001 in YMD mode
1999-Jan-08	January 8 in any mode
Jan-08-1999	January 8 in any mode
08-Jan-1999	January 8 in any mode
99-Jan-08	January 8 in YMD mode, else error
08-Jan-99	January 8, except error in YMD mode
Jan-08-99	January 8, except error in YMD mode
19990108	ISO 8601; January 8, 1999 in any mode
990108	ISO 8601; January 8, 1999 in any mode
1999.008	year and day of year
J2451187	Julian date
January 8, 99 BC	year 99 BC

8.5.1.2. Times

The time-of-day types are `time [(p)]` without time zone and `time [(p)] with time zone`. `time` alone is equivalent to `time without time zone`.

Valid input for these types consists of a time of day followed by an optional time zone. (See Table 8.11 and Table 8.12.) If a time zone is specified in the input for `time without time zone`, it is silently ignored. You can also specify a date but it will be ignored, except when you use a time zone name that involves a daylight-savings rule, such as `America/New_York`. In this case specifying the date is required in order to determine whether standard or daylight-savings time applies. The appropriate time zone offset is recorded in the `time with time zone` value.

Table 8.11. Time Input

Example	Description
04:05:06.789	ISO 8601
04:05:06	ISO 8601
04:05	ISO 8601
040506	ISO 8601
04:05 AM	same as 04:05; AM does not affect value
04:05 PM	same as 16:05; input hour must be ≤ 12
04:05:06.789-8	ISO 8601
04:05:06-08:00	ISO 8601
04:05-08:00	ISO 8601

Example	Description
040506-08	ISO 8601
04:05:06 PST	time zone specified by abbreviation
2003-04-12 04:05:06 America/New_York	time zone specified by full name

Table 8.12. Time Zone Input

Example	Description
PST	Abbreviation (for Pacific Standard Time)
America/New_York	Full time zone name
PST8PDT	POSIX-style time zone specification
-8:00	ISO-8601 offset for PST
-800	ISO-8601 offset for PST
-8	ISO-8601 offset for PST
zulu	Military abbreviation for UTC
z	Short form of zulu

Refer to Section 8.5.3 for more information on how to specify time zones.

8.5.1.3. Time Stamps

Valid input for the time stamp types consists of the concatenation of a date and a time, followed by an optional time zone, followed by an optional AD or BC. (Alternatively, AD/BC can appear before the time zone, but this is not the preferred ordering.) Thus:

```
1999-01-08 04:05:06
```

and:

```
1999-01-08 04:05:06 -8:00
```

are valid values, which follow the ISO 8601 standard. In addition, the common format:

```
January 8 04:05:06 1999 PST
```

is supported.

The SQL standard differentiates `timestamp without time zone` and `timestamp with time zone` literals by the presence of a “+” or “-” symbol and time zone offset after the time. Hence, according to the standard,

```
TIMESTAMP '2004-10-19 10:23:54'
```

is a `timestamp without time zone`, while

```
TIMESTAMP '2004-10-19 10:23:54+02'
```

is a `timestamp with time zone`. PostgreSQL never examines the content of a literal string before determining its type, and therefore will treat both of the above as `timestamp without time zone`. To ensure that a literal is treated as `timestamp with time zone`, give it the correct explicit type:

```
TIMESTAMP WITH TIME ZONE '2004-10-19 10:23:54+02'
```

In a literal that has been determined to be `timestamp without time zone`, PostgreSQL will silently ignore any time zone indication. That is, the resulting value is derived from the date/time fields in the input value, and is not adjusted for time zone.

For `timestamp with time zone`, the internally stored value is always in UTC (Universal Coordinated Time, traditionally known as Greenwich Mean Time, GMT). An input value that has an explicit time zone specified is converted to UTC using the appropriate offset for that time zone. If no time zone is stated in the input string, then it is assumed to be in the time zone indicated by the system's `TimeZone` parameter, and is converted to UTC using the offset for the `timezone` zone.

When a `timestamp with time zone` value is output, it is always converted from UTC to the current `timezone` zone, and displayed as local time in that zone. To see the time in another time zone, either change `timezone` or use the `AT TIME ZONE` construct (see Section 9.9.3).

Conversions between `timestamp without time zone` and `timestamp with time zone` normally assume that the `timestamp without time zone` value should be taken or given as `timezone` local time. A different time zone can be specified for the conversion using `AT TIME ZONE`.

8.5.1.4. Special Values

PostgreSQL supports several special date/time input values for convenience, as shown in Table 8.13. The values `infinity` and `-infinity` are specially represented inside the system and will be displayed unchanged; but the others are simply notational shorthands that will be converted to ordinary date/time values when read. (In particular, `now` and related strings are converted to a specific time value as soon as they are read.) All of these values need to be enclosed in single quotes when used as constants in SQL commands.

Table 8.13. Special Date/Time Inputs

Input String	Valid Types	Description
<code>epoch</code>	<code>date</code> , <code>timestamp</code>	1970-01-01 00:00:00+00 (Unix system time zero)
<code>infinity</code>	<code>date</code> , <code>timestamp</code>	later than all other time stamps
<code>-infinity</code>	<code>date</code> , <code>timestamp</code>	earlier than all other time stamps
<code>now</code>	<code>date</code> , <code>time</code> , <code>timestamp</code>	current transaction's start time
<code>today</code>	<code>date</code> , <code>timestamp</code>	midnight (00:00) today
<code>tomorrow</code>	<code>date</code> , <code>timestamp</code>	midnight (00:00) tomorrow
<code>yesterday</code>	<code>date</code> , <code>timestamp</code>	midnight (00:00) yesterday
<code>allballs</code>	<code>time</code>	00:00:00.00 UTC

The following SQL-compatible functions can also be used to obtain the current time value for the corresponding data type: `CURRENT_DATE`, `CURRENT_TIME`, `CURRENT_TIMESTAMP`, `LOCALTIME`, `LOCALTIMESTAMP`. The latter four accept an optional subsecond precision specification. (See Section 9.9.4.) Note that these are SQL functions and are *not* recognized in data input strings.

8.5.2. Date/Time Output

The output format of the date/time types can be set to one of the four styles ISO 8601, SQL (Ingres), traditional POSTGRES (Unix date format), or German. The default is the ISO format. (The SQL standard requires the use of the ISO 8601 format. The name of the “SQL” output format is a historical accident.) Table 8.14 shows examples of each output style. The output of the `date` and `time` types is generally only the date or time part in accordance with the given examples. However, the POSTGRES style outputs date-only values in ISO format.

Table 8.14. Date/Time Output Styles

Style Specification	Description	Example
ISO	ISO 8601, SQL standard	1997-12-17 07:37:16-08
SQL	traditional style	12/17/1997 07:37:16.00 PST
Postgres	original style	Wed Dec 17 07:37:16 1997 PST
German	regional style	17.12.1997 07:37:16.00 PST

Note

ISO 8601 specifies the use of uppercase letter T to separate the date and time. PostgreSQL accepts that format on input, but on output it uses a space rather than T, as shown above. This is for readability and for consistency with RFC 3339 as well as some other database systems.

In the SQL and POSTGRES styles, day appears before month if DMY field ordering has been specified, otherwise month appears before day. (See Section 8.5.1 for how this setting also affects interpretation of input values.) Table 8.15 shows examples.

Table 8.15. Date Order Conventions

<code>datestyle</code> Setting	Input Ordering	Example Output
SQL, DMY	<i>day/month/year</i>	17/12/1997 15:37:16.00 CET
SQL, MDY	<i>month/day/year</i>	12/17/1997 07:37:16.00 PST
Postgres, DMY	<i>day/month/year</i>	Wed 17 Dec 07:37:16 1997 PST

The date/time style can be selected by the user using the `SET datestyle` command, the `DateStyle` parameter in the `postgresql.conf` configuration file, or the `PGDATESTYLE` environment variable on the server or client.

The formatting function `to_char` (see Section 9.8) is also available as a more flexible way to format date/time output.

8.5.3. Time Zones

Time zones, and time-zone conventions, are influenced by political decisions, not just earth geometry. Time zones around the world became somewhat standardized during the 1900s, but continue to be prone to arbitrary changes, particularly with respect to daylight-savings rules. PostgreSQL uses the widely-used IANA (Olson) time zone database for information about historical time zone rules. For times in the future, the assumption is that the latest known rules for a given time zone will continue to be observed indefinitely far into the future.

PostgreSQL endeavors to be compatible with the SQL standard definitions for typical usage. However, the SQL standard has an odd mix of date and time types and capabilities. Two obvious problems are:

- Although the `date` type cannot have an associated time zone, the `time` type can. Time zones in the real world have little meaning unless associated with a date as well as a time, since the offset can vary through the year with daylight-saving time boundaries.

- The default time zone is specified as a constant numeric offset from UTC. It is therefore impossible to adapt to daylight-saving time when doing date/time arithmetic across DST boundaries.

To address these difficulties, we recommend using date/time types that contain both date and time when using time zones. We do *not* recommend using the type `time with time zone` (though it is supported by PostgreSQL for legacy applications and for compliance with the SQL standard). PostgreSQL assumes your local time zone for any type containing only date or time.

All timezone-aware dates and times are stored internally in UTC. They are converted to local time in the zone specified by the `TimeZone` configuration parameter before being displayed to the client.

PostgreSQL allows you to specify time zones in three different forms:

- A full time zone name, for example `America/New_York`. The recognized time zone names are listed in the `pg_timezone_names` view (see Section 51.92). PostgreSQL uses the widely-used IANA time zone data for this purpose, so the same time zone names are also recognized by other software.
- A time zone abbreviation, for example `PST`. Such a specification merely defines a particular offset from UTC, in contrast to full time zone names which can imply a set of daylight savings transition-date rules as well. The recognized abbreviations are listed in the `pg_timezone_abbrevs` view (see Section 51.91). You cannot set the configuration parameters `TimeZone` or `log_timezone` to a time zone abbreviation, but you can use abbreviations in date/time input values and with the `AT TIME ZONE` operator.
- In addition to the timezone names and abbreviations, PostgreSQL will accept POSIX-style time zone specifications of the form `STDoffset` or `STDoffsetDST`, where `STD` is a zone abbreviation, `offset` is a numeric offset in hours west from UTC, and `DST` is an optional daylight-savings zone abbreviation, assumed to stand for one hour ahead of the given offset. For example, if `EST5EDT` were not already a recognized zone name, it would be accepted and would be functionally equivalent to United States East Coast time. In this syntax, a zone abbreviation can be a string of letters, or an arbitrary string surrounded by angle brackets (`<>`). When a daylight-savings zone abbreviation is present, it is assumed to be used according to the same daylight-savings transition rules used in the IANA time zone database's `posixrules` entry. In a standard PostgreSQL installation, `posixrules` is the same as `US/Eastern`, so that POSIX-style time zone specifications follow USA daylight-savings rules. If needed, you can adjust this behavior by replacing the `posixrules` file.

In short, this is the difference between abbreviations and full names: abbreviations represent a specific offset from UTC, whereas many of the full names imply a local daylight-savings time rule, and so have two possible UTC offsets. As an example, `2014-06-04 12:00 America/New_York` represents noon local time in New York, which for this particular date was Eastern Daylight Time (UTC-4). So `2014-06-04 12:00 EDT` specifies that same time instant. But `2014-06-04 12:00 EST` specifies noon Eastern Standard Time (UTC-5), regardless of whether daylight savings was nominally in effect on that date.

To complicate matters, some jurisdictions have used the same timezone abbreviation to mean different UTC offsets at different times; for example, in Moscow `MSK` has meant UTC+3 in some years and UTC+4 in others. PostgreSQL interprets such abbreviations according to whatever they meant (or had most recently meant) on the specified date; but, as with the `EST` example above, this is not necessarily the same as local civil time on that date.

One should be wary that the POSIX-style time zone feature can lead to silently accepting bogus input, since there is no check on the reasonableness of the zone abbreviations. For example, `SET TIMEZONE TO FOOBAR0` will work, leaving the system effectively using a rather peculiar abbreviation for UTC. Another issue to keep in mind is that in POSIX time zone names, positive offsets are used for locations *west* of Greenwich. Everywhere else, PostgreSQL follows the ISO-8601 convention that positive timezone offsets are *east* of Greenwich.

In all cases, timezone names and abbreviations are recognized case-insensitively. (This is a change from PostgreSQL versions prior to 8.2, which were case-sensitive in some contexts but not others.)

Neither timezone names nor abbreviations are hard-wired into the server; they are obtained from configuration files stored under `.../share/timezone/` and `.../share/timezonesets/` of the installation directory (see Section B.4).

The `TimeZone` configuration parameter can be set in the file `postgresql.conf`, or in any of the other standard ways described in Chapter 19. There are also some special ways to set it:

- The SQL command `SET TIME ZONE` sets the time zone for the session. This is an alternative spelling of `SET TIMEZONE TO` with a more SQL-spec-compatible syntax.
- The `PGTZ` environment variable is used by libpq clients to send a `SET TIME ZONE` command to the server upon connection.

8.5.4. Interval Input

`interval` values can be written using the following verbose syntax:

```
[@] quantity unit [quantity unit...] [direction]
```

where *quantity* is a number (possibly signed); *unit* is microsecond, millisecond, second, minute, hour, day, week, month, year, decade, century, millennium, or abbreviations or plurals of these units; *direction* can be `ago` or empty. The at sign (@) is optional noise. The amounts of the different units are implicitly added with appropriate sign accounting. `ago` negates all the fields. This syntax is also used for interval output, if `IntervalStyle` is set to `postgres_verbose`.

Quantities of days, hours, minutes, and seconds can be specified without explicit unit markings. For example, `'1 12:59:10'` is read the same as `'1 day 12 hours 59 min 10 sec'`. Also, a combination of years and months can be specified with a dash; for example `'200-10'` is read the same as `'200 years 10 months'`. (These shorter forms are in fact the only ones allowed by the SQL standard, and are used for output when `IntervalStyle` is set to `sql_standard`.)

Interval values can also be written as ISO 8601 time intervals, using either the “format with designators” of the standard’s section 4.4.3.2 or the “alternative format” of section 4.4.3.3. The format with designators looks like this:

```
P quantity unit [ quantity unit ...] [ T [ quantity unit ...]]
```

The string must start with a `P`, and may include a `T` that introduces the time-of-day units. The available unit abbreviations are given in Table 8.16. Units may be omitted, and may be specified in any order, but units smaller than a day must appear after `T`. In particular, the meaning of `M` depends on whether it is before or after `T`.

Table 8.16. ISO 8601 Interval Unit Abbreviations

Abbreviation	Meaning
Y	Years
M	Months (in the date part)
W	Weeks
D	Days
H	Hours
M	Minutes (in the time part)
S	Seconds

In the alternative format:

```
P [ years-months-days ] [ T hours:minutes:seconds ]
```

the string must begin with P, and a T separates the date and time parts of the interval. The values are given as numbers similar to ISO 8601 dates.

When writing an interval constant with a *fields* specification, or when assigning a string to an interval column that was defined with a *fields* specification, the interpretation of unmarked quantities depends on the *fields*. For example INTERVAL '1' YEAR is read as 1 year, whereas INTERVAL '1' means 1 second. Also, field values “to the right” of the least significant field allowed by the *fields* specification are silently discarded. For example, writing INTERVAL '1 day 2:03:04' HOUR TO MINUTE results in dropping the seconds field, but not the day field.

According to the SQL standard all fields of an interval value must have the same sign, so a leading negative sign applies to all fields; for example the negative sign in the interval literal '-1 2:03:04' applies to both the days and hour/minute/second parts. PostgreSQL allows the fields to have different signs, and traditionally treats each field in the textual representation as independently signed, so that the hour/minute/second part is considered positive in this example. If IntervalStyle is set to sql_standard then a leading sign is considered to apply to all fields (but only if no additional signs appear). Otherwise the traditional PostgreSQL interpretation is used. To avoid ambiguity, it's recommended to attach an explicit sign to each field if any field is negative.

In the verbose input format, and in some fields of the more compact input formats, field values can have fractional parts; for example '1.5 week' or '01:02:03.45'. Such input is converted to the appropriate number of months, days, and seconds for storage. When this would result in a fractional number of months or days, the fraction is added to the lower-order fields using the conversion factors 1 month = 30 days and 1 day = 24 hours. For example, '1.5 month' becomes 1 month and 15 days. Only seconds will ever be shown as fractional on output.

Table 8.17 shows some examples of valid interval input.

Table 8.17. Interval Input

Example	Description
1-2	SQL standard format: 1 year 2 months
3 4:05:06	SQL standard format: 3 days 4 hours 5 minutes 6 seconds
1 year 2 months 3 days 4 hours 5 minutes 6 seconds	Traditional Postgres format: 1 year 2 months 3 days 4 hours 5 minutes 6 seconds
P1Y2M3DT4H5M6S	ISO 8601 “format with designators”: same meaning as above
P0001-02-03T04:05:06	ISO 8601 “alternative format”: same meaning as above

Internally interval values are stored as months, days, and seconds. This is done because the number of days in a month varies, and a day can have 23 or 25 hours if a daylight savings time adjustment is involved. The months and days fields are integers while the seconds field can store fractions. Because intervals are usually created from constant strings or timestamp subtraction, this storage method works well in most cases, but can cause unexpected results:

```
SELECT EXTRACT(hours from '80 minutes'::interval);
 date_part
-----
          1
```

```
SELECT EXTRACT(days from '80 hours'::interval);
```

```
date_part
```

```
-----  
0
```

Functions `justify_days` and `justify_hours` are available for adjusting days and hours that overflow their normal ranges.

8.5.5. Interval Output

The output format of the interval type can be set to one of the four styles `sql_standard`, `postgres`, `postgres_verbose`, or `iso_8601`, using the command `SET intervalstyle`. The default is the `postgres` format. Table 8.18 shows examples of each output style.

The `sql_standard` style produces output that conforms to the SQL standard's specification for interval literal strings, if the interval value meets the standard's restrictions (either year-month only or day-time only, with no mixing of positive and negative components). Otherwise the output looks like a standard year-month literal string followed by a day-time literal string, with explicit signs added to disambiguate mixed-sign intervals.

The output of the `postgres` style matches the output of PostgreSQL releases prior to 8.4 when the `DateStyle` parameter was set to `ISO`.

The output of the `postgres_verbose` style matches the output of PostgreSQL releases prior to 8.4 when the `DateStyle` parameter was set to non-ISO output.

The output of the `iso_8601` style matches the “format with designators” described in section 4.4.3.2 of the ISO 8601 standard.

Table 8.18. Interval Output Style Examples

Style Specification	Year-Month Interval	Day-Time Interval	Mixed Interval
<code>sql_standard</code>	1-2	3 4:05:06	-1-2 +3 -4:05:06
<code>postgres</code>	1 year 2 mons	3 days 04:05:06	-1 year -2 mons +3 days -04:05:06
<code>postgres_verbose</code>	@ 1 year 2 mons	@ 3 days 4 hours 5 mins 6 secs	@ 1 year 2 mons -3 days 4 hours 5 mins 6 secs ago
<code>iso_8601</code>	P1Y2M	P3DT4H5M6S	P-1Y-2M3DT-4H-5M-6S

8.6. Boolean Type

PostgreSQL provides the standard SQL type `boolean`; see Table 8.19. The `boolean` type can have several states: “true”, “false”, and a third state, “unknown”, which is represented by the SQL null value.

Table 8.19. Boolean Data Type

Name	Storage Size	Description
<code>boolean</code>	1 byte	state of true or false

Boolean constants can be represented in SQL queries by the SQL key words `TRUE`, `FALSE`, and `NULL`.

The datatype input function for type `boolean` accepts these string representations for the “true” state:

```
true  
yes  
on  
1
```

and these representations for the “false” state:

```
false
no
off
0
```

Unique prefixes of these strings are also accepted, for example `t` or `n`. Leading or trailing whitespace is ignored, and case does not matter.

The datatype output function for type `boolean` always emits either `t` or `f`, as shown in Example 8.2.

Example 8.2. Using the `boolean` Type

```
CREATE TABLE test1 (a boolean, b text);
INSERT INTO test1 VALUES (TRUE, 'sic est');
INSERT INTO test1 VALUES (FALSE, 'non est');
SELECT * FROM test1;
 a |    b
---+-----
 t | sic est
 f | non est

SELECT * FROM test1 WHERE a;
 a |    b
---+-----
 t | sic est
```

The key words `TRUE` and `FALSE` are the preferred (SQL-compliant) method for writing Boolean constants in SQL queries. But you can also use the string representations by following the generic string-literal constant syntax described in Section 4.1.2.7, for example `'yes'::boolean`.

Note that the parser automatically understands that `TRUE` and `FALSE` are of type `boolean`, but this is not so for `NULL` because that can have any type. So in some contexts you might have to cast `NULL` to `boolean` explicitly, for example `NULL::boolean`. Conversely, the cast can be omitted from a string-literal Boolean value in contexts where the parser can deduce that the literal must be of type `boolean`.

8.7. Enumerated Types

Enumerated (enum) types are data types that comprise a static, ordered set of values. They are equivalent to the enum types supported in a number of programming languages. An example of an enum type might be the days of the week, or a set of status values for a piece of data.

8.7.1. Declaration of Enumerated Types

Enum types are created using the `CREATE TYPE` command, for example:

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
```

Once created, the enum type can be used in table and function definitions much like any other type:

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
CREATE TABLE person (
    name text,
    current_mood mood
```

```
);
INSERT INTO person VALUES ('Moe', 'happy');
SELECT * FROM person WHERE current_mood = 'happy';
  name | current_mood
-----+-----
  Moe  | happy
(1 row)
```

8.7.2. Ordering

The ordering of the values in an enum type is the order in which the values were listed when the type was created. All standard comparison operators and related aggregate functions are supported for enums. For example:

```
INSERT INTO person VALUES ('Larry', 'sad');
INSERT INTO person VALUES ('Curly', 'ok');
SELECT * FROM person WHERE current_mood > 'sad';
  name | current_mood
-----+-----
  Moe  | happy
  Curly | ok
(2 rows)
```

```
SELECT * FROM person WHERE current_mood > 'sad' ORDER BY
  current_mood;
  name | current_mood
-----+-----
  Curly | ok
  Moe   | happy
(2 rows)
```

```
SELECT name
FROM person
WHERE current_mood = (SELECT MIN(current_mood) FROM person);
  name
-----
  Larry
(1 row)
```

8.7.3. Type Safety

Each enumerated data type is separate and cannot be compared with other enumerated types. See this example:

```
CREATE TYPE happiness AS ENUM ('happy', 'very happy', 'ecstatic');
CREATE TABLE holidays (
    num_weeks integer,
    happiness happiness
);
INSERT INTO holidays(num_weeks,happiness) VALUES (4, 'happy');
INSERT INTO holidays(num_weeks,happiness) VALUES (6, 'very happy');
INSERT INTO holidays(num_weeks,happiness) VALUES (8, 'ecstatic');
INSERT INTO holidays(num_weeks,happiness) VALUES (2, 'sad');
ERROR:  invalid input value for enum happiness: "sad"
SELECT person.name, holidays.num_weeks FROM person, holidays
WHERE person.current_mood = holidays.happiness;
```

```
ERROR: operator does not exist: mood = happiness
```

If you really need to do something like that, you can either write a custom operator or add explicit casts to your query:

```
SELECT person.name, holidays.num_weeks FROM person, holidays
   WHERE person.current_mood::text = holidays.happiness::text;
 name | num_weeks
-----+-----
 Moe  |          4
(1 row)
```

8.7.4. Implementation Details

Enum labels are case sensitive, so 'happy' is not the same as 'HAPPY'. White space in the labels is significant too.

Although enum types are primarily intended for static sets of values, there is support for adding new values to an existing enum type, and for renaming values (see `ALTER TYPE`). Existing values cannot be removed from an enum type, nor can the sort ordering of such values be changed, short of dropping and re-creating the enum type.

An enum value occupies four bytes on disk. The length of an enum value's textual label is limited by the `NAMEDATALEN` setting compiled into PostgreSQL; in standard builds this means at most 63 bytes.

The translations from internal enum values to textual labels are kept in the system catalog `pg_enum`. Querying this catalog directly can be useful.

8.8. Geometric Types

Geometric data types represent two-dimensional spatial objects. Table 8.20 shows the geometric types available in PostgreSQL.

Table 8.20. Geometric Types

Name	Storage Size	Description	Representation
point	16 bytes	Point on a plane	(x,y)
line	32 bytes	Infinite line	{A,B,C}
lseg	32 bytes	Finite line segment	((x1,y1),(x2,y2))
box	32 bytes	Rectangular box	((x1,y1),(x2,y2))
path	16+16n bytes	Closed path (similar to polygon)	((x1,y1),...)
path	16+16n bytes	Open path	[(x1,y1),...]
polygon	40+16n bytes	Polygon (similar to closed path)	((x1,y1),...)
circle	24 bytes	Circle	<(x,y),r> (center point and radius)

A rich set of functions and operators is available to perform various geometric operations such as scaling, translation, rotation, and determining intersections. They are explained in Section 9.11.

8.8.1. Points

Points are the fundamental two-dimensional building block for geometric types. Values of type `point` are specified using either of the following syntaxes:

```
( x , y )
x , y
```

where `x` and `y` are the respective coordinates, as floating-point numbers.

Points are output using the first syntax.

8.8.2. Lines

Lines are represented by the linear equation $Ax + By + C = 0$, where `A` and `B` are not both zero. Values of type `line` are input and output in the following form:

```
{ A, B, C }
```

Alternatively, any of the following forms can be used for input:

```
[ ( x1 , y1 ) , ( x2 , y2 ) ]
( ( x1 , y1 ) , ( x2 , y2 ) )
( x1 , y1 ) , ( x2 , y2 )
x1 , y1 , x2 , y2
```

where (x_1, y_1) and (x_2, y_2) are two different points on the line.

8.8.3. Line Segments

Line segments are represented by pairs of points that are the endpoints of the segment. Values of type `lseg` are specified using any of the following syntaxes:

```
[ ( x1 , y1 ) , ( x2 , y2 ) ]
( ( x1 , y1 ) , ( x2 , y2 ) )
( x1 , y1 ) , ( x2 , y2 )
x1 , y1 , x2 , y2
```

where (x_1, y_1) and (x_2, y_2) are the end points of the line segment.

Line segments are output using the first syntax.

8.8.4. Boxes

Boxes are represented by pairs of points that are opposite corners of the box. Values of type `box` are specified using any of the following syntaxes:

```
( ( x1 , y1 ) , ( x2 , y2 ) )
( x1 , y1 ) , ( x2 , y2 )
x1 , y1 , x2 , y2
```

where (x_1, y_1) and (x_2, y_2) are any two opposite corners of the box.

Boxes are output using the second syntax.

Any two opposite corners can be supplied on input, but the values will be reordered as needed to store the upper right and lower left corners, in that order.

8.8.5. Paths

Paths are represented by lists of connected points. Paths can be *open*, where the first and last points in the list are considered not connected, or *closed*, where the first and last points are considered connected.

Values of type `path` are specified using any of the following syntaxes:

```
[ ( x1 , y1 ) , ... , ( xn , yn ) ]
( ( x1 , y1 ) , ... , ( xn , yn ) )
( x1 , y1 ) , ... , ( xn , yn )
( x1 , y1 , ... , xn , yn )
x1 , y1 , ... , xn , yn
```

where the points are the end points of the line segments comprising the path. Square brackets ([]) indicate an open path, while parentheses (()) indicate a closed path. When the outermost parentheses are omitted, as in the third through fifth syntaxes, a closed path is assumed.

Paths are output using the first or second syntax, as appropriate.

8.8.6. Polygons

Polygons are represented by lists of points (the vertexes of the polygon). Polygons are very similar to closed paths, but are stored differently and have their own set of support routines.

Values of type `polygon` are specified using any of the following syntaxes:

```
( ( x1 , y1 ) , ... , ( xn , yn ) )
( x1 , y1 ) , ... , ( xn , yn )
( x1 , y1 , ... , xn , yn )
x1 , y1 , ... , xn , yn
```

where the points are the end points of the line segments comprising the boundary of the polygon.

Polygons are output using the first syntax.

8.8.7. Circles

Circles are represented by a center point and radius. Values of type `circle` are specified using any of the following syntaxes:

```
< ( x , y ) , r >
( ( x , y ) , r )
( x , y ) , r
x , y , r
```

where (*x*, *y*) is the center point and *r* is the radius of the circle.

Circles are output using the first syntax.

8.9. Network Address Types

PostgreSQL offers data types to store IPv4, IPv6, and MAC addresses, as shown in Table 8.21. It is better to use these types instead of plain text types to store network addresses, because these types offer input error checking and specialized operators and functions (see Section 9.12).

Table 8.21. Network Address Types

Name	Storage Size	Description
<code>cidr</code>	7 or 19 bytes	IPv4 and IPv6 networks
<code>inet</code>	7 or 19 bytes	IPv4 and IPv6 hosts and networks
<code>macaddr</code>	6 bytes	MAC addresses
<code>macaddr8</code>	8 bytes	MAC addresses (EUI-64 format)

When sorting `inet` or `cidr` data types, IPv4 addresses will always sort before IPv6 addresses, including IPv4 addresses encapsulated or mapped to IPv6 addresses, such as `::10.2.3.4` or `::ffff:10.4.3.2`.

8.9.1. `inet`

The `inet` type holds an IPv4 or IPv6 host address, and optionally its subnet, all in one field. The subnet is represented by the number of network address bits present in the host address (the “netmask”). If the netmask is 32 and the address is IPv4, then the value does not indicate a subnet, only a single host. In IPv6, the address length is 128 bits, so 128 bits specify a unique host address. Note that if you want to accept only networks, you should use the `cidr` type rather than `inet`.

The input format for this type is `address/y` where `address` is an IPv4 or IPv6 address and `y` is the number of bits in the netmask. If the `/y` portion is missing, the netmask is 32 for IPv4 and 128 for IPv6, so the value represents just a single host. On display, the `/y` portion is suppressed if the netmask specifies a single host.

8.9.2. `cidr`

The `cidr` type holds an IPv4 or IPv6 network specification. Input and output formats follow Classless Internet Domain Routing conventions. The format for specifying networks is `address/y` where `address` is the network represented as an IPv4 or IPv6 address, and `y` is the number of bits in the netmask. If `y` is omitted, it is calculated using assumptions from the older classful network numbering system, except it will be at least large enough to include all of the octets written in the input. It is an error to specify a network address that has bits set to the right of the specified netmask.

Table 8.22 shows some examples.

Table 8.22. `cidr` Type Input Examples

<code>cidr</code> Input	<code>cidr</code> Output	<code>abbrev(cidr)</code>
192.168.100.128/25	192.168.100.128/25	192.168.100.128/25
192.168/24	192.168.0.0/24	192.168.0/24
192.168/25	192.168.0.0/25	192.168.0.0/25
192.168.1	192.168.1.0/24	192.168.1/24
192.168	192.168.0.0/24	192.168.0/24
128.1	128.1.0.0/16	128.1/16
128	128.0.0.0/16	128.0/16
128.1.2	128.1.2.0/24	128.1.2/24
10.1.2	10.1.2.0/24	10.1.2/24
10.1	10.1.0.0/16	10.1/16
10	10.0.0.0/8	10/8
10.1.2.3/32	10.1.2.3/32	10.1.2.3/32

<code>cidr</code> Input	<code>cidr</code> Output	<code>abbrev(cidr)</code>
2001:4f8:3:ba::/64	2001:4f8:3:ba::/64	2001:4f8:3:ba::/64
2001:4f8:3:ba:2e0:81f-f:fe22:d1f1/128	2001:4f8:3:ba:2e0:81f-f:fe22:d1f1/128	2001:4f8:3:ba:2e0:81f-f:fe22:d1f1
::ffff:1.2.3.0/120	::ffff:1.2.3.0/120	::ffff:1.2.3/120
::ffff:1.2.3.0/128	::ffff:1.2.3.0/128	::ffff:1.2.3.0/128

8.9.3. `inet` vs. `cidr`

The essential difference between `inet` and `cidr` data types is that `inet` accepts values with nonzero bits to the right of the netmask, whereas `cidr` does not. For example, `192.168.0.1/24` is valid for `inet` but not for `cidr`.

Tip

If you do not like the output format for `inet` or `cidr` values, try the functions `host`, `text`, and `abbrev`.

8.9.4. `macaddr`

The `macaddr` type stores MAC addresses, known for example from Ethernet card hardware addresses (although MAC addresses are used for other purposes as well). Input is accepted in the following formats:

```
'08:00:2b:01:02:03'
'08-00-2b-01-02-03'
'08002b:010203'
'08002b-010203'
'0800.2b01.0203'
'0800-2b01-0203'
'08002b010203'
```

These examples would all specify the same address. Upper and lower case is accepted for the digits a through f. Output is always in the first of the forms shown.

IEEE Std 802-2001 specifies the second shown form (with hyphens) as the canonical form for MAC addresses, and specifies the first form (with colons) as the bit-reversed notation, so that `08-00-2b-01-02-03` = `01:00:4D:08:04:0C`. This convention is widely ignored nowadays, and it is relevant only for obsolete network protocols (such as Token Ring). PostgreSQL makes no provisions for bit reversal, and all accepted formats use the canonical LSB order.

The remaining five input formats are not part of any standard.

8.9.5. `macaddr8`

The `macaddr8` type stores MAC addresses in EUI-64 format, known for example from Ethernet card hardware addresses (although MAC addresses are used for other purposes as well). This type can accept both 6 and 8 byte length MAC addresses and stores them in 8 byte length format. MAC addresses given in 6 byte format will be stored in 8 byte length format with the 4th and 5th bytes set to FF and FE, respectively. Note that IPv6 uses a modified EUI-64 format where the 7th bit should be set to one after the conversion from EUI-48. The function `macaddr8_set7bit` is provided to make this change. Generally speaking, any input which is comprised of pairs of hex digits (on byte boundaries), optionally separated consistently by one of `:`, `-` or `.`, is accepted. The number

of hex digits must be either 16 (8 bytes) or 12 (6 bytes). Leading and trailing whitespace is ignored. The following are examples of input formats that are accepted:

```
'08:00:2b:01:02:03:04:05'
'08-00-2b-01-02-03-04-05'
'08002b:0102030405'
'08002b-0102030405'
'0800.2b01.0203.0405'
'0800-2b01-0203-0405'
'08002b01:02030405'
'08002b0102030405'
```

These examples would all specify the same address. Upper and lower case is accepted for the digits a through f. Output is always in the first of the forms shown. The last six input formats that are mentioned above are not part of any standard. To convert a traditional 48 bit MAC address in EUI-48 format to modified EUI-64 format to be included as the host portion of an IPv6 address, use `macaddr8_set7bit` as shown:

```
SELECT macaddr8_set7bit('08:00:2b:01:02:03');

 macaddr8_set7bit
-----
0a:00:2b:ff:fe:01:02:03
(1 row)
```

8.10. Bit String Types

Bit strings are strings of 1's and 0's. They can be used to store or visualize bit masks. There are two SQL bit types: `bit(n)` and `bit varying(n)`, where n is a positive integer.

`bit` type data must match the length n exactly; it is an error to attempt to store shorter or longer bit strings. `bit varying` data is of variable length up to the maximum length n ; longer strings will be rejected. Writing `bit` without a length is equivalent to `bit(1)`, while `bit varying` without a length specification means unlimited length.

Note

If one explicitly casts a bit-string value to `bit(n)`, it will be truncated or zero-padded on the right to be exactly n bits, without raising an error. Similarly, if one explicitly casts a bit-string value to `bit varying(n)`, it will be truncated on the right if it is more than n bits.

Refer to Section 4.1.2.5 for information about the syntax of bit string constants. Bit-logical operators and string manipulation functions are available; see Section 9.6.

Example 8.3. Using the Bit String Types

```
CREATE TABLE test (a BIT(3), b BIT VARYING(5));
INSERT INTO test VALUES (B'101', B'00');
INSERT INTO test VALUES (B'10', B'101');

ERROR: bit string length 2 does not match type bit(3)
```

```
INSERT INTO test VALUES (B'10'::bit(3), B'101');
SELECT * FROM test;
```

```

 a | b
-----+-----
101 | 00
100 | 101
```

A bit string value requires 1 byte for each group of 8 bits, plus 5 or 8 bytes overhead depending on the length of the string (but long values may be compressed or moved out-of-line, as explained in Section 8.3 for character strings).

8.11. Text Search Types

PostgreSQL provides two data types that are designed to support full text search, which is the activity of searching through a collection of natural-language *documents* to locate those that best match a *query*. The `tsvector` type represents a document in a form optimized for text search; the `tsquery` type similarly represents a text query. Chapter 12 provides a detailed explanation of this facility, and Section 9.13 summarizes the related functions and operators.

8.11.1. `tsvector`

A `tsvector` value is a sorted list of distinct *lexemes*, which are words that have been *normalized* to merge different variants of the same word (see Chapter 12 for details). Sorting and duplicate-elimination are done automatically during input, as shown in this example:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector;
           tsvector
-----
'a' 'and' 'ate' 'cat' 'fat' 'mat' 'on' 'rat' 'sat'
```

To represent lexemes containing whitespace or punctuation, surround them with quotes:

```
SELECT $$the lexeme '    ' contains spaces$$::tsvector;
           tsvector
-----
'    ' 'contains' 'lexeme' 'spaces' 'the'
```

(We use dollar-quoted string literals in this example and the next one to avoid the confusion of having to double quote marks within the literals.) Embedded quotes and backslashes must be doubled:

```
SELECT $$the lexeme 'Joe''s' contains a quote$$::tsvector;
           tsvector
-----
'Joe''s' 'a' 'contains' 'lexeme' 'quote' 'the'
```

Optionally, integer *positions* can be attached to lexemes:

```
SELECT 'a:1 fat:2 cat:3 sat:4 on:5 a:6 mat:7 and:8 ate:9 a:10
fat:11 rat:12'::tsvector;
           tsvector
-----
'a':1,6,10 'and':8 'ate':9 'cat':3 'fat':2,11 'mat':7 'on':5
'rat':12 'sat':4
```

A position normally indicates the source word's location in the document. Positional information can be used for *proximity ranking*. Position values can range from 1 to 16383; larger numbers are silently set to 16383. Duplicate positions for the same lexeme are discarded.

Lexemes that have positions can further be labeled with a *weight*, which can be A, B, C, or D. D is the default and hence is not shown on output:

```
SELECT 'a:1A fat:2B,4C cat:5D'::tsvector;
      tsvector
-----
'a':1A 'cat':5 'fat':2B,4C
```

Weights are typically used to reflect document structure, for example by marking title words differently from body words. Text search ranking functions can assign different priorities to the different weight markers.

It is important to understand that the `tsvector` type itself does not perform any word normalization; it assumes the words it is given are normalized appropriately for the application. For example,

```
SELECT 'The Fat Rats'::tsvector;
      tsvector
-----
'Fat' 'Rats' 'The'
```

For most English-text-searching applications the above words would be considered non-normalized, but `tsvector` doesn't care. Raw document text should usually be passed through `to_tsvector` to normalize the words appropriately for searching:

```
SELECT to_tsvector('english', 'The Fat Rats');
      to_tsvector
-----
'fat':2 'rat':3
```

Again, see Chapter 12 for more detail.

8.11.2. tsquery

A `tsquery` value stores lexemes that are to be searched for, and can combine them using the Boolean operators `&` (AND), `|` (OR), and `!` (NOT), as well as the phrase search operator `<->` (FOLLOWED BY). There is also a variant `<N>` of the FOLLOWED BY operator, where *N* is an integer constant that specifies the distance between the two lexemes being searched for. `<->` is equivalent to `<1>`.

Parentheses can be used to enforce grouping of these operators. In the absence of parentheses, `!` (NOT) binds most tightly, `<->` (FOLLOWED BY) next most tightly, then `&` (AND), with `|` (OR) binding the least tightly.

Here are some examples:

```
SELECT 'fat & rat'::tsquery;
      tsquery
-----
'fat' & 'rat'

SELECT 'fat & (rat | cat)'::tsquery;
      tsquery
-----
```

```
'fat' & ( 'rat' | 'cat' )

SELECT 'fat & rat & ! cat'::tsquery;
      tsquery
-----
'fat' & 'rat' & !'cat'
```

Optionally, lexemes in a `tsquery` can be labeled with one or more weight letters, which restricts them to match only `tsvector` lexemes with one of those weights:

```
SELECT 'fat:ab & cat'::tsquery;
      tsquery
-----
'fat':AB & 'cat'
```

Also, lexemes in a `tsquery` can be labeled with `*` to specify prefix matching:

```
SELECT 'super:*'::tsquery;
      tsquery
-----
'super':*
```

This query will match any word in a `tsvector` that begins with “super”.

Quoting rules for lexemes are the same as described previously for lexemes in `tsvector`; and, as with `tsvector`, any required normalization of words must be done before converting to the `tsquery` type. The `to_tsquery` function is convenient for performing such normalization:

```
SELECT to_tsquery('Fat:ab & Cats');
      to_tsquery
-----
'fat':AB & 'cat'
```

Note that `to_tsquery` will process prefixes in the same way as other words, which means this comparison returns true:

```
SELECT to_tsvector( 'postgraduate' ) @@ to_tsquery( 'postgres:*' );
?column?
-----
t
```

because `postgres` gets stemmed to `postgr`:

```
SELECT to_tsvector( 'postgraduate' ), to_tsquery( 'postgres:*' );
      to_tsvector | to_tsquery
-----+-----
'postgradu':1 | 'postgr':*
```

which will match the stemmed form of `postgraduate`.

8.12. UUID Type

The data type `uuid` stores Universally Unique Identifiers (UUID) as defined by RFC 4122, ISO/IEC 9834-8:2005, and related standards. (Some systems refer to this data type as a globally unique identifier, or GUID, instead.) This identifier is a 128-bit quantity that is generated by an algorithm

chosen to make it very unlikely that the same identifier will be generated by anyone else in the known universe using the same algorithm. Therefore, for distributed systems, these identifiers provide a better uniqueness guarantee than sequence generators, which are only unique within a single database.

A UUID is written as a sequence of lower-case hexadecimal digits, in several groups separated by hyphens, specifically a group of 8 digits followed by three groups of 4 digits followed by a group of 12 digits, for a total of 32 digits representing the 128 bits. An example of a UUID in this standard form is:

```
a0eebc99-9c0b-4ef8-bb6d-6bb9bd380a11
```

PostgreSQL also accepts the following alternative forms for input: use of upper-case digits, the standard format surrounded by braces, omitting some or all hyphens, adding a hyphen after any group of four digits. Examples are:

```
A0EEBC99-9C0B-4EF8-BB6D-6BB9BD380A11
{a0eebc99-9c0b-4ef8-bb6d-6bb9bd380a11}
a0eebc999c0b4ef8bb6d6bb9bd380a11
a0ee-bc99-9c0b-4ef8-bb6d-6bb9-bd38-0a11
{a0eebc99-9c0b4ef8-bb6d6bb9-bd380a11}
```

Output is always in the standard form.

PostgreSQL provides storage and comparison functions for UUIDs, but the core database does not include any function for generating UUIDs, because no single algorithm is well suited for every application. The `uuid-oss` module provides functions that implement several standard algorithms. The `pgcrypto` module also provides a generation function for random UUIDs. Alternatively, UUIDs could be generated by client applications or other libraries invoked through a server-side function.

8.13. XML Type

The `xml` data type can be used to store XML data. Its advantage over storing XML data in a `text` field is that it checks the input values for well-formedness, and there are support functions to perform type-safe operations on it; see Section 9.14. Use of this data type requires the installation to have been built with `configure --with-libxml`.

The `xml` type can store well-formed “documents”, as defined by the XML standard, as well as “content” fragments, which are defined by reference to the more permissive “document node”¹ of the XQuery and XPath data model. Roughly, this means that content fragments can have more than one top-level element or character node. The expression `xmlvalue IS DOCUMENT` can be used to evaluate whether a particular `xml` value is a full document or only a content fragment.

Limits and compatibility notes for the `xml` data type can be found in Section D.3.

8.13.1. Creating XML Values

To produce a value of type `xml` from character data, use the function `xmlparse`:

```
XMLPARSE ( { DOCUMENT | CONTENT } value)
```

Examples:

```
XMLPARSE (DOCUMENT '<?xml version="1.0"?><book><title>Manual</title><chapter>...</chapter></book>')
XMLPARSE (CONTENT 'abc<foo>bar</foo><bar>foo</bar>')
```

¹ <https://www.w3.org/TR/2010/REC-xpath-datamodel-20101214/#DocumentNode>

While this is the only way to convert character strings into XML values according to the SQL standard, the PostgreSQL-specific syntaxes:

```
xml '<foo>bar</foo>'
'<foo>bar</foo>'::xml
```

can also be used.

The `xml` type does not validate input values against a document type declaration (DTD), even when the input value specifies a DTD. There is also currently no built-in support for validating against other XML schema languages such as XML Schema.

The inverse operation, producing a character string value from `xml`, uses the function `xmlserialize`:

```
XMLSERIALIZE ( { DOCUMENT | CONTENT } value AS type )
```

`type` can be `character`, `character varying`, or `text` (or an alias for one of those). Again, according to the SQL standard, this is the only way to convert between type `xml` and character types, but PostgreSQL also allows you to simply cast the value.

When a character string value is cast to or from type `xml` without going through `XMLPARSE` or `XMLSERIALIZE`, respectively, the choice of `DOCUMENT` versus `CONTENT` is determined by the “XML option” session configuration parameter, which can be set using the standard command:

```
SET XML OPTION { DOCUMENT | CONTENT };
```

or the more PostgreSQL-like syntax

```
SET xmloption TO { DOCUMENT | CONTENT };
```

The default is `CONTENT`, so all forms of XML data are allowed.

8.13.2. Encoding Handling

Care must be taken when dealing with multiple character encodings on the client, server, and in the XML data passed through them. When using the text mode to pass queries to the server and query results to the client (which is the normal mode), PostgreSQL converts all character data passed between the client and the server and vice versa to the character encoding of the respective end; see Section 23.3. This includes string representations of XML values, such as in the above examples. This would ordinarily mean that encoding declarations contained in XML data can become invalid as the character data is converted to other encodings while traveling between client and server, because the embedded encoding declaration is not changed. To cope with this behavior, encoding declarations contained in character strings presented for input to the `xml` type are *ignored*, and content is assumed to be in the current server encoding. Consequently, for correct processing, character strings of XML data must be sent from the client in the current client encoding. It is the responsibility of the client to either convert documents to the current client encoding before sending them to the server, or to adjust the client encoding appropriately. On output, values of type `xml` will not have an encoding declaration, and clients should assume all data is in the current client encoding.

When using binary mode to pass query parameters to the server and query results back to the client, no encoding conversion is performed, so the situation is different. In this case, an encoding declaration in the XML data will be observed, and if it is absent, the data will be assumed to be in UTF-8 (as required by the XML standard; note that PostgreSQL does not support UTF-16). On output, data will have an encoding declaration specifying the client encoding, unless the client encoding is UTF-8, in which case it will be omitted.

Needless to say, processing XML data with PostgreSQL will be less error-prone and more efficient if the XML data encoding, client encoding, and server encoding are the same. Since XML data is internally processed in UTF-8, computations will be most efficient if the server encoding is also UTF-8.

Caution

Some XML-related functions may not work at all on non-ASCII data when the server encoding is not UTF-8. This is known to be an issue for `xmltable()` and `xpath()` in particular.

8.13.3. Accessing XML Values

The `xml` data type is unusual in that it does not provide any comparison operators. This is because there is no well-defined and universally useful comparison algorithm for XML data. One consequence of this is that you cannot retrieve rows by comparing an `xml` column against a search value. XML values should therefore typically be accompanied by a separate key field such as an ID. An alternative solution for comparing XML values is to convert them to character strings first, but note that character string comparison has little to do with a useful XML comparison method.

Since there are no comparison operators for the `xml` data type, it is not possible to create an index directly on a column of this type. If speedy searches in XML data are desired, possible workarounds include casting the expression to a character string type and indexing that, or indexing an XPath expression. Of course, the actual query would have to be adjusted to search by the indexed expression.

The text-search functionality in PostgreSQL can also be used to speed up full-document searches of XML data. The necessary preprocessing support is, however, not yet available in the PostgreSQL distribution.

8.14. JSON Types

JSON data types are for storing JSON (JavaScript Object Notation) data, as specified in RFC 7159². Such data can also be stored as `text`, but the JSON data types have the advantage of enforcing that each stored value is valid according to the JSON rules. There are also assorted JSON-specific functions and operators available for data stored in these data types; see Section 9.15.

PostgreSQL offers two types for storing JSON data: `json` and `jsonb`. To implement efficient query mechanisms for these data types, PostgreSQL also provides the `jsonpath` data type described in Section 8.14.6.

The `json` and `jsonb` data types accept *almost* identical sets of values as input. The major practical difference is one of efficiency. The `json` data type stores an exact copy of the input text, which processing functions must reparse on each execution; while `jsonb` data is stored in a decomposed binary format that makes it slightly slower to input due to added conversion overhead, but significantly faster to process, since no reparsing is needed. `jsonb` also supports indexing, which can be a significant advantage.

Because the `json` type stores an exact copy of the input text, it will preserve semantically-insignificant white space between tokens, as well as the order of keys within JSON objects. Also, if a JSON object within the value contains the same key more than once, all the key/value pairs are kept. (The processing functions consider the last value as the operative one.) By contrast, `jsonb` does not preserve white space, does not preserve the order of object keys, and does not keep duplicate object keys. If duplicate keys are specified in the input, only the last value is kept.

In general, most applications should prefer to store JSON data as `jsonb`, unless there are quite specialized needs, such as legacy assumptions about ordering of object keys.

² <https://tools.ietf.org/html/rfc7159>

PostgreSQL allows only one character set encoding per database. It is therefore not possible for the JSON types to conform rigidly to the JSON specification unless the database encoding is UTF8. Attempts to directly include characters that cannot be represented in the database encoding will fail; conversely, characters that can be represented in the database encoding but not in UTF8 will be allowed.

RFC 7159 permits JSON strings to contain Unicode escape sequences denoted by `\uXXXX`. In the input function for the `json` type, Unicode escapes are allowed regardless of the database encoding, and are checked only for syntactic correctness (that is, that four hex digits follow `\u`). However, the input function for `jsonb` is stricter: it disallows Unicode escapes for non-ASCII characters (those above `U+007F`) unless the database encoding is UTF8. The `jsonb` type also rejects `\u0000` (because that cannot be represented in PostgreSQL's `text` type), and it insists that any use of Unicode surrogate pairs to designate characters outside the Unicode Basic Multilingual Plane be correct. Valid Unicode escapes are converted to the equivalent ASCII or UTF8 character for storage; this includes folding surrogate pairs into a single character.

Note

Many of the JSON processing functions described in Section 9.15 will convert Unicode escapes to regular characters, and will therefore throw the same types of errors just described even if their input is of type `json` not `jsonb`. The fact that the `json` input function does not make these checks may be considered a historical artifact, although it does allow for simple storage (without processing) of JSON Unicode escapes in a non-UTF8 database encoding. In general, it is best to avoid mixing Unicode escapes in JSON with a non-UTF8 database encoding, if possible.

When converting textual JSON input into `jsonb`, the primitive types described by RFC 7159 are effectively mapped onto native PostgreSQL types, as shown in Table 8.23. Therefore, there are some minor additional constraints on what constitutes valid `jsonb` data that do not apply to the `json` type, nor to JSON in the abstract, corresponding to limits on what can be represented by the underlying data type. Notably, `jsonb` will reject numbers that are outside the range of the PostgreSQL `numeric` data type, while `json` will not. Such implementation-defined restrictions are permitted by RFC 7159. However, in practice such problems are far more likely to occur in other implementations, as it is common to represent JSON's `number` primitive type as IEEE 754 double precision floating point (which RFC 7159 explicitly anticipates and allows for). When using JSON as an interchange format with such systems, the danger of losing numeric precision compared to data originally stored by PostgreSQL should be considered.

Conversely, as noted in the table there are some minor restrictions on the input format of JSON primitive types that do not apply to the corresponding PostgreSQL types.

Table 8.23. JSON Primitive Types and Corresponding PostgreSQL Types

JSON primitive type	PostgreSQL type	Notes
<code>string</code>	<code>text</code>	<code>\u0000</code> is disallowed, as are non-ASCII Unicode escapes if database encoding is not UTF8
<code>number</code>	<code>numeric</code>	<code>NaN</code> and <code>infinity</code> values are disallowed
<code>boolean</code>	<code>boolean</code>	Only lowercase <code>true</code> and <code>false</code> spellings are accepted
<code>null</code>	(none)	SQL <code>NULL</code> is a different concept

8.14.1. JSON Input and Output Syntax

The input/output syntax for the JSON data types is as specified in RFC 7159.

The following are all valid json (or jsonb) expressions:

```
-- Simple scalar/primitive value
-- Primitive values can be numbers, quoted strings, true, false, or
  null
SELECT '5'::json;

-- Array of zero or more elements (elements need not be of same
  type)
SELECT '[1, 2, "foo", null]'::json;

-- Object containing pairs of keys and values
-- Note that object keys must always be quoted strings
SELECT '{"bar": "baz", "balance": 7.77, "active": false}'::json;

-- Arrays and objects can be nested arbitrarily
SELECT '{"foo": [true, "bar"], "tags": {"a": 1, "b": null}}'::json;
```

As previously stated, when a JSON value is input and then printed without any additional processing, json outputs the same text that was input, while jsonb does not preserve semantically-insignificant details such as whitespace. For example, note the differences here:

```
SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::json;
           json
-----
{"bar": "baz", "balance": 7.77, "active":false}
(1 row)

SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::jsonb;
           jsonb
-----
{"bar": "baz", "active": false, "balance": 7.77}
(1 row)
```

One semantically-insignificant detail worth noting is that in jsonb, numbers will be printed according to the behavior of the underlying numeric type. In practice this means that numbers entered with E notation will be printed without it, for example:

```
SELECT '{"reading": 1.230e-5}'::json, '{"reading":
  1.230e-5}'::jsonb;
           json           |           jsonb
-----+-----
{"reading": 1.230e-5} | {"reading": 0.00001230}
(1 row)
```

However, jsonb will preserve trailing fractional zeroes, as seen in this example, even though those are semantically insignificant for purposes such as equality checks.

For the list of built-in functions and operators available for constructing and processing JSON values, see Section 9.15.

8.14.2. Designing JSON Documents

Representing data as JSON can be considerably more flexible than the traditional relational data model, which is compelling in environments where requirements are fluid. It is quite possible for both approaches to co-exist and complement each other within the same application. However, even for

applications where maximal flexibility is desired, it is still recommended that JSON documents have a somewhat fixed structure. The structure is typically unenforced (though enforcing some business rules declaratively is possible), but having a predictable structure makes it easier to write queries that usefully summarize a set of “documents” (datums) in a table.

JSON data is subject to the same concurrency-control considerations as any other data type when stored in a table. Although storing large documents is practicable, keep in mind that any update acquires a row-level lock on the whole row. Consider limiting JSON documents to a manageable size in order to decrease lock contention among updating transactions. Ideally, JSON documents should each represent an atomic datum that business rules dictate cannot reasonably be further subdivided into smaller datums that could be modified independently.

8.14.3. jsonb Containment and Existence

Testing *containment* is an important capability of jsonb. There is no parallel set of facilities for the json type. Containment tests whether one jsonb document has contained within it another one. These examples return true except as noted:

```
-- Simple scalar/primitive values contain only the identical value:
SELECT '"foo"'::jsonb @> '"foo"'::jsonb;

-- The array on the right side is contained within the one on the
left:
SELECT '[1, 2, 3]'::jsonb @> '[1, 3]'::jsonb;

-- Order of array elements is not significant, so this is also
true:
SELECT '[1, 2, 3]'::jsonb @> '[3, 1]'::jsonb;

-- Duplicate array elements don't matter either:
SELECT '[1, 2, 3]'::jsonb @> '[1, 2, 2]'::jsonb;

-- The object with a single pair on the right side is contained
-- within the object on the left side:
SELECT '{"product": "PostgreSQL", "version": 9.4, "jsonb":
true}'::jsonb @> '{"version": 9.4}'::jsonb;

-- The array on the right side is not considered contained within
the
array on the left, even though a similar array is nested within
it:
SELECT '[1, 2, [1, 3]]'::jsonb @> '[1, 3]'::jsonb; -- yields false

-- But with a layer of nesting, it is contained:
SELECT '[1, 2, [1, 3]]'::jsonb @> '[[1, 3]]'::jsonb;

-- Similarly, containment is not reported here:
SELECT '{"foo": {"bar": "baz"}}'::jsonb @> '{"bar": "baz"}'::jsonb;
-- yields false

-- A top-level key and an empty object is contained:
SELECT '{"foo": {"bar": "baz"}}'::jsonb @> '{"foo": {}}'::jsonb;
```

The general principle is that the contained object must match the containing object as to structure and data contents, possibly after discarding some non-matching array elements or object key/value pairs from the containing object. But remember that the order of array elements is not significant when doing a containment match, and duplicate array elements are effectively considered only once.

As a special exception to the general principle that the structures must match, an array may contain a primitive value:

```
-- This array contains the primitive string value:
SELECT '["foo", "bar"]'::jsonb @> '"bar"'::jsonb;

-- This exception is not reciprocal -- non-containment is reported
  here:
SELECT '"bar"'::jsonb @> '["bar"]'::jsonb; -- yields false
```

jsonb also has an *existence* operator, which is a variation on the theme of containment: it tests whether a string (given as a text value) appears as an object key or array element at the top level of the jsonb value. These examples return true except as noted:

```
-- String exists as array element:
SELECT '["foo", "bar", "baz"]'::jsonb ? 'bar';

-- String exists as object key:
SELECT '{"foo": "bar"}'::jsonb ? 'foo';

-- Object values are not considered:
SELECT '{"foo": "bar"}'::jsonb ? 'bar'; -- yields false

-- As with containment, existence must match at the top level:
SELECT '{"foo": {"bar": "baz"}}'::jsonb ? 'bar'; -- yields false

-- A string is considered to exist if it matches a primitive JSON
  string:
SELECT '"foo"'::jsonb ? 'foo';
```

JSON objects are better suited than arrays for testing containment or existence when there are many keys or elements involved, because unlike arrays they are internally optimized for searching, and do not need to be searched linearly.

Tip

Because JSON containment is nested, an appropriate query can skip explicit selection of sub-objects. As an example, suppose that we have a `doc` column containing objects at the top level, with most objects containing `tags` fields that contain arrays of sub-objects. This query finds entries in which sub-objects containing both `"term": "paris"` and `"term": "food"` appear, while ignoring any such keys outside the `tags` array:

```
SELECT doc->'site_name' FROM websites
  WHERE doc @> '{"tags": [{"term": "paris"},
 {"term": "food"}]';
```

One could accomplish the same thing with, say,

```
SELECT doc->'site_name' FROM websites
  WHERE doc->'tags' @> '[{"term": "paris"},
 {"term": "food"}]';
```

but that approach is less flexible, and often less efficient as well.

On the other hand, the JSON existence operator is not nested: it will only look for the specified key or array element at top level of the JSON value.

The various containment and existence operators, along with all other JSON operators and functions are documented in Section 9.15.

8.14.4. jsonb Indexing

GIN indexes can be used to efficiently search for keys or key/value pairs occurring within a large number of jsonb documents (datums). Two GIN “operator classes” are provided, offering different performance and flexibility trade-offs.

The default GIN operator class for jsonb supports queries with top-level key-exists operators `?`, `?&` and `?|` operators and path/value-exists operator `@>`. (For details of the semantics that these operators implement, see Table 9.45.) An example of creating an index with this operator class is:

```
CREATE INDEX idxgin ON api USING GIN (jdoc);
```

The non-default GIN operator class `jsonb_path_ops` supports indexing the `@>` operator only. An example of creating an index with this operator class is:

```
CREATE INDEX idxginp ON api USING GIN (jdoc jsonb_path_ops);
```

Consider the example of a table that stores JSON documents retrieved from a third-party web service, with a documented schema definition. A typical document is:

```
{
  "guid": "9c36adc1-7fb5-4d5b-83b4-90356a46061a",
  "name": "Angela Barton",
  "is_active": true,
  "company": "Magnafone",
  "address": "178 Howard Place, Gulf, Washington, 702",
  "registered": "2009-11-07T08:53:22 +08:00",
  "latitude": 19.793713,
  "longitude": 86.513373,
  "tags": [
    "enim",
    "aliquip",
    "qui"
  ]
}
```

We store these documents in a table named `api`, in a `jsonb` column named `jdoc`. If a GIN index is created on this column, queries like the following can make use of the index:

```
-- Find documents in which the key "company" has value "Magnafone"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @>
'{"company": "Magnafone"}';
```

However, the index could not be used for queries like the following, because though the operator `?|` is indexable, it is not applied directly to the indexed column `jdoc`:

```
-- Find documents in which the key "tags" contains key or array
element "qui"
```

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc -> 'tags' ?
'qui';
```

Still, with appropriate use of expression indexes, the above query can use an index. If querying for particular items within the "tags" key is common, defining an index like this may be worthwhile:

```
CREATE INDEX idxgintags ON api USING GIN ((jdoc -> 'tags'));
```

Now, the WHERE clause `jdoc -> 'tags' ? 'qui'` will be recognized as an application of the indexable operator `?` to the indexed expression `jdoc -> 'tags'`. (More information on expression indexes can be found in Section 11.7.)

Also, GIN index supports `@@` and `@?` operators, which perform `jsonpath` matching.

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @@ '$.tags[*]
=="qui";
```

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @@
'$.tags[*] ? (@ == "qui")';
```

GIN index extracts statements of following form out of `jsonpath`: `accessors_chain = const`. Accessors chain may consist of `.key`, `[*]`, and `[index]` accessors. `jsonb_ops` additionally supports `.*` and `.**` accessors.

Another approach to querying is to exploit containment, for example:

```
-- Find documents in which the key "tags" contains array element
"qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @> '{"tags":
["qui"]}';
```

A simple GIN index on the `jdoc` column can support this query. But note that such an index will store copies of every key and value in the `jdoc` column, whereas the expression index of the previous example stores only data found under the `tags` key. While the simple-index approach is far more flexible (since it supports queries about any key), targeted expression indexes are likely to be smaller and faster to search than a simple index.

Although the `jsonb_path_ops` operator class supports only queries with the `@>`, `@@` and `@?` operators, it has notable performance advantages over the default operator class `jsonb_ops`. A `jsonb_path_ops` index is usually much smaller than a `jsonb_ops` index over the same data, and the specificity of searches is better, particularly when queries contain keys that appear frequently in the data. Therefore search operations typically perform better than with the default operator class.

The technical difference between a `jsonb_ops` and a `jsonb_path_ops` GIN index is that the former creates independent index items for each key and value in the data, while the latter creates index items only for each value in the data.³ Basically, each `jsonb_path_ops` index item is a hash of the value and the key(s) leading to it; for example to index `{"foo": {"bar": "baz"}}`, a single index item would be created incorporating all three of `foo`, `bar`, and `baz` into the hash value. Thus a containment query looking for this structure would result in an extremely specific index search; but there is no way at all to find out whether `foo` appears as a key. On the other hand, a `jsonb_ops` index would create three index items representing `foo`, `bar`, and `baz` separately; then to do the containment query, it would look for rows containing all three of these items. While GIN indexes can perform such an AND search fairly efficiently, it will still be less specific and slower

³ For this purpose, the term "value" includes array elements, though JSON terminology sometimes considers array elements distinct from values within objects.

than the equivalent `jsonb_path_ops` search, especially if there are a very large number of rows containing any single one of the three index items.

A disadvantage of the `jsonb_path_ops` approach is that it produces no index entries for JSON structures not containing any values, such as `{"a": {}}`. If a search for documents containing such a structure is requested, it will require a full-index scan, which is quite slow. `jsonb_path_ops` is therefore ill-suited for applications that often perform such searches.

`jsonb` also supports `btree` and `hash` indexes. These are usually useful only if it's important to check equality of complete JSON documents. The `btree` ordering for `jsonb` datums is seldom of great interest, but for completeness it is:

Object > Array > Boolean > Number > String > Null

Object with n pairs > object with n - 1 pairs

Array with n elements > array with n - 1 elements

Objects with equal numbers of pairs are compared in the order:

key-1, value-1, key-2 ...

Note that object keys are compared in their storage order; in particular, since shorter keys are stored before longer keys, this can lead to results that might be unintuitive, such as:

```
{ "aa": 1, "c": 1 } > { "b": 1, "d": 1 }
```

Similarly, arrays with equal numbers of elements are compared in the order:

element-1, element-2 ...

Primitive JSON values are compared using the same comparison rules as for the underlying PostgreSQL data type. Strings are compared using the default database collation.

8.14.5. Transforms

Additional extensions are available that implement transforms for the `jsonb` type for different procedural languages.

The extensions for PL/Perl are called `jsonb_plperl` and `jsonb_plperlu`. If you use them, `jsonb` values are mapped to Perl arrays, hashes, and scalars, as appropriate.

The extensions for PL/Python are called `jsonb_plpythonu`, `jsonb_plpython2u`, and `jsonb_plpython3u` (see Section 45.1 for the PL/Python naming convention). If you use them, `jsonb` values are mapped to Python dictionaries, lists, and scalars, as appropriate.

8.14.6. jsonpath Type

The `jsonpath` type implements support for the SQL/JSON path language in PostgreSQL to efficiently query JSON data. It provides a binary representation of the parsed SQL/JSON path expression that specifies the items to be retrieved by the path engine from the JSON data for further processing with the SQL/JSON query functions.

The semantics of SQL/JSON path predicates and operators generally follow SQL. At the same time, to provide a most natural way of working with JSON data, SQL/JSON path syntax uses some of the JavaScript conventions:

- Dot (`.`) is used for member access.
- Square brackets (`[]`) are used for array access.
- SQL/JSON arrays are 0-relative, unlike regular SQL arrays that start from 1.

An SQL/JSON path expression is typically written in an SQL query as an SQL character string literal, so it must be enclosed in single quotes, and any single quotes desired within the value must be doubled (see Section 4.1.2.1). Some forms of path expressions require string literals within them. These embedded string literals follow JavaScript/ECMAScript conventions: they must be surrounded by double quotes, and backslash escapes may be used within them to represent otherwise-hard-to-type characters. In particular, the way to write a double quote within an embedded string literal is `\`, and to write a backslash itself, you must write `\\`. Other special backslash sequences include those recognized in JSON strings: `\b`, `\f`, `\n`, `\r`, `\t`, `\v` for various ASCII control characters, and `\uNNNN` for a Unicode character identified by its 4-hex-digit code point. The backslash syntax also includes two cases not allowed by JSON: `\xNN` for a character code written with only two hex digits, and `\u{N. . . }` for a character code written with 1 to 6 hex digits.

A path expression consists of a sequence of path elements, which can be the following:

- Path literals of JSON primitive types: Unicode text, numeric, true, false, or null.
- Path variables listed in Table 8.24.
- Accessor operators listed in Table 8.25.
- `jsonpath` operators and methods listed in Section 9.15.2.3
- Parentheses, which can be used to provide filter expressions or define the order of path evaluation.

For details on using `jsonpath` expressions with SQL/JSON query functions, see Section 9.15.2.

Table 8.24. `jsonpath` Variables

Variable	Description
<code>\$</code>	A variable representing the JSON text to be queried (the <i>context item</i>).
<code>\$varname</code>	A named variable. Its value can be set by the parameter <i>vars</i> of several JSON processing functions. See Table 9.47 and its notes for details.
<code>@</code>	A variable representing the result of path evaluation in filter expressions.

Table 8.25. `jsonpath` Accessors

Accessor Operator	Description
<code>.key</code> <code>."\$varname"</code>	Member accessor that returns an object member with the specified key. If the key name is a named variable starting with <code>\$</code> or does not meet the JavaScript rules of an identifier, it must be enclosed in double quotes as a character string literal.
<code>.*</code>	Wildcard member accessor that returns the values of all members located at the top level of the current object.
<code>.**</code>	Recursive wildcard member accessor that processes all levels of the JSON hierarchy of the

Accessor Operator	Description
	current object and returns all the member values, regardless of their nesting level. This is a PostgreSQL extension of the SQL/JSON standard.
<code>.**{level}</code> <code>.**{start_level to end_level}</code>	Same as <code>.**</code> , but with a filter over nesting levels of JSON hierarchy. Nesting levels are specified as integers. Zero level corresponds to the current object. To access the lowest nesting level, you can use the <code>last</code> keyword. This is a PostgreSQL extension of the SQL/JSON standard.
<code>[subscript, ...]</code>	<p>Array element accessor. <i>subscript</i> can be given in two forms: <i>index</i> or <i>start_index to end_index</i>. The first form returns a single array element by its index. The second form returns an array slice by the range of indexes, including the elements that correspond to the provided <i>start_index</i> and <i>end_index</i>.</p> <p>The specified <i>index</i> can be an integer, as well as an expression returning a single numeric value, which is automatically cast to integer. Zero index corresponds to the first array element. You can also use the <code>last</code> keyword to denote the last array element, which is useful for handling arrays of unknown length.</p>
<code>[*]</code>	Wildcard array element accessor that returns all array elements.

8.15. Arrays

PostgreSQL allows columns of a table to be defined as variable-length multidimensional arrays. Arrays of any built-in or user-defined base type, enum type, composite type, range type, or domain can be created.

8.15.1. Declaration of Array Types

To illustrate the use of array types, we create this table:

```
CREATE TABLE sal_emp (
    name          text,
    pay_by_quarter integer[],
    schedule      text[][]
);
```

As shown, an array data type is named by appending square brackets (`[]`) to the data type name of the array elements. The above command will create a table named `sal_emp` with a column of type `text` (`name`), a one-dimensional array of type `integer` (`pay_by_quarter`), which represents the employee's salary by quarter, and a two-dimensional array of `text` (`schedule`), which represents the employee's weekly schedule.

The syntax for `CREATE TABLE` allows the exact size of arrays to be specified, for example:

```
CREATE TABLE tictactoe (
    squares      integer[3][3]
```

```
);
```

However, the current implementation ignores any supplied array size limits, i.e., the behavior is the same as for arrays of unspecified length.

The current implementation does not enforce the declared number of dimensions either. Arrays of a particular element type are all considered to be of the same type, regardless of size or number of dimensions. So, declaring the array size or number of dimensions in `CREATE TABLE` is simply documentation; it does not affect run-time behavior.

An alternative syntax, which conforms to the SQL standard by using the keyword `ARRAY`, can be used for one-dimensional arrays. `pay_by_quarter` could have been defined as:

```
pay_by_quarter integer ARRAY[4],
```

Or, if no array size is to be specified:

```
pay_by_quarter integer ARRAY,
```

As before, however, PostgreSQL does not enforce the size restriction in any case.

8.15.2. Array Value Input

To write an array value as a literal constant, enclose the element values within curly braces and separate them by commas. (If you know C, this is not unlike the C syntax for initializing structures.) You can put double quotes around any element value, and must do so if it contains commas or curly braces. (More details appear below.) Thus, the general format of an array constant is the following:

```
'{ val1 delim val2 delim ... }'
```

where *delim* is the delimiter character for the type, as recorded in its `pg_type` entry. Among the standard data types provided in the PostgreSQL distribution, all use a comma (`,`), except for type `box` which uses a semicolon (`;`). Each *val* is either a constant of the array element type, or a subarray. An example of an array constant is:

```
'{{1,2,3},{4,5,6},{7,8,9}}'
```

This constant is a two-dimensional, 3-by-3 array consisting of three subarrays of integers.

To set an element of an array constant to `NULL`, write `NULL` for the element value. (Any upper- or lower-case variant of `NULL` will do.) If you want an actual string value “`NULL`”, you must put double quotes around it.

(These kinds of array constants are actually only a special case of the generic type constants discussed in Section 4.1.2.7. The constant is initially treated as a string and passed to the array input conversion routine. An explicit type specification might be necessary.)

Now we can show some `INSERT` statements:

```
INSERT INTO sal_emp
VALUES ('Bill',
       '{10000, 10000, 10000, 10000}',
       '{{"meeting", "lunch"}, {"training", "presentation"}}');
```

```
INSERT INTO sal_emp
VALUES ('Carol',
       '{20000, 25000, 25000, 25000}',
       '{{"breakfast", "consulting"}, {"meeting", "lunch"}}');
```

The result of the previous two inserts looks like this:

```
SELECT * FROM sal_emp;
name | pay_by_quarter | schedule
-----+-----
Bill | {10000,10000,10000,10000} | {{meeting,lunch},
{training,presentation}}
Carol | {20000,25000,25000,25000} | {{breakfast,consulting},
{meeting,lunch}}
(2 rows)
```

Multidimensional arrays must have matching extents for each dimension. A mismatch causes an error, for example:

```
INSERT INTO sal_emp
VALUES ('Bill',
       '{10000, 10000, 10000, 10000}',
       '{{"meeting", "lunch"}, {"meeting"}}');
ERROR: multidimensional arrays must have array expressions with
matching dimensions
```

The ARRAY constructor syntax can also be used:

```
INSERT INTO sal_emp
VALUES ('Bill',
       ARRAY[10000, 10000, 10000, 10000],
       ARRAY[['meeting', 'lunch'], ['training', 'presentation']]);

INSERT INTO sal_emp
VALUES ('Carol',
       ARRAY[20000, 25000, 25000, 25000],
       ARRAY[['breakfast', 'consulting'], ['meeting', 'lunch']]);
```

Notice that the array elements are ordinary SQL constants or expressions; for instance, string literals are single quoted, instead of double quoted as they would be in an array literal. The ARRAY constructor syntax is discussed in more detail in Section 4.2.12.

8.15.3. Accessing Arrays

Now, we can run some queries on the table. First, we show how to access a single element of an array. This query retrieves the names of the employees whose pay changed in the second quarter:

```
SELECT name FROM sal_emp WHERE pay_by_quarter[1] <>
pay_by_quarter[2];

name
-----
Carol
(1 row)
```

The array subscript numbers are written within square brackets. By default PostgreSQL uses a one-based numbering convention for arrays, that is, an array of n elements starts with `array[1]` and ends with `array[n]`.

This query retrieves the third quarter pay of all employees:

```
SELECT pay_by_quarter[3] FROM sal_emp;

 pay_by_quarter
-----
          10000
          25000
(2 rows)
```

We can also access arbitrary rectangular slices of an array, or subarrays. An array slice is denoted by writing *lower-bound:upper-bound* for one or more array dimensions. For example, this query retrieves the first item on Bill's schedule for the first two days of the week:

```
SELECT schedule[1:2][1:1] FROM sal_emp WHERE name = 'Bill';

      schedule
-----
 {{meeting},{training}}
(1 row)
```

If any dimension is written as a slice, i.e., contains a colon, then all dimensions are treated as slices. Any dimension that has only a single number (no colon) is treated as being from 1 to the number specified. For example, `[2]` is treated as `[1:2]`, as in this example:

```
SELECT schedule[1:2][2] FROM sal_emp WHERE name = 'Bill';

      schedule
-----
 {{meeting,lunch},{training,presentation}}
(1 row)
```

To avoid confusion with the non-slice case, it's best to use slice syntax for all dimensions, e.g., `[1:2][1:1]`, not `[2][1:1]`.

It is possible to omit the *lower-bound* and/or *upper-bound* of a slice specifier; the missing bound is replaced by the lower or upper limit of the array's subscripts. For example:

```
SELECT schedule[:2][2:] FROM sal_emp WHERE name = 'Bill';

      schedule
-----
 {{lunch},{presentation}}
(1 row)

SELECT schedule[:][1:1] FROM sal_emp WHERE name = 'Bill';

      schedule
-----
 {{meeting},{training}}
(1 row)
```

An array subscript expression will return null if either the array itself or any of the subscript expressions are null. Also, null is returned if a subscript is outside the array bounds (this case does not raise an error). For example, if `schedule` currently has the dimensions `[1:3][1:2]` then referencing `schedule[3][3]` yields NULL. Similarly, an array reference with the wrong number of subscripts yields a null rather than an error.

An array slice expression likewise yields null if the array itself or any of the subscript expressions are null. However, in other cases such as selecting an array slice that is completely outside the current array bounds, a slice expression yields an empty (zero-dimensional) array instead of null. (This does not match non-slice behavior and is done for historical reasons.) If the requested slice partially overlaps the array bounds, then it is silently reduced to just the overlapping region instead of returning null.

The current dimensions of any array value can be retrieved with the `array_dims` function:

```
SELECT array_dims(schedule) FROM sal_emp WHERE name = 'Carol';

 array_dims
-----
 [1:2][1:2]
(1 row)
```

`array_dims` produces a text result, which is convenient for people to read but perhaps inconvenient for programs. Dimensions can also be retrieved with `array_upper` and `array_lower`, which return the upper and lower bound of a specified array dimension, respectively:

```
SELECT array_upper(schedule, 1) FROM sal_emp WHERE name = 'Carol';

 array_upper
-----
                2
(1 row)
```

`array_length` will return the length of a specified array dimension:

```
SELECT array_length(schedule, 1) FROM sal_emp WHERE name = 'Carol';

 array_length
-----
                2
(1 row)
```

`cardinality` returns the total number of elements in an array across all dimensions. It is effectively the number of rows a call to `unnest` would yield:

```
SELECT cardinality(schedule) FROM sal_emp WHERE name = 'Carol';

 cardinality
-----
                4
(1 row)
```

8.15.4. Modifying Arrays

An array value can be replaced completely:

```
UPDATE sal_emp SET pay_by_quarter = '{25000,25000,27000,27000}'
WHERE name = 'Carol';
```

or using the ARRAY expression syntax:

```
UPDATE sal_emp SET pay_by_quarter = ARRAY[25000,25000,27000,27000]
WHERE name = 'Carol';
```

An array can also be updated at a single element:

```
UPDATE sal_emp SET pay_by_quarter[4] = 15000
WHERE name = 'Bill';
```

or updated in a slice:

```
UPDATE sal_emp SET pay_by_quarter[1:2] = '{27000,27000}'
WHERE name = 'Carol';
```

The slice syntaxes with omitted *lower-bound* and/or *upper-bound* can be used too, but only when updating an array value that is not NULL or zero-dimensional (otherwise, there is no existing subscript limit to substitute).

A stored array value can be enlarged by assigning to elements not already present. Any positions between those previously present and the newly assigned elements will be filled with nulls. For example, if array `myarray` currently has 4 elements, it will have six elements after an update that assigns to `myarray[6]`; `myarray[5]` will contain null. Currently, enlargement in this fashion is only allowed for one-dimensional arrays, not multidimensional arrays.

Subscripted assignment allows creation of arrays that do not use one-based subscripts. For example one might assign to `myarray[-2:7]` to create an array with subscript values from -2 to 7.

New array values can also be constructed using the concatenation operator, `||`:

```
SELECT ARRAY[1,2] || ARRAY[3,4];
?column?
-----
{1,2,3,4}
(1 row)
```

```
SELECT ARRAY[5,6] || ARRAY[[1,2],[3,4]];
?column?
-----
{{5,6},{1,2},{3,4}}
(1 row)
```

The concatenation operator allows a single element to be pushed onto the beginning or end of a one-dimensional array. It also accepts two N -dimensional arrays, or an N -dimensional and an $N+1$ -dimensional array.

When a single element is pushed onto either the beginning or end of a one-dimensional array, the result is an array with the same lower bound subscript as the array operand. For example:

```
SELECT array_dims(1 || '[0:1]={2,3}'::int[]);
array_dims
-----
```

```
[0:2]
(1 row)
```

```
SELECT array_dims(ARRAY[1,2] || 3);
 array_dims
-----
 [1:3]
(1 row)
```

When two arrays with an equal number of dimensions are concatenated, the result retains the lower bound subscript of the left-hand operand's outer dimension. The result is an array comprising every element of the left-hand operand followed by every element of the right-hand operand. For example:

```
SELECT array_dims(ARRAY[1,2] || ARRAY[3,4,5]);
 array_dims
-----
 [1:5]
(1 row)
```

```
SELECT array_dims(ARRAY[[1,2],[3,4]] || ARRAY[[5,6],[7,8],[9,0]]);
 array_dims
-----
 [1:5][1:2]
(1 row)
```

When an N -dimensional array is pushed onto the beginning or end of an $N+1$ -dimensional array, the result is analogous to the element-array case above. Each N -dimensional sub-array is essentially an element of the $N+1$ -dimensional array's outer dimension. For example:

```
SELECT array_dims(ARRAY[1,2] || ARRAY[[3,4],[5,6]]);
 array_dims
-----
 [1:3][1:2]
(1 row)
```

An array can also be constructed by using the functions `array_prepend`, `array_append`, or `array_cat`. The first two only support one-dimensional arrays, but `array_cat` supports multidimensional arrays. Some examples:

```
SELECT array_prepend(1, ARRAY[2,3]);
 array_prepend
-----
 {1,2,3}
(1 row)
```

```
SELECT array_append(ARRAY[1,2], 3);
 array_append
-----
 {1,2,3}
(1 row)
```

```
SELECT array_cat(ARRAY[1,2], ARRAY[3,4]);
 array_cat
-----
 {1,2,3,4}
(1 row)
```

```
SELECT array_cat(ARRAY[[1,2],[3,4]], ARRAY[5,6]);
      array_cat
-----
  {{1,2},{3,4},{5,6}}
(1 row)
```

```
SELECT array_cat(ARRAY[5,6], ARRAY[[1,2],[3,4]]);
      array_cat
-----
  {{5,6},{1,2},{3,4}}
```

In simple cases, the concatenation operator discussed above is preferred over direct use of these functions. However, because the concatenation operator is overloaded to serve all three cases, there are situations where use of one of the functions is helpful to avoid ambiguity. For example consider:

```
SELECT ARRAY[1, 2] || '{3, 4}'; -- the untyped literal is taken as
      an array
      ?column?
-----
  {1,2,3,4}
```

```
SELECT ARRAY[1, 2] || '7'; -- so is this one
ERROR:  malformed array literal: "7"
```

```
SELECT ARRAY[1, 2] || NULL; -- so is an undecorated
      NULL
      ?column?
-----
  {1,2}
(1 row)
```

```
SELECT array_append(ARRAY[1, 2], NULL); -- this might have been
      meant
      array_append
-----
  {1,2,NULL}
```

In the examples above, the parser sees an integer array on one side of the concatenation operator, and a constant of undetermined type on the other. The heuristic it uses to resolve the constant's type is to assume it's of the same type as the operator's other input — in this case, integer array. So the concatenation operator is presumed to represent `array_cat`, not `array_append`. When that's the wrong choice, it could be fixed by casting the constant to the array's element type; but explicit use of `array_append` might be a preferable solution.

8.15.5. Searching in Arrays

To search for a value in an array, each value must be checked. This can be done manually, if you know the size of the array. For example:

```
SELECT * FROM sal_emp WHERE pay_by_quarter[1] = 10000 OR
      pay_by_quarter[2] = 10000 OR
      pay_by_quarter[3] = 10000 OR
      pay_by_quarter[4] = 10000;
```

However, this quickly becomes tedious for large arrays, and is not helpful if the size of the array is unknown. An alternative method is described in Section 9.23. The above query could be replaced by:

```
SELECT * FROM sal_emp WHERE 10000 = ANY (pay_by_quarter);
```

In addition, you can find rows where the array has all values equal to 10000 with:

```
SELECT * FROM sal_emp WHERE 10000 = ALL (pay_by_quarter);
```

Alternatively, the `generate_subscripts` function can be used. For example:

```
SELECT * FROM
  (SELECT pay_by_quarter,
         generate_subscripts(pay_by_quarter, 1) AS s
   FROM sal_emp) AS foo
WHERE pay_by_quarter[s] = 10000;
```

This function is described in Table 9.62.

You can also search an array using the `&&` operator, which checks whether the left operand overlaps with the right operand. For instance:

```
SELECT * FROM sal_emp WHERE pay_by_quarter && ARRAY[10000];
```

This and other array operators are further described in Section 9.18. It can be accelerated by an appropriate index, as described in Section 11.2.

You can also search for specific values in an array using the `array_position` and `array_positions` functions. The former returns the subscript of the first occurrence of a value in an array; the latter returns an array with the subscripts of all occurrences of the value in the array. For example:

```
SELECT
  array_position(ARRAY['sun','mon','tue','wed','thu','fri','sat'],
                'mon');
array_positions
-----
2

SELECT array_positions(ARRAY[1, 4, 3, 1, 3, 4, 2, 1], 1);
array_positions
-----
{1,4,8}
```

Tip

Arrays are not sets; searching for specific array elements can be a sign of database misdesign. Consider using a separate table with a row for each item that would be an array element. This will be easier to search, and is likely to scale better for a large number of elements.

8.15.6. Array Input and Output Syntax

The external text representation of an array value consists of items that are interpreted according to the I/O conversion rules for the array's element type, plus decoration that indicates the array structure. The decoration consists of curly braces (`{` and `}`) around the array value plus delimiter characters between adjacent items. The delimiter character is usually a comma (`,`) but can be something else: it

is determined by the `typedelim` setting for the array's element type. Among the standard data types provided in the PostgreSQL distribution, all use a comma, except for type `box`, which uses a semicolon (`;`). In a multidimensional array, each dimension (row, plane, cube, etc.) gets its own level of curly braces, and delimiters must be written between adjacent curly-braced entities of the same level.

The array output routine will put double quotes around element values if they are empty strings, contain curly braces, delimiter characters, double quotes, backslashes, or white space, or match the word `NULL`. Double quotes and backslashes embedded in element values will be backslash-escaped. For numeric data types it is safe to assume that double quotes will never appear, but for textual data types one should be prepared to cope with either the presence or absence of quotes.

By default, the lower bound index value of an array's dimensions is set to one. To represent arrays with other lower bounds, the array subscript ranges can be specified explicitly before writing the array contents. This decoration consists of square brackets (`[]`) around each array dimension's lower and upper bounds, with a colon (`:`) delimiter character in between. The array dimension decoration is followed by an equal sign (`=`). For example:

```
SELECT f1[1][-2][3] AS e1, f1[1][-1][5] AS e2
FROM (SELECT '[1:1][-2:-1][3:5]={{{1,2,3},{4,5,6}}}'::int[] AS f1)
AS ss;

 e1 | e2
-----+-----
  1 |  6
(1 row)
```

The array output routine will include explicit dimensions in its result only when there are one or more lower bounds different from one.

If the value written for an element is `NULL` (in any case variant), the element is taken to be `NULL`. The presence of any quotes or backslashes disables this and allows the literal string value “`NULL`” to be entered. Also, for backward compatibility with pre-8.2 versions of PostgreSQL, the `array_nulls` configuration parameter can be turned `off` to suppress recognition of `NULL` as a `NULL`.

As shown previously, when writing an array value you can use double quotes around any individual array element. You *must* do so if the element value would otherwise confuse the array-value parser. For example, elements containing curly braces, commas (or the data type's delimiter character), double quotes, backslashes, or leading or trailing whitespace must be double-quoted. Empty strings and strings matching the word `NULL` must be quoted, too. To put a double quote or backslash in a quoted array element value, precede it with a backslash. Alternatively, you can avoid quotes and use backslash-escaping to protect all data characters that would otherwise be taken as array syntax.

You can add whitespace before a left brace or after a right brace. You can also add whitespace before or after any individual item string. In all of these cases the whitespace will be ignored. However, whitespace within double-quoted elements, or surrounded on both sides by non-whitespace characters of an element, is not ignored.

Tip

The `ARRAY` constructor syntax (see Section 4.2.12) is often easier to work with than the array-literal syntax when writing array values in SQL commands. In `ARRAY`, individual element values are written the same way they would be written when not members of an array.

8.16. Composite Types

A *composite type* represents the structure of a row or record; it is essentially just a list of field names and their data types. PostgreSQL allows composite types to be used in many of the same ways that simple types can be used. For example, a column of a table can be declared to be of a composite type.

8.16.1. Declaration of Composite Types

Here are two simple examples of defining composite types:

```
CREATE TYPE complex AS (  
    r        double precision,  
    i        double precision  
);  
  
CREATE TYPE inventory_item AS (  
    name            text,  
    supplier_id    integer,  
    price           numeric  
);
```

The syntax is comparable to `CREATE TABLE`, except that only field names and types can be specified; no constraints (such as `NOT NULL`) can presently be included. Note that the `AS` keyword is essential; without it, the system will think a different kind of `CREATE TYPE` command is meant, and you will get odd syntax errors.

Having defined the types, we can use them to create tables:

```
CREATE TABLE on_hand (  
    item        inventory_item,  
    count       integer  
);  
  
INSERT INTO on_hand VALUES (ROW('fuzzy dice', 42, 1.99), 1000);
```

or functions:

```
CREATE FUNCTION price_extension(inventory_item, integer) RETURNS  
    numeric  
AS 'SELECT $1.price * $2' LANGUAGE SQL;  
  
SELECT price_extension(item, 10) FROM on_hand;
```

Whenever you create a table, a composite type is also automatically created, with the same name as the table, to represent the table's row type. For example, had we said:

```
CREATE TABLE inventory_item (  
    name            text,  
    supplier_id    integer REFERENCES suppliers,  
    price           numeric CHECK (price > 0)  
);
```

then the same `inventory_item` composite type shown above would come into being as a byproduct, and could be used just as above. Note however an important restriction of the current implementation: since no constraints are associated with a composite type, the constraints shown in the table definition *do not apply* to values of the composite type outside the table. (To work around this, create a domain over the composite type, and apply the desired constraints as `CHECK` constraints of the domain.)

8.16.2. Constructing Composite Values

To write a composite value as a literal constant, enclose the field values within parentheses and separate them by commas. You can put double quotes around any field value, and must do so if it contains commas or parentheses. (More details appear below.) Thus, the general format of a composite constant is the following:

```
'( val1 , val2 , ... )'
```

An example is:

```
'("fuzzy dice",42,1.99)'
```

which would be a valid value of the `inventory_item` type defined above. To make a field be `NULL`, write no characters at all in its position in the list. For example, this constant specifies a `NULL` third field:

```
'("fuzzy dice",42,)'
```

If you want an empty string rather than `NULL`, write double quotes:

```
'( "", 42, )'
```

Here the first field is a non-`NULL` empty string, the third is `NULL`.

(These constants are actually only a special case of the generic type constants discussed in Section 4.1.2.7. The constant is initially treated as a string and passed to the composite-type input conversion routine. An explicit type specification might be necessary to tell which type to convert the constant to.)

The `ROW` expression syntax can also be used to construct composite values. In most cases this is considerably simpler to use than the string-literal syntax since you don't have to worry about multiple layers of quoting. We already used this method above:

```
ROW('fuzzy dice', 42, 1.99)
ROW('', 42, NULL)
```

The `ROW` keyword is actually optional as long as you have more than one field in the expression, so these can be simplified to:

```
('fuzzy dice', 42, 1.99)
('', 42, NULL)
```

The `ROW` expression syntax is discussed in more detail in Section 4.2.13.

8.16.3. Accessing Composite Types

To access a field of a composite column, one writes a dot and the field name, much like selecting a field from a table name. In fact, it's so much like selecting from a table name that you often have to use parentheses to keep from confusing the parser. For example, you might try to select some subfields from our `on_hand` example table with something like:

```
SELECT item.name FROM on_hand WHERE item.price > 9.99;
```

This will not work since the name `item` is taken to be a table name, not a column name of `on_hand`, per SQL syntax rules. You must write it like this:

```
SELECT (item).name FROM on_hand WHERE (item).price > 9.99;
```

or if you need to use the table name as well (for instance in a multitable query), like this:

```
SELECT (on_hand.item).name FROM on_hand WHERE (on_hand.item).price > 9.99;
```

Now the parenthesized object is correctly interpreted as a reference to the `item` column, and then the subfield can be selected from it.

Similar syntactic issues apply whenever you select a field from a composite value. For instance, to select just one field from the result of a function that returns a composite value, you'd need to write something like:

```
SELECT (my_func(...)).field FROM ...
```

Without the extra parentheses, this will generate a syntax error.

The special field name `*` means “all fields”, as further explained in Section 8.16.5.

8.16.4. Modifying Composite Types

Here are some examples of the proper syntax for inserting and updating composite columns. First, inserting or updating a whole column:

```
INSERT INTO mytab (complex_col) VALUES((1.1,2.2));
```

```
UPDATE mytab SET complex_col = ROW(1.1,2.2) WHERE ...;
```

The first example omits `ROW`, the second uses it; we could have done it either way.

We can update an individual subfield of a composite column:

```
UPDATE mytab SET complex_col.r = (complex_col).r + 1 WHERE ...;
```

Notice here that we don't need to (and indeed cannot) put parentheses around the column name appearing just after `SET`, but we do need parentheses when referencing the same column in the expression to the right of the equal sign.

And we can specify subfields as targets for `INSERT`, too:

```
INSERT INTO mytab (complex_col.r, complex_col.i) VALUES(1.1, 2.2);
```

Had we not supplied values for all the subfields of the column, the remaining subfields would have been filled with null values.

8.16.5. Using Composite Types in Queries

There are various special syntax rules and behaviors associated with composite types in queries. These rules provide useful shortcuts, but can be confusing if you don't know the logic behind them.

In PostgreSQL, a reference to a table name (or alias) in a query is effectively a reference to the composite value of the table's current row. For example, if we had a table `inventory_item` as shown above, we could write:

```
SELECT c FROM inventory_item c;
```

This query produces a single composite-valued column, so we might get output like:

```

          c
-----
 ("fuzzy dice",42,1.99)
(1 row)
```

Note however that simple names are matched to column names before table names, so this example works only because there is no column named `c` in the query's tables.

The ordinary qualified-column-name syntax `table_name.column_name` can be understood as applying field selection to the composite value of the table's current row. (For efficiency reasons, it's not actually implemented that way.)

When we write

```
SELECT c.* FROM inventory_item c;
```

then, according to the SQL standard, we should get the contents of the table expanded into separate columns:

```

 name      | supplier_id | price
-----+-----+-----
 fuzzy dice |          42 |  1.99
(1 row)
```

as if the query were

```
SELECT c.name, c.supplier_id, c.price FROM inventory_item c;
```

PostgreSQL will apply this expansion behavior to any composite-valued expression, although as shown above, you need to write parentheses around the value that `.*` is applied to whenever it's not a simple table name. For example, if `myfunc()` is a function returning a composite type with columns `a`, `b`, and `c`, then these two queries have the same result:

```
SELECT (myfunc(x)).* FROM some_table;
SELECT (myfunc(x)).a, (myfunc(x)).b, (myfunc(x)).c FROM some_table;
```

Tip

PostgreSQL handles column expansion by actually transforming the first form into the second. So, in this example, `myfunc()` would get invoked three times per row with either syntax. If it's an expensive function you may wish to avoid that, which you can do with a query like:

```
SELECT m.* FROM some_table, LATERAL myfunc(x) AS m;
```

Placing the function in a LATERAL FROM item keeps it from being invoked more than once per row. `m.*` is still expanded into `m.a`, `m.b`, `m.c`, but now those variables are just references to the output of the FROM item. (The LATERAL keyword is optional here, but we show it to clarify that the function is getting `x` from `some_table`.)

The `composite_value.*` syntax results in column expansion of this kind when it appears at the top level of a SELECT output list, a RETURNING list in INSERT/UPDATE/DELETE, a VALUES clause, or a row constructor. In all other contexts (including when nested inside one of those constructs), attaching `.*` to a composite value does not change the value, since it means “all columns” and so the same composite value is produced again. For example, if `somefunc()` accepts a composite-valued argument, these queries are the same:

```
SELECT somefunc(c.*) FROM inventory_item c;
SELECT somefunc(c) FROM inventory_item c;
```

In both cases, the current row of `inventory_item` is passed to the function as a single composite-valued argument. Even though `.*` does nothing in such cases, using it is good style, since it makes clear that a composite value is intended. In particular, the parser will consider `c` in `c.*` to refer to a table name or alias, not to a column name, so that there is no ambiguity; whereas without `.*`, it is not clear whether `c` means a table name or a column name, and in fact the column-name interpretation will be preferred if there is a column named `c`.

Another example demonstrating these concepts is that all these queries mean the same thing:

```
SELECT * FROM inventory_item c ORDER BY c;
SELECT * FROM inventory_item c ORDER BY c.*;
SELECT * FROM inventory_item c ORDER BY ROW(c.*);
```

All of these ORDER BY clauses specify the row's composite value, resulting in sorting the rows according to the rules described in Section 9.23.6. However, if `inventory_item` contained a column named `c`, the first case would be different from the others, as it would mean to sort by that column only. Given the column names previously shown, these queries are also equivalent to those above:

```
SELECT * FROM inventory_item c ORDER BY ROW(c.name, c.supplier_id,
c.price);
SELECT * FROM inventory_item c ORDER BY (c.name, c.supplier_id,
c.price);
```

(The last case uses a row constructor with the key word ROW omitted.)

Another special syntactical behavior associated with composite values is that we can use *functional notation* for extracting a field of a composite value. The simple way to explain this is that the notations `field(table)` and `table.field` are interchangeable. For example, these queries are equivalent:

```
SELECT c.name FROM inventory_item c WHERE c.price > 1000;
SELECT name(c) FROM inventory_item c WHERE price(c) > 1000;
```

Moreover, if we have a function that accepts a single argument of a composite type, we can call it with either notation. These queries are all equivalent:

```
SELECT somefunc(c) FROM inventory_item c;
SELECT somefunc(c.*) FROM inventory_item c;
```

```
SELECT c.somefunc FROM inventory_item c;
```

This equivalence between functional notation and field notation makes it possible to use functions on composite types to implement “computed fields”. An application using the last query above wouldn't need to be directly aware that `somefunc` isn't a real column of the table.

Tip

Because of this behavior, it's unwise to give a function that takes a single composite-type argument the same name as any of the fields of that composite type. If there is ambiguity, the field-name interpretation will be chosen if field-name syntax is used, while the function will be chosen if function-call syntax is used. However, PostgreSQL versions before 11 always chose the field-name interpretation, unless the syntax of the call required it to be a function call. One way to force the function interpretation in older versions is to schema-qualify the function name, that is, write `schema.func(compositevalue)`.

8.16.6. Composite Type Input and Output Syntax

The external text representation of a composite value consists of items that are interpreted according to the I/O conversion rules for the individual field types, plus decoration that indicates the composite structure. The decoration consists of parentheses ((and)) around the whole value, plus commas (,) between adjacent items. Whitespace outside the parentheses is ignored, but within the parentheses it is considered part of the field value, and might or might not be significant depending on the input conversion rules for the field data type. For example, in:

```
' ( 42 ) '
```

the whitespace will be ignored if the field type is integer, but not if it is text.

As shown previously, when writing a composite value you can write double quotes around any individual field value. You *must* do so if the field value would otherwise confuse the composite-value parser. In particular, fields containing parentheses, commas, double quotes, or backslashes must be double-quoted. To put a double quote or backslash in a quoted composite field value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted field value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as composite syntax.

A completely empty field value (no characters at all between the commas or parentheses) represents a NULL. To write a value that is an empty string rather than NULL, write " ".

The composite output routine will put double quotes around field values if they are empty strings or contain parentheses, commas, double quotes, backslashes, or white space. (Doing so for white space is not essential, but aids legibility.) Double quotes and backslashes embedded in field values will be doubled.

Note

Remember that what you write in an SQL command will first be interpreted as a string literal, and then as a composite. This doubles the number of backslashes you need (assuming escape string syntax is used). For example, to insert a `text` field containing a double quote and a backslash in a composite value, you'd need to write:

```
INSERT ... VALUES ( ('\"\\\"') );
```

The string-literal processor removes one level of backslashes, so that what arrives at the composite-value parser looks like (\"\\\"). In turn, the string fed to the `text` data type's input routine becomes `\"`. (If we were working with a data type whose input routine also treated backslashes specially, `bytea` for example, we might need as many as eight backslashes in the command to get one backslash into the stored composite field.) Dollar quoting (see Section 4.1.2.4) can be used to avoid the need to double backslashes.

Tip

The `ROW` constructor syntax is usually easier to work with than the composite-literal syntax when writing composite values in SQL commands. In `ROW`, individual field values are written the same way they would be written when not members of a composite.

8.17. Range Types

Range types are data types representing a range of values of some element type (called the range's *subtype*). For instance, ranges of `timestamp` might be used to represent the ranges of time that a meeting room is reserved. In this case the data type is `tsrange` (short for “timestamp range”), and `timestamp` is the subtype. The subtype must have a total order so that it is well-defined whether element values are within, before, or after a range of values.

Range types are useful because they represent many element values in a single range value, and because concepts such as overlapping ranges can be expressed clearly. The use of time and date ranges for scheduling purposes is the clearest example; but price ranges, measurement ranges from an instrument, and so forth can also be useful.

8.17.1. Built-in Range Types

PostgreSQL comes with the following built-in range types:

- `int4range` — Range of integer
- `int8range` — Range of bigint
- `numrange` — Range of numeric
- `tsrange` — Range of timestamp without time zone
- `tstzrange` — Range of timestamp with time zone
- `daterange` — Range of date

In addition, you can define your own range types; see `CREATE TYPE` for more information.

8.17.2. Examples

```
CREATE TABLE reservation (room int, during tsrange);
INSERT INTO reservation VALUES
    (1108, '[2010-01-01 14:30, 2010-01-01 15:30)');
```

```
-- Containment
SELECT int4range(10, 20) @> 3;

-- Overlaps
SELECT numrange(11.1, 22.2) && numrange(20.0, 30.0);

-- Extract the upper bound
SELECT upper(int8range(15, 25));

-- Compute the intersection
SELECT int4range(10, 20) * int4range(15, 25);

-- Is the range empty?
SELECT isempty(numrange(1, 5));
```

See Table 9.53 and Table 9.54 for complete lists of operators and functions on range types.

8.17.3. Inclusive and Exclusive Bounds

Every non-empty range has two bounds, the lower bound and the upper bound. All points between these values are included in the range. An inclusive bound means that the boundary point itself is included in the range as well, while an exclusive bound means that the boundary point is not included in the range.

In the text form of a range, an inclusive lower bound is represented by “[” while an exclusive lower bound is represented by “(”. Likewise, an inclusive upper bound is represented by “]”, while an exclusive upper bound is represented by “)”. (See Section 8.17.5 for more details.)

The functions `lower_inc` and `upper_inc` test the inclusivity of the lower and upper bounds of a range value, respectively.

8.17.4. Infinite (Unbounded) Ranges

The lower bound of a range can be omitted, meaning that all points less than the upper bound are included in the range. Likewise, if the upper bound of the range is omitted, then all points greater than the lower bound are included in the range. If both lower and upper bounds are omitted, all values of the element type are considered to be in the range.

This is equivalent to considering that the lower bound is “minus infinity”, or the upper bound is “plus infinity”, respectively. But note that these infinite values are never values of the range's element type, and can never be part of the range. (So there is no such thing as an inclusive infinite bound — if you try to write one, it will automatically be converted to an exclusive bound.)

Also, some element types have a notion of “infinity”, but that is just another value so far as the range type mechanisms are concerned. For example, in timestamp ranges, `[today,]` means the same thing as `[today,)`. But `[today, infinity]` means something different from `[today, infinity)` — the latter excludes the special timestamp value `infinity`.

The functions `lower_inf` and `upper_inf` test for infinite lower and upper bounds of a range, respectively.

8.17.5. Range Input/Output

The input for a range value must follow one of the following patterns:

```
(lower-bound, upper-bound)
```

```
( lower-bound , upper-bound ]
[ lower-bound , upper-bound )
[ lower-bound , upper-bound ]
empty
```

The parentheses or brackets indicate whether the lower and upper bounds are exclusive or inclusive, as described previously. Notice that the final pattern is `empty`, which represents an empty range (a range that contains no points).

The *lower-bound* may be either a string that is valid input for the subtype, or `empty` to indicate no lower bound. Likewise, *upper-bound* may be either a string that is valid input for the subtype, or `empty` to indicate no upper bound.

Each bound value can be quoted using " (double quote) characters. This is necessary if the bound value contains parentheses, brackets, commas, double quotes, or backslashes, since these characters would otherwise be taken as part of the range syntax. To put a double quote or backslash in a quoted bound value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted bound value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as range syntax. Also, to write a bound value that is an empty string, write "", since writing nothing means an infinite bound.

Whitespace is allowed before and after the range value, but any whitespace between the parentheses or brackets is taken as part of the lower or upper bound value. (Depending on the element type, it might or might not be significant.)

Note

These rules are very similar to those for writing field values in composite-type literals. See Section 8.16.6 for additional commentary.

Examples:

```
-- includes 3, does not include 7, and does include all points in
  between
SELECT '[3,7)>:::int4range;

-- does not include either 3 or 7, but includes all points in
  between
SELECT '(3,7)>:::int4range;

-- includes only the single point 4
SELECT '[4,4]>:::int4range;

-- includes no points (and will be normalized to 'empty')
SELECT '[4,4)>:::int4range;
```

8.17.6. Constructing Ranges

Each range type has a constructor function with the same name as the range type. Using the constructor function is frequently more convenient than writing a range literal constant, since it avoids the need for extra quoting of the bound values. The constructor function accepts two or three arguments. The two-argument form constructs a range in standard form (lower bound inclusive, upper bound exclusive), while the three-argument form constructs a range with bounds of the form specified by the third argument. The third argument must be one of the strings "()", "(]", "[)", or "[]". For example:

```
-- The full form is: lower bound, upper bound, and text argument
  indicating
-- inclusivity/exclusivity of bounds.
SELECT numrange(1.0, 14.0, '()');

-- If the third argument is omitted, '()' is assumed.
SELECT numrange(1.0, 14.0);

-- Although '()' is specified here, on display the value will be
  converted to
-- canonical form, since int8range is a discrete range type (see
  below).
SELECT int8range(1, 14, '()');

-- Using NULL for either bound causes the range to be unbounded on
  that side.
SELECT numrange(NULL, 2.2);
```

8.17.7. Discrete Range Types

A discrete range is one whose element type has a well-defined “step”, such as `integer` or `date`. In these types two elements can be said to be adjacent, when there are no valid values between them. This contrasts with continuous ranges, where it's always (or almost always) possible to identify other element values between two given values. For example, a range over the `numeric` type is continuous, as is a range over `timestamp`. (Even though `timestamp` has limited precision, and so could theoretically be treated as discrete, it's better to consider it continuous since the step size is normally not of interest.)

Another way to think about a discrete range type is that there is a clear idea of a “next” or “previous” value for each element value. Knowing that, it is possible to convert between inclusive and exclusive representations of a range's bounds, by choosing the next or previous element value instead of the one originally given. For example, in an integer range type `[4, 8]` and `(3, 9)` denote the same set of values; but this would not be so for a range over `numeric`.

A discrete range type should have a *canonicalization* function that is aware of the desired step size for the element type. The canonicalization function is charged with converting equivalent values of the range type to have identical representations, in particular consistently inclusive or exclusive bounds. If a canonicalization function is not specified, then ranges with different formatting will always be treated as unequal, even though they might represent the same set of values in reality.

The built-in range types `int4range`, `int8range`, and `daterange` all use a canonical form that includes the lower bound and excludes the upper bound; that is, `[)`. User-defined range types can use other conventions, however.

8.17.8. Defining New Range Types

Users can define their own range types. The most common reason to do this is to use ranges over subtypes not provided among the built-in range types. For example, to define a new range type of subtype `float8`:

```
CREATE TYPE floatrange AS RANGE (
    subtype = float8,
    subtype_diff = float8mi
);

SELECT '[1.234, 5.678]':floatrange;
```

Because `float8` has no meaningful “step”, we do not define a canonicalization function in this example.

Defining your own range type also allows you to specify a different subtype B-tree operator class or collation to use, so as to change the sort ordering that determines which values fall into a given range.

If the subtype is considered to have discrete rather than continuous values, the `CREATE TYPE` command should specify a `canonical` function. The canonicalization function takes an input range value, and must return an equivalent range value that may have different bounds and formatting. The canonical output for two ranges that represent the same set of values, for example the integer ranges `[1, 7]` and `[1, 8)`, must be identical. It doesn't matter which representation you choose to be the canonical one, so long as two equivalent values with different formattings are always mapped to the same value with the same formatting. In addition to adjusting the inclusive/exclusive bounds format, a canonicalization function might round off boundary values, in case the desired step size is larger than what the subtype is capable of storing. For instance, a range type over `timestamp` could be defined to have a step size of an hour, in which case the canonicalization function would need to round off bounds that weren't a multiple of an hour, or perhaps throw an error instead.

In addition, any range type that is meant to be used with GiST or SP-GiST indexes should define a subtype difference, or `subtype_diff`, function. (The index will still work without `subtype_diff`, but it is likely to be considerably less efficient than if a difference function is provided.) The subtype difference function takes two input values of the subtype, and returns their difference (i.e., X minus Y) represented as a `float8` value. In our example above, the function `float8mi` that underlies the regular `float8` minus operator can be used; but for any other subtype, some type conversion would be necessary. Some creative thought about how to represent differences as numbers might be needed, too. To the greatest extent possible, the `subtype_diff` function should agree with the sort ordering implied by the selected operator class and collation; that is, its result should be positive whenever its first argument is greater than its second according to the sort ordering.

A less-oversimplified example of a `subtype_diff` function is:

```
CREATE FUNCTION time_subtype_diff(x time, y time) RETURNS float8 AS
'SELECT EXTRACT(EPOCH FROM (x - y))' LANGUAGE sql STRICT IMMUTABLE;

CREATE TYPE timerange AS RANGE (
    subtype = time,
    subtype_diff = time_subtype_diff
);

SELECT '[11:10, 23:00]':timerange;
```

See `CREATE TYPE` for more information about creating range types.

8.17.9. Indexing

GiST and SP-GiST indexes can be created for table columns of range types. For instance, to create a GiST index:

```
CREATE INDEX reservation_idx ON reservation USING GIST (during);
```

A GiST or SP-GiST index can accelerate queries involving these range operators: `=`, `&&`, `<@`, `@>`, `<<`, `>>`, `-|-`, `&<`, and `&>` (see Table 9.53 for more information).

In addition, B-tree and hash indexes can be created for table columns of range types. For these index types, basically the only useful range operation is equality. There is a B-tree sort ordering defined for range values, with corresponding `<` and `>` operators, but the ordering is rather arbitrary and not usually useful in the real world. Range types' B-tree and hash support is primarily meant to allow sorting and hashing internally in queries, rather than creation of actual indexes.

8.17.10. Constraints on Ranges

While `UNIQUE` is a natural constraint for scalar values, it is usually unsuitable for range types. Instead, an exclusion constraint is often more appropriate (see `CREATE TABLE ... CONSTRAINT ... EXCLUDE`). Exclusion constraints allow the specification of constraints such as “non-overlapping” on a range type. For example:

```
CREATE TABLE reservation (
    during tsrange,
    EXCLUDE USING GIST (during WITH &&)
);
```

That constraint will prevent any overlapping values from existing in the table at the same time:

```
INSERT INTO reservation VALUES
    ('[2010-01-01 11:30, 2010-01-01 15:00)');
INSERT 0 1

INSERT INTO reservation VALUES
    ('[2010-01-01 14:45, 2010-01-01 15:45)');
ERROR:  conflicting key value violates exclusion constraint
        "reservation_during_excl"
DETAIL:  Key (during)=(["2010-01-01 14:45:00", "2010-01-01
15:45:00"]) conflicts
with existing key (during)=(["2010-01-01 11:30:00", "2010-01-01
15:00:00"]).
```

You can use the `btree_gist` extension to define exclusion constraints on plain scalar data types, which can then be combined with range exclusions for maximum flexibility. For example, after `btree_gist` is installed, the following constraint will reject overlapping ranges only if the meeting room numbers are equal:

```
CREATE EXTENSION btree_gist;
CREATE TABLE room_reservation (
    room text,
    during tsrange,
    EXCLUDE USING GIST (room WITH =, during WITH &&)
);

INSERT INTO room_reservation VALUES
    ('123A', '[2010-01-01 14:00, 2010-01-01 15:00)');
INSERT 0 1

INSERT INTO room_reservation VALUES
    ('123A', '[2010-01-01 14:30, 2010-01-01 15:30)');
ERROR:  conflicting key value violates exclusion constraint
        "room_reservation_room_during_excl"
DETAIL:  Key (room, during)=(123A, ["2010-01-01
14:30:00", "2010-01-01 15:30:00"]) conflicts
with existing key (room, during)=(123A, ["2010-01-01
14:00:00", "2010-01-01 15:00:00"]).

INSERT INTO room_reservation VALUES
    ('123B', '[2010-01-01 14:30, 2010-01-01 15:30)');
INSERT 0 1
```

8.18. Domain Types

A *domain* is a user-defined data type that is based on another *underlying type*. Optionally, it can have constraints that restrict its valid values to a subset of what the underlying type would allow. Otherwise it behaves like the underlying type — for example, any operator or function that can be applied to the underlying type will work on the domain type. The underlying type can be any built-in or user-defined base type, enum type, array type, composite type, range type, or another domain.

For example, we could create a domain over integers that accepts only positive integers:

```
CREATE DOMAIN posint AS integer CHECK (VALUE > 0);
CREATE TABLE mytable (id posint);
INSERT INTO mytable VALUES(1);    -- works
INSERT INTO mytable VALUES(-1);  -- fails
```

When an operator or function of the underlying type is applied to a domain value, the domain is automatically down-cast to the underlying type. Thus, for example, the result of `mytable.id - 1` is considered to be of type `integer` not `posint`. We could write `(mytable.id - 1)::posint` to cast the result back to `posint`, causing the domain's constraints to be rechecked. In this case, that would result in an error if the expression had been applied to an `id` value of 1. Assigning a value of the underlying type to a field or variable of the domain type is allowed without writing an explicit cast, but the domain's constraints will be checked.

For additional information see `CREATE DOMAIN`.

8.19. Object Identifier Types

Object identifiers (OIDs) are used internally by PostgreSQL as primary keys for various system tables. Type `oid` represents an object identifier. There are also several alias types for `oid`: `regproc`, `regprocedure`, `regoper`, `regoperator`, `regclass`, `regtype`, `regrole`, `regnamespace`, `regconfig`, and `regdictionary`. Table 8.26 shows an overview.

The `oid` type is currently implemented as an unsigned four-byte integer. Therefore, it is not large enough to provide database-wide uniqueness in large databases, or even in large individual tables.

The `oid` type itself has few operations beyond comparison. It can be cast to `integer`, however, and then manipulated using the standard integer operators. (Beware of possible signed-versus-unsigned confusion if you do this.)

The OID alias types have no operations of their own except for specialized input and output routines. These routines are able to accept and display symbolic names for system objects, rather than the raw numeric value that type `oid` would use. The alias types allow simplified lookup of OID values for objects. For example, to examine the `pg_attribute` rows related to a table `mytable`, one could write:

```
SELECT * FROM pg_attribute WHERE attrelid = 'mytable'::regclass;
```

rather than:

```
SELECT * FROM pg_attribute
  WHERE attrelid = (SELECT oid FROM pg_class WHERE relname =
    'mytable');
```

While that doesn't look all that bad by itself, it's still oversimplified. A far more complicated subselect would be needed to select the right OID if there are multiple tables named `mytable` in different schemas. The `regclass` input converter handles the table lookup according to the schema path

setting, and so it does the “right thing” automatically. Similarly, casting a table's OID to `regclass` is handy for symbolic display of a numeric OID.

Table 8.26. Object Identifier Types

Name	References	Description	Value Example
<code>oid</code>	<code>any</code>	numeric object identifier	564182
<code>regproc</code>	<code>pg_proc</code>	function name	<code>sum</code>
<code>regprocedure</code>	<code>pg_proc</code>	function with argument types	<code>sum(int4)</code>
<code>regoper</code>	<code>pg_operator</code>	operator name	<code>+</code>
<code>regoperator</code>	<code>pg_operator</code>	operator with argument types	<code>*(integer, integer)</code> or <code>-(NONE, integer)</code>
<code>regclass</code>	<code>pg_class</code>	relation name	<code>pg_type</code>
<code>regtype</code>	<code>pg_type</code>	data type name	<code>integer</code>
<code>regrole</code>	<code>pg_authid</code>	role name	<code>smithee</code>
<code>regnamespace</code>	<code>pg_namespace</code>	namespace name	<code>pg_catalog</code>
<code>regconfig</code>	<code>pg_ts_config</code>	text search configuration	<code>english</code>
<code>regdictionary</code>	<code>pg_ts_dict</code>	text search dictionary	<code>simple</code>

All of the OID alias types for objects grouped by namespace accept schema-qualified names, and will display schema-qualified names on output if the object would not be found in the current search path without being qualified. The `regproc` and `regoper` alias types will only accept input names that are unique (not overloaded), so they are of limited use; for most uses `regprocedure` or `regoperator` are more appropriate. For `regoperator`, unary operators are identified by writing `NONE` for the unused operand.

An additional property of most of the OID alias types is the creation of dependencies. If a constant of one of these types appears in a stored expression (such as a column default expression or view), it creates a dependency on the referenced object. For example, if a column has a default expression `nextval('my_seq'::regclass)`, PostgreSQL understands that the default expression depends on the sequence `my_seq`; the system will not let the sequence be dropped without first removing the default expression. `regrole` is the only exception for the property. Constants of this type are not allowed in such expressions.

Note

The OID alias types do not completely follow transaction isolation rules. The planner also treats them as simple constants, which may result in sub-optimal planning.

Another identifier type used by the system is `xid`, or transaction (abbreviated `xact`) identifier. This is the data type of the system columns `xmin` and `xmax`. Transaction identifiers are 32-bit quantities.

A third identifier type used by the system is `cid`, or command identifier. This is the data type of the system columns `cmin` and `cmax`. Command identifiers are also 32-bit quantities.

A final identifier type used by the system is `tid`, or tuple identifier (row identifier). This is the data type of the system column `ctid`. A tuple ID is a pair (block number, tuple index within block) that identifies the physical location of the row within its table.

(The system columns are further explained in Section 5.5.)

8.20. pg_lsn Type

The `pg_lsn` data type can be used to store LSN (Log Sequence Number) data which is a pointer to a location in the WAL. This type is a representation of `XLogRecPtr` and an internal system type of PostgreSQL.

Internally, an LSN is a 64-bit integer, representing a byte position in the write-ahead log stream. It is printed as two hexadecimal numbers of up to 8 digits each, separated by a slash; for example, `16/B374D848`. The `pg_lsn` type supports the standard comparison operators, like `=` and `>`. Two LSNs can be subtracted using the `-` operator; the result is the number of bytes separating those write-ahead log locations.

8.21. Pseudo-Types

The PostgreSQL type system contains a number of special-purpose entries that are collectively called *pseudo-types*. A pseudo-type cannot be used as a column data type, but it can be used to declare a function's argument or result type. Each of the available pseudo-types is useful in situations where a function's behavior does not correspond to simply taking or returning a value of a specific SQL data type. Table 8.27 lists the existing pseudo-types.

Table 8.27. Pseudo-Types

Name	Description
<code>any</code>	Indicates that a function accepts any input data type.
<code>anyelement</code>	Indicates that a function accepts any data type (see Section 37.2.5).
<code>anyarray</code>	Indicates that a function accepts any array data type (see Section 37.2.5).
<code>anynonarray</code>	Indicates that a function accepts any non-array data type (see Section 37.2.5).
<code>anyenum</code>	Indicates that a function accepts any enum data type (see Section 37.2.5 and Section 8.7).
<code>anyrange</code>	Indicates that a function accepts any range data type (see Section 37.2.5 and Section 8.17).
<code>cstring</code>	Indicates that a function accepts or returns a null-terminated C string.
<code>internal</code>	Indicates that a function accepts or returns a server-internal data type.
<code>language_handler</code>	A procedural language call handler is declared to return <code>language_handler</code> .
<code>fdw_handler</code>	A foreign-data wrapper handler is declared to return <code>fdw_handler</code> .
<code>index_am_handler</code>	An index access method handler is declared to return <code>index_am_handler</code> .
<code>tsm_handler</code>	A tablesample method handler is declared to return <code>tsm_handler</code> .
<code>record</code>	Identifies a function taking or returning an unspecified row type.
<code>trigger</code>	A trigger function is declared to return <code>trigger</code> .

Name	Description
<code>event_trigger</code>	An event trigger function is declared to return <code>event_trigger</code> .
<code>pg_ddl_command</code>	Identifies a representation of DDL commands that is available to event triggers.
<code>void</code>	Indicates that a function returns no value.
<code>unknown</code>	Identifies a not-yet-resolved type, e.g. of an undecorated string literal.
<code>opaque</code>	An obsolete type name that formerly served many of the above purposes.

Functions coded in C (whether built-in or dynamically loaded) can be declared to accept or return any of these pseudo data types. It is up to the function author to ensure that the function will behave safely when a pseudo-type is used as an argument type.

Functions coded in procedural languages can use pseudo-types only as allowed by their implementation languages. At present most procedural languages forbid use of a pseudo-type as an argument type, and allow only `void` and `record` as a result type (plus `trigger` or `event_trigger` when the function is used as a trigger or event trigger). Some also support polymorphic functions using the types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`.

The `internal` pseudo-type is used to declare functions that are meant only to be called internally by the database system, and not by direct invocation in an SQL query. If a function has at least one `internal`-type argument then it cannot be called from SQL. To preserve the type safety of this restriction it is important to follow this coding rule: do not create any function that is declared to return `internal` unless it has at least one `internal` argument.

Chapter 9. Functions and Operators

PostgreSQL provides a large number of functions and operators for the built-in data types. Users can also define their own functions and operators, as described in Part V. The `psql` commands `\df` and `\do` can be used to list all available functions and operators, respectively.

If you are concerned about portability then note that most of the functions and operators described in this chapter, with the exception of the most trivial arithmetic and comparison operators and some explicitly marked functions, are not specified by the SQL standard. Some of this extended functionality is present in other SQL database management systems, and in many cases this functionality is compatible and consistent between the various implementations. This chapter is also not exhaustive; additional functions appear in relevant sections of the manual.

9.1. Logical Operators

The usual logical operators are available:

AND
OR
NOT

SQL uses a three-valued logic system with `true`, `false`, and `null`, which represents “unknown”. Observe the following truth tables:

a	b	a AND b	a OR b
TRUE	TRUE	TRUE	TRUE
TRUE	FALSE	FALSE	TRUE
TRUE	NULL	NULL	TRUE
FALSE	FALSE	FALSE	FALSE
FALSE	NULL	FALSE	NULL
NULL	NULL	NULL	NULL

a	NOT a
TRUE	FALSE
FALSE	TRUE
NULL	NULL

The operators `AND` and `OR` are commutative, that is, you can switch the left and right operand without affecting the result. But see Section 4.2.14 for more information about the order of evaluation of subexpressions.

9.2. Comparison Functions and Operators

The usual comparison operators are available, as shown in Table 9.1.

Table 9.1. Comparison Operators

Operator	Description
<code><</code>	less than
<code>></code>	greater than
<code><=</code>	less than or equal to
<code>>=</code>	greater than or equal to

Operator	Description
=	equal
<> or !=	not equal

Note

The != operator is converted to <> in the parser stage. It is not possible to implement != and <> operators that do different things.

Comparison operators are available for all relevant data types. All comparison operators are binary operators that return values of type `boolean`; expressions like `1 < 2 < 3` are not valid (because there is no `<` operator to compare a Boolean value with 3).

There are also some comparison predicates, as shown in Table 9.2. These behave much like operators, but have special syntax mandated by the SQL standard.

Table 9.2. Comparison Predicates

Predicate	Description
<code>a BETWEEN x AND y</code>	between
<code>a NOT BETWEEN x AND y</code>	not between
<code>a BETWEEN SYMMETRIC x AND y</code>	between, after sorting the comparison values
<code>a NOT BETWEEN SYMMETRIC x AND y</code>	not between, after sorting the comparison values
<code>a IS DISTINCT FROM b</code>	not equal, treating null like an ordinary value
<code>a IS NOT DISTINCT FROM b</code>	equal, treating null like an ordinary value
<code>expression IS NULL</code>	is null
<code>expression IS NOT NULL</code>	is not null
<code>expression ISNULL</code>	is null (nonstandard syntax)
<code>expression NOTNULL</code>	is not null (nonstandard syntax)
<code>boolean_expression IS TRUE</code>	is true
<code>boolean_expression IS NOT TRUE</code>	is false or unknown
<code>boolean_expression IS FALSE</code>	is false
<code>boolean_expression IS NOT FALSE</code>	is true or unknown
<code>boolean_expression IS UNKNOWN</code>	is unknown
<code>boolean_expression IS NOT UNKNOWN</code>	is true or false

The `BETWEEN` predicate simplifies range tests:

`a BETWEEN x AND y`

is equivalent to

`a >= x AND a <= y`

Notice that `BETWEEN` treats the endpoint values as included in the range. `NOT BETWEEN` does the opposite comparison:

`a NOT BETWEEN x AND y`

is equivalent to

$a < x$ OR $a > y$

BETWEEN SYMMETRIC is like BETWEEN except there is no requirement that the argument to the left of AND be less than or equal to the argument on the right. If it is not, those two arguments are automatically swapped, so that a nonempty range is always implied.

Ordinary comparison operators yield null (signifying “unknown”), not true or false, when either input is null. For example, $7 = \text{NULL}$ yields null, as does $7 <> \text{NULL}$. When this behavior is not suitable, use the IS [NOT] DISTINCT FROM predicates:

a IS DISTINCT FROM b
 a IS NOT DISTINCT FROM b

For non-null inputs, IS DISTINCT FROM is the same as the $<>$ operator. However, if both inputs are null it returns false, and if only one input is null it returns true. Similarly, IS NOT DISTINCT FROM is identical to $=$ for non-null inputs, but it returns true when both inputs are null, and false when only one input is null. Thus, these predicates effectively act as though null were a normal data value, rather than “unknown”.

To check whether a value is or is not null, use the predicates:

expression IS NULL
expression IS NOT NULL

or the equivalent, but nonstandard, predicates:

expression ISNULL
expression NOTNULL

Do not write *expression* = NULL because NULL is not “equal to” NULL. (The null value represents an unknown value, and it is not known whether two unknown values are equal.)

Tip

Some applications might expect that *expression* = NULL returns true if *expression* evaluates to the null value. It is highly recommended that these applications be modified to comply with the SQL standard. However, if that cannot be done the transform_null_equals configuration variable is available. If it is enabled, PostgreSQL will convert $x = \text{NULL}$ clauses to x IS NULL.

If the *expression* is row-valued, then IS NULL is true when the row expression itself is null or when all the row's fields are null, while IS NOT NULL is true when the row expression itself is non-null and all the row's fields are non-null. Because of this behavior, IS NULL and IS NOT NULL do not always return inverse results for row-valued expressions; in particular, a row-valued expression that contains both null and non-null fields will return false for both tests. In some cases, it may be preferable to write *row* IS DISTINCT FROM NULL or *row* IS NOT DISTINCT FROM NULL, which will simply check whether the overall row value is null without any additional tests on the row fields.

Boolean values can also be tested using the predicates

boolean_expression IS TRUE

```
boolean_expression IS NOT TRUE
boolean_expression IS FALSE
boolean_expression IS NOT FALSE
boolean_expression IS UNKNOWN
boolean_expression IS NOT UNKNOWN
```

These will always return true or false, never a null value, even when the operand is null. A null input is treated as the logical value “unknown”. Notice that `IS UNKNOWN` and `IS NOT UNKNOWN` are effectively the same as `IS NULL` and `IS NOT NULL`, respectively, except that the input expression must be of Boolean type.

Some comparison-related functions are also available, as shown in Table 9.3.

Table 9.3. Comparison Functions

Function	Description	Example	Example Result
<code>num_nonnulls(VARIADIC "any")</code>	returns the number of non-null arguments	<code>num_nonnulls(1, NULL, 2)</code>	2
<code>num_nulls(VARIADIC "any")</code>	returns the number of null arguments	<code>num_nulls(1, NULL, 2)</code>	1

9.3. Mathematical Functions and Operators

Mathematical operators are provided for many PostgreSQL types. For types without standard mathematical conventions (e.g., date/time types) we describe the actual behavior in subsequent sections.

Table 9.4 shows the available mathematical operators.

Table 9.4. Mathematical Operators

Operator	Description	Example	Result
<code>+</code>	addition	<code>2 + 3</code>	5
<code>-</code>	subtraction	<code>2 - 3</code>	-1
<code>*</code>	multiplication	<code>2 * 3</code>	6
<code>/</code>	division (integer division truncates the result)	<code>4 / 2</code>	2
<code>%</code>	modulo (remainder)	<code>5 % 4</code>	1
<code>^</code>	exponentiation (associates left to right)	<code>2.0 ^ 3.0</code>	8
<code> /</code>	square root	<code> / 25.0</code>	5
<code> /</code>	cube root	<code> / 27.0</code>	3
<code>!</code>	factorial	<code>5 !</code>	120
<code>!!</code>	factorial (prefix operator)	<code>!! 5</code>	120
<code>@</code>	absolute value	<code>@ -5.0</code>	5
<code>&</code>	bitwise AND	<code>91 & 15</code>	11
<code> </code>	bitwise OR	<code>32 3</code>	35
<code>#</code>	bitwise XOR	<code>17 # 5</code>	20
<code>~</code>	bitwise NOT	<code>~1</code>	-2
<code><<</code>	bitwise shift left	<code>1 << 4</code>	16

Operator	Description	Example	Result
>>	bitwise shift right	8 >> 2	2

The bitwise operators work only on integral data types, whereas the others are available for all numeric data types. The bitwise operators are also available for the bit string types `bit` and `bit varying`, as shown in Table 9.14.

Table 9.5 shows the available mathematical functions. In the table, `dp` indicates double precision. Many of these functions are provided in multiple forms with different argument types. Except where noted, any given form of a function returns the same data type as its argument. The functions working with double precision data are mostly implemented on top of the host system's C library; accuracy and behavior in boundary cases can therefore vary depending on the host system.

Table 9.5. Mathematical Functions

Function	Return Type	Description	Example	Result
<code>abs(x)</code>	(same as input)	absolute value	<code>abs(-17.4)</code>	17.4
<code>cbrt(dp)</code>	<code>dp</code>	cube root	<code>cbrt(27.0)</code>	3
<code>ceil(dp or numeric)</code>	(same as input)	nearest integer greater than or equal to argument	<code>ceil(-42.8)</code>	-42
<code>ceiling(dp or numeric)</code>	(same as input)	nearest integer greater than or equal to argument (same as <code>ceil</code>)	<code>ceiling(-95.3)</code>	-95
<code>degrees(dp)</code>	<code>dp</code>	radians to degrees	<code>degrees(0.5)</code>	28.6478897565412
<code>div(y numeric, x numeric)</code>	numeric	integer quotient of y/x	<code>div(9,4)</code>	2
<code>exp(dp or numeric)</code>	(same as input)	exponential	<code>exp(1.0)</code>	2.71828182845905
<code>floor(dp or numeric)</code>	(same as input)	nearest integer less than or equal to argument	<code>floor(-42.8)</code>	-43
<code>ln(dp or numeric)</code>	(same as input)	natural logarithm	<code>ln(2.0)</code>	0.693147180559945
<code>log(dp or numeric)</code>	(same as input)	base 10 logarithm	<code>log(100.0)</code>	2
<code>log10(dp or numeric)</code>	(same as input)	base 10 logarithm	<code>log10(100.0)</code>	2
<code>log(b numeric, x numeric)</code>	numeric	logarithm to base b	<code>log(2.0, 64.0)</code>	6.0000000000
<code>mod(y, x)</code>	(same as argument types)	remainder of y/x	<code>mod(9,4)</code>	1
<code>pi()</code>	<code>dp</code>	"#" constant	<code>pi()</code>	3.14159265358979
<code>power(a dp, b dp)</code>	<code>dp</code>	a raised to the power of b	<code>power(9.0, 3.0)</code>	729
<code>power(a numeric, b numeric)</code>	numeric	a raised to the power of b	<code>power(9.0, 3.0)</code>	729

Function	Return Type	Description	Example	Result
<code>radians(dp)</code>	dp	degrees to radians	<code>radians(45.0)</code>	0.785398163397448
<code>round(dp or numeric)</code>	(same as input)	round to nearest integer	<code>round(42.4)</code>	42
<code>round(v numeric, s int)</code>	numeric	round to <i>s</i> decimal places	<code>round(42.43822)</code>	42.44
<code>scale(numeric)</code>	integer	scale of the argument (the number of decimal digits in the fractional part)	<code>scale(8.41)</code>	2
<code>sign(dp or numeric)</code>	(same as input)	sign of the argument (-1, 0, +1)	<code>sign(-8.4)</code>	-1
<code>sqrt(dp or numeric)</code>	(same as input)	square root	<code>sqrt(2.0)</code>	1.4142135623731
<code>trunc(dp or numeric)</code>	(same as input)	truncate toward zero	<code>trunc(42.8)</code>	42
<code>trunc(v numeric, s int)</code>	numeric	truncate to <i>s</i> decimal places	<code>trunc(42.43822)</code>	42.43
<code>width_bucket(operand dp, b1 dp, b2 dp, count int)</code>	int	return the bucket number to which <i>operand</i> would be assigned in a histogram having <i>count</i> equal-width buckets spanning the range <i>b1</i> to <i>b2</i> ; returns 0 or <i>count</i> +1 for an input outside the range	<code>width_bucket(5.35, 0.024, 10.06, 5)</code>	3
<code>width_bucket(operand numeric, b1 numeric, b2 numeric, count int)</code>	int	return the bucket number to which <i>operand</i> would be assigned in a histogram having <i>count</i> equal-width buckets spanning the range <i>b1</i> to <i>b2</i> ; returns 0 or <i>count</i> +1 for an input outside the range	<code>width_bucket(5.35, 0.024, 10.06, 5)</code>	3
<code>width_bucket(operand anyelement, thresholds anyarray)</code>	int	return the bucket number to which <i>operand</i> would be assigned given an array listing the lower bounds of the buckets; returns 0 for an in-	<code>width_bucket(now(), array['yesterday', 'today', 'tomorrow']::timestampz[])</code>	2

Function	Return Type	Description	Example	Result
		put less than the first lower bound; the <i>thresholds</i> array <i>must be sorted</i> , smallest first, or unexpected results will be obtained		

Table 9.6 shows functions for generating random numbers.

Table 9.6. Random Functions

Function	Return Type	Description
<code>random()</code>	<code>dp</code>	random value in the range $0.0 \leq x < 1.0$
<code>setseed(dp)</code>	<code>void</code>	set seed for subsequent <code>random()</code> calls (value between -1.0 and 1.0, inclusive)

The `random()` function uses a simple linear congruential algorithm. It is fast but not suitable for cryptographic applications; see the `pgcrypto` module for a more secure alternative. If `setseed()` is called, the results of subsequent `random()` calls in the current session are repeatable by re-issuing `setseed()` with the same argument.

Table 9.7 shows the available trigonometric functions. All these functions take arguments and return values of type `double precision`. Each of the trigonometric functions comes in two variants, one that measures angles in radians and one that measures angles in degrees.

Table 9.7. Trigonometric Functions

Function (radians)	Function (degrees)	Description
<code>acos(x)</code>	<code>acosd(x)</code>	inverse cosine
<code>asin(x)</code>	<code>asind(x)</code>	inverse sine
<code>atan(x)</code>	<code>atand(x)</code>	inverse tangent
<code>atan2(y, x)</code>	<code>atan2d(y, x)</code>	inverse tangent of y/x
<code>cos(x)</code>	<code>cosd(x)</code>	cosine
<code>cot(x)</code>	<code>cotd(x)</code>	cotangent
<code>sin(x)</code>	<code>sind(x)</code>	sine
<code>tan(x)</code>	<code>tand(x)</code>	tangent

Note

Another way to work with angles measured in degrees is to use the unit transformation functions `radians()` and `degrees()` shown earlier. However, using the degree-based trigonometric functions is preferred, as that way avoids round-off error for special cases such as `sind(30)`.

Table 9.8 shows the available hyperbolic functions. All these functions take arguments and return values of type `double precision`.

Table 9.8. Hyperbolic Functions

Function	Description	Example	Result
<code>sinh(x)</code>	hyperbolic sine	<code>sinh(0)</code>	0
<code>cosh(x)</code>	hyperbolic cosine	<code>cosh(0)</code>	1
<code>tanh(x)</code>	hyperbolic tangent	<code>tanh(0)</code>	0
<code>asinh(x)</code>	inverse hyperbolic sine	<code>asinh(0)</code>	0
<code>acosh(x)</code>	inverse hyperbolic cosine	<code>acosh(1)</code>	0
<code>atanh(x)</code>	inverse hyperbolic tangent	<code>atanh(0)</code>	0

9.4. String Functions and Operators

This section describes functions and operators for examining and manipulating string values. Strings in this context include values of the types `character`, `character varying`, and `text`. Unless otherwise noted, all of the functions listed below work on all of these types, but be wary of potential effects of automatic space-padding when using the `character` type. Some functions also exist natively for the bit-string types.

SQL defines some string functions that use key words, rather than commas, to separate arguments. Details are in Table 9.9. PostgreSQL also provides versions of these functions that use the regular function invocation syntax (see Table 9.10).

Note

Before PostgreSQL 8.3, these functions would silently accept values of several non-string data types as well, due to the presence of implicit coercions from those data types to `text`. Those coercions have been removed because they frequently caused surprising behaviors. However, the string concatenation operator (`||`) still accepts non-string input, so long as at least one input is of a string type, as shown in Table 9.9. For other cases, insert an explicit coercion to `text` if you need to duplicate the previous behavior.

Table 9.9. SQL String Functions and Operators

Function	Return Type	Description	Example	Result
<code>string string</code>	<code>text</code>	String concatenation	<code>'Post' 'greSQL'</code>	PostgreSQL
<code>string non-string</code> or <code>non-string string</code>	<code>text</code>	String concatenation with one non-string input	<code>'Value: ' 42</code>	Value: 42
<code>bit_length(string)</code>	<code>int</code>	Number of bits in string	<code>bit_length('jose')</code>	32
<code>char_length(string)</code> or <code>character_length(string)</code>	<code>int</code>	Number of characters in string	<code>char_length('jose')</code>	4
<code>lower(string)</code>	<code>text</code>	Convert string to lower case	<code>lower('TOM')</code>	tom

Function	Return Type	Description	Example	Result
<code>octet_length(<i>string</i>)</code>	int	Number of bytes in string	<code>octet_length('jose')</code>	4
<code>overlay(<i>string</i> placing <i>string</i> from int [for int])</code>	text	Replace substring	<code>overlay('Txxxxas' placing 'hom' from 2 for 4)</code>	Thomas
<code>position(<i>substring</i> in <i>string</i>)</code>	int	Location of specified substring	<code>position('om' in 'Thomas')</code>	3
<code>substring(<i>string</i> [from int] [for int])</code>	text	Extract substring	<code>substring('Thomas' from 2 for 3)</code>	hom
<code>substring(<i>string</i> from <i>pattern</i>)</code>	text	Extract substring matching POSIX regular expression. See Section 9.7 for more information on pattern matching.	<code>substring('Thomas' from '...\$')</code>	mas
<code>substring(<i>string</i> from <i>pattern</i> for <i>escape</i>)</code>	text	Extract substring matching SQL regular expression. See Section 9.7 for more information on pattern matching.	<code>substring('Thomas' from '%#"o_a#"_' for '#')</code>	oma
<code>trim([leading trailing both] [<i>characters</i>] from <i>string</i>)</code>	text	Remove the longest string containing only characters from <i>characters</i> (a space by default) from the start, end, or both ends (both is the default) of <i>string</i>	<code>trim(both 'xyz' from 'yxTomxx')</code>	Tom
<code>trim([leading trailing both] [from] <i>string</i> [, <i>characters</i>])</code>	text	Non-standard syntax for trim()	<code>trim(both from 'yxTomxx', 'xyz')</code>	Tom
<code>upper(<i>string</i>)</code>	text	Convert string to upper case	<code>upper('tom')</code>	TOM

Additional string manipulation functions are available and are listed in Table 9.10. Some of them are used internally to implement the SQL-standard string functions listed in Table 9.9.

Table 9.10. Other String Functions

Function	Return Type	Description	Example	Result
<code>ascii(<i>string</i>)</code>	int	ASCII code of the first character of the argument. For UTF8 returns the Unicode code point of the character. For other multibyte encodings, the argument must be an ASCII character.	<code>ascii('x')</code>	120
<code>btrim(<i>string</i> [, <i>characters</i>])</code>	text	Remove the longest string consisting only of characters in <i>characters</i> (a space by default) from the start and end of <i>string</i>	<code>btrim('xyxtrimxyz', 'xyz')</code>	<code>xyz</code>
<code>chr(<i>int</i>)</code>	text	Character with the given code. For UTF8 the argument is treated as a Unicode code point. For other multibyte encodings the argument must designate an ASCII character. The NULL (0) character is not allowed because text data types cannot store such bytes.	<code>chr(65)</code>	A
<code>concat(<i>str</i> [, <i>str</i> [, ...]])</code>	text	Concatenate the text representations of all the arguments. NULL arguments are ignored.	<code>concat('abcde', 2, NULL, 22)</code>	abcde222
<code>concat_ws(<i>sep</i>, <i>str</i> [, <i>str</i> [, ...]])</code>	text	Concatenate all but the first argument with separators. The first argument is used as the separator string. NULL arguments are ignored.	<code>concat_ws(',', 'abcde', 2, NULL, 22)</code>	abcde,2,22
<code>convert(<i>string</i> [, <i>src_encoding</i>])</code>	bytea	Convert string to <i>dest_encoding</i> . The original encoding is speci-	<code>convert('text_in_utf8', 'latin1')</code>	text_in_utf8 represented in Latin-1 encoding (ISO 8859-1)

Function	Return Type	Description	Example	Result
<code>name, dest_encoding name)</code>		ified by <i>src_encoding</i> . The <i>string</i> must be valid in this encoding. Conversions can be defined by CREATE CONVERSION. Also there are some predefined conversions. See Table 9.11 for available conversions.	'UTF8', 'LATIN1')	
<code>convert_from(string bytea, src_encoding name)</code>	text	Convert string to the database encoding. The original encoding is specified by <i>src_encoding</i> . The <i>string</i> must be valid in this encoding.	<code>convert_from('text_in_utf8', 'UTF8')</code>	text_in_utf8 represented in the current database encoding
<code>convert_to(string text, dest_encoding name)</code>	bytea	Convert string to <i>dest_encoding</i> .	<code>convert_to('some text', 'UTF8')</code>	some text represented in the UTF8 encoding
<code>decode(string text, format text)</code>	bytea	Decode binary data from textual representation in <i>string</i> . Options for <i>format</i> are same as in encode.	<code>decode('MTIzAAE=', 'base64')</code>	\x3132330001
<code>encode(data bytea, format text)</code>	text	Encode binary data into a textual representation. Supported formats are: base64, hex, escape. escape converts zero bytes and high-bit-set bytes to octal sequences (<i>\nnn</i>) and doubles backslashes.	<code>encode('123\000', 'base64')</code>	MTIzAAE=\001',
<code>format(formatstr text [, formatarg "any" [, ...]])</code>	text	Format arguments according to a format string. This function is similar to the C function <code>sprintf</code> . See Section 9.4.1.	<code>format('Hello %s, %1\$s', 'World')</code>	Hello World, World

Function	Return Type	Description	Example	Result
<code>initcap(string)</code>	text	Convert the first letter of each word to upper case and the rest to lower case. Words are sequences of alphanumeric characters separated by non-alphanumeric characters.	<code>initcap('hi THOMAS')</code>	Hi Thomas
<code>left(string, n int)</code>	text	Return first <i>n</i> characters in the string. When <i>n</i> is negative, return all but last $ n $ characters.	<code>left('abcde', 2)</code>	ab
<code>length(string)</code>	int	Number of characters in <i>string</i>	<code>length('jose')</code>	4
<code>length(string, encoding name)</code>	int	Number of characters in <i>string</i> in the given <i>encoding</i> . The <i>string</i> must be valid in this encoding.	<code>length('jose', 'UTF8')</code>	4
<code>lpad(string, length int [, fill text])</code>	text	Fill up the <i>string</i> to length <i>length</i> by prepending the characters <i>fill</i> (a space by default). If the <i>string</i> is already longer than <i>length</i> then it is truncated (on the right).	<code>lpad('hi', 5, 'xy')</code>	xyxhi
<code>ltrim(string, characters text [, characters text])</code>	text	Remove the longest string containing only characters from <i>characters</i> (a space by default) from the start of <i>string</i>	<code>ltrim('zzzytest', 'xyz')</code>	test
<code>md5(string)</code>	text	Calculates the MD5 hash of <i>string</i> , returning the result in hexadecimal	<code>md5('abc')</code>	900150983cd24fb0d6963f7d28e17f72
<code>parse_identifiers(text [, strictmode boolean])</code>	text[]	Split <i>qualified_identifier</i> into an array of identifiers, removing any quoting of individual	<code>parse_identifiers('\"SomeSchema\".someTable')</code>	{SomeSchema, sometable}

Function	Return Type	Description	Example	Result
<pre>FAULT true])</pre>		<p>identifiers. By default, extra characters after the last identifier are considered an error; but if the second parameter is <code>false</code>, then such extra characters are ignored. (This behavior is useful for parsing names for objects like functions.) Note that this function does not truncate over-length identifiers. If you want truncation you can cast the result to <code>name[]</code>.</p>		
<pre>pg_client_encoding()</pre>	name	Current client encoding name	<pre>pg_client_encoding()</pre>	SQL_ASCII
<pre>quote_identifier(string text)</pre>	text	<p>Return the given string suitably quoted to be used as an identifier in an SQL statement <code>string</code>. Quotes are added only if necessary (i.e., if the string contains non-identifier characters or would be case-folded). Embedded quotes are properly doubled. See also Example 42.1.</p>	<pre>quote_identifier('Foo bar')</pre>	"Foo bar"
<pre>quote_literal(string text)</pre>	text	<p>Return the given string suitably quoted to be used as a string literal in an SQL statement <code>string</code>. Embedded single-quotes and backslashes are properly doubled. Note that <code>quote_literal</code> returns null on null input; if the argument might be null, <code>quote_nul-</code></p>	<pre>quote_literal(E'O\'Reilly')</pre>	'O'Reilly'

Function	Return Type	Description	Example	Result
		lable is often more suitable. See also Example 42.1.		
<code>quote_literal(value anyelement)</code>	text	Coerce the given value to text and then quote it as a literal. Embedded single-quotes and backslashes are properly doubled.	<code>quote_literal(42.5)</code>	'42.5'
<code>quote_nullable(string text)</code>	text	Return the given string suitably quoted to be used as a string literal in an SQL statement <i>string</i> ; or, if the argument is null, return NULL. Embedded single-quotes and backslashes are properly doubled. See also Example 42.1.	<code>quote_nullable(NULL)</code>	NULL
<code>quote_nullable(value anyelement)</code>	text	Coerce the given value to text and then quote it as a literal; or, if the argument is null, return NULL. Embedded single-quotes and backslashes are properly doubled.	<code>quote_nullable(42.5)</code>	'42.5'
<code>regex_p_match(string text, pattern text [, flags text])</code>	text[]	Return captured substring(s) resulting from the first match of a POSIX regular expression to the <i>string</i> . See Section 9.7.3 for more information.	<code>regex_p_match('foobarbequebaz', '(bar)(beque)')</code>	{bar,beque}
<code>regex_p_matches(string text, pattern text [, flags text])</code>	setof text[]	Return captured substring(s) resulting from matching a POSIX regular expression to the <i>string</i> . See Section 9.7.3 for more information.	<code>regex_p_matches('foobarbequebaz', 'ba.', 'g')</code>	{bar} {baz} (2 rows)
<code>regexp_replace(string</code>	text	Replace substring(s) matching	<code>regexp_replace('Thomas',</code>	ThM

Function	Return Type	Description	Example	Result
<code>text, pattern</code> <code>text, re-</code> <code>placement</code> <code>text [, flags</code> <code>text])</code>		a POSIX regular expression. See Section 9.7.3 for more information.	<code>'.[mN]a.'</code> , <code>'M')</code>	
<code>regex_s-</code> <code>plit_to_ar-</code> <code>ray(string</code> <code>text, pattern</code> <code>text [, flags</code> <code>text])</code>	<code>text[]</code>	Split <i>string</i> using a POSIX regular expression as the delimiter. See Section 9.7.3 for more information.	<code>regex_s-</code> <code>plit_to_ar-</code> <code>ray('hello</code> <code>world', '\s</code> <code>+')</code>	{hel- lo,world}
<code>regex_s-</code> <code>plit_to_ta-</code> <code>ble(string</code> <code>text, pattern</code> <code>text [, flags</code> <code>text])</code>	<code>setof text</code>	Split <i>string</i> using a POSIX regular expression as the delimiter. See Section 9.7.3 for more information.	<code>regex_s-</code> <code>plit_to_ta-</code> <code>ble('hello</code> <code>world', '\s</code> <code>+')</code>	hello world (2 rows)
<code>re-</code> <code>peat(string</code> <code>text, number</code> <code>int)</code>	<code>text</code>	Repeat <i>string</i> the specified <i>number</i> of times	<code>repeat('Pg',</code> <code>4)</code>	PgPgPgPg
<code>re-</code> <code>place(string</code> <code>text, from</code> <code>text, to</code> <code>text)</code>	<code>text</code>	Replace all occurrences in <i>string</i> of substring <i>from</i> with substring <i>to</i>	<code>re-</code> <code>place('abcde-</code> <code>fabcdef',</code> <code>'cd', 'XX')</code>	abXXefabXXef
<code>reverse(str)</code>	<code>text</code>	Return reversed string.	<code>re-</code> <code>verse('abcde')</code>	edcba
<code>right(str</code> <code>text, n int)</code>	<code>text</code>	Return last <i>n</i> characters in the string. When <i>n</i> is negative, return all but first $ n $ characters.	<code>right('abcde'</code> <code>2)</code>	de
<code>rpad(string</code> <code>text, length</code> <code>int [, fill</code> <code>text])</code>	<code>text</code>	Fill up the <i>string</i> to length <i>length</i> by appending the characters <i>fill</i> (a space by default). If the <i>string</i> is already longer than <i>length</i> then it is truncated.	<code>rpad('hi', 5,</code> <code>'xy')</code>	hixyx
<code>rtrim(string</code> <code>text [, char-</code> <code>acters text])</code>	<code>text</code>	Remove the longest string containing only characters from <i>characters</i> (a space by default) from the end of <i>string</i>	<code>rtrim('testxxx'</code> <code>'xyz')</code>	test
<code>split_part(string</code> <code>text, delim-</code>	<code>text</code>	Split <i>string</i> on <i>delimiter</i> and return the giv-	<code>split_part('abcde-</code> <code>f~@~ghi',</code> <code>'~@~', 2)</code>	def

Function	Return Type	Description	Example	Result
<code>iter text, field int)</code>		en field (counting from one)		
<code>str-pos(string, substring)</code>	int	Location of specified substring (same as <code>position(substring in string)</code> , but note the reversed argument order)	<code>str-pos('high', 'ig')</code>	2
<code>substr(string, from [, count])</code>	text	Extract substring (same as <code>substring(string from from for count)</code>)	<code>substr('alphabet', 3, 2)</code>	ph
<code>starts_with(string, prefix)</code>	bool	Returns true if <code>string</code> starts with <code>prefix</code> .	<code>starts_with('alphabet', 'alph')</code>	t
<code>to_ascii(string text [, encoding text])</code>	text	Convert <code>string</code> to ASCII from another encoding (only supports conversion from LATIN1, LATIN2, LATIN9, and WIN1250 encodings)	<code>to_ascii('Karel')</code>	Karel
<code>to_hex(number int or bigint)</code>	text	Convert <code>number</code> to its equivalent hexadecimal representation	<code>to_hex(2147483647)</code>	7fffffff
<code>translate(string text, from text, to text)</code>	text	Any character in <code>string</code> that matches a character in the <code>from</code> set is replaced by the corresponding character in the <code>to</code> set. If <code>from</code> is longer than <code>to</code> , occurrences of the extra characters in <code>from</code> are removed.	<code>translate('12345', '143', 'ax')</code>	a2x5

The `concat`, `concat_ws` and `format` functions are variadic, so it is possible to pass the values to be concatenated or formatted as an array marked with the `VARIADIC` keyword (see Section 37.5.5). The array's elements are treated as if they were separate ordinary arguments to the function. If the variadic array argument is `NULL`, `concat` and `concat_ws` return `NULL`, but `format` treats a `NULL` as a zero-element array.

See also the aggregate function `string_agg` in Section 9.20.

Table 9.11. Built-in Conversions

Conversion Name ^a	Source Encoding	Destination Encoding
ascii_to_mic	SQL_ASCII	MULE_INTERNAL
ascii_to_utf8	SQL_ASCII	UTF8
big5_to_euc_tw	BIG5	EUC_TW
big5_to_mic	BIG5	MULE_INTERNAL
big5_to_utf8	BIG5	UTF8
euc_cn_to_mic	EUC_CN	MULE_INTERNAL
euc_cn_to_utf8	EUC_CN	UTF8
euc_jp_to_mic	EUC_JP	MULE_INTERNAL
euc_jp_to_sjis	EUC_JP	SJIS
euc_jp_to_utf8	EUC_JP	UTF8
euc_kr_to_mic	EUC_KR	MULE_INTERNAL
euc_kr_to_utf8	EUC_KR	UTF8
euc_tw_to_big5	EUC_TW	BIG5
euc_tw_to_mic	EUC_TW	MULE_INTERNAL
euc_tw_to_utf8	EUC_TW	UTF8
gb18030_to_utf8	GB18030	UTF8
gbk_to_utf8	GBK	UTF8
iso_8859_10_to_utf8	LATIN6	UTF8
iso_8859_13_to_utf8	LATIN7	UTF8
iso_8859_14_to_utf8	LATIN8	UTF8
iso_8859_15_to_utf8	LATIN9	UTF8
iso_8859_16_to_utf8	LATIN10	UTF8
iso_8859_1_to_mic	LATIN1	MULE_INTERNAL
iso_8859_1_to_utf8	LATIN1	UTF8
iso_8859_2_to_mic	LATIN2	MULE_INTERNAL
iso_8859_2_to_utf8	LATIN2	UTF8
iso_8859_2_to_windows_1250	LATIN2	WIN1250
iso_8859_3_to_mic	LATIN3	MULE_INTERNAL
iso_8859_3_to_utf8	LATIN3	UTF8
iso_8859_4_to_mic	LATIN4	MULE_INTERNAL
iso_8859_4_to_utf8	LATIN4	UTF8
iso_8859_5_to_koi8_r	ISO_8859_5	KOI8R
iso_8859_5_to_mic	ISO_8859_5	MULE_INTERNAL
iso_8859_5_to_utf8	ISO_8859_5	UTF8
iso_8859_5_to_windows_1251	ISO_8859_5	WIN1251
iso_8859_5_to_windows_866	ISO_8859_5	WIN866
iso_8859_6_to_utf8	ISO_8859_6	UTF8

Conversion Name ^a	Source Encoding	Destination Encoding
iso_8859_7_to_utf8	ISO_8859_7	UTF8
iso_8859_8_to_utf8	ISO_8859_8	UTF8
iso_8859_9_to_utf8	LATIN5	UTF8
johab_to_utf8	JOHAB	UTF8
koi8_r_to_iso_8859_5	KOI8R	ISO_8859_5
koi8_r_to_mic	KOI8R	MULE_INTERNAL
koi8_r_to_utf8	KOI8R	UTF8
koi8_r_to_windows_1251	KOI8R	WIN1251
koi8_r_to_windows_866	KOI8R	WIN866
koi8_u_to_utf8	KOI8U	UTF8
mic_to_ascii	MULE_INTERNAL	SQL_ASCII
mic_to_big5	MULE_INTERNAL	BIG5
mic_to_euc_cn	MULE_INTERNAL	EUC_CN
mic_to_euc_jp	MULE_INTERNAL	EUC_JP
mic_to_euc_kr	MULE_INTERNAL	EUC_KR
mic_to_euc_tw	MULE_INTERNAL	EUC_TW
mic_to_iso_8859_1	MULE_INTERNAL	LATIN1
mic_to_iso_8859_2	MULE_INTERNAL	LATIN2
mic_to_iso_8859_3	MULE_INTERNAL	LATIN3
mic_to_iso_8859_4	MULE_INTERNAL	LATIN4
mic_to_iso_8859_5	MULE_INTERNAL	ISO_8859_5
mic_to_koi8_r	MULE_INTERNAL	KOI8R
mic_to_sjis	MULE_INTERNAL	SJIS
mic_to_windows_1250	MULE_INTERNAL	WIN1250
mic_to_windows_1251	MULE_INTERNAL	WIN1251
mic_to_windows_866	MULE_INTERNAL	WIN866
sjis_to_euc_jp	SJIS	EUC_JP
sjis_to_mic	SJIS	MULE_INTERNAL
sjis_to_utf8	SJIS	UTF8
windows_1258_to_utf8	WIN1258	UTF8
uhc_to_utf8	UHC	UTF8
utf8_to_ascii	UTF8	SQL_ASCII
utf8_to_big5	UTF8	BIG5
utf8_to_euc_cn	UTF8	EUC_CN
utf8_to_euc_jp	UTF8	EUC_JP
utf8_to_euc_kr	UTF8	EUC_KR
utf8_to_euc_tw	UTF8	EUC_TW
utf8_to_gb18030	UTF8	GB18030
utf8_to_gbk	UTF8	GBK
utf8_to_iso_8859_1	UTF8	LATIN1

Conversion Name ^a	Source Encoding	Destination Encoding
utf8_to_iso_8859_10	UTF8	LATIN6
utf8_to_iso_8859_13	UTF8	LATIN7
utf8_to_iso_8859_14	UTF8	LATIN8
utf8_to_iso_8859_15	UTF8	LATIN9
utf8_to_iso_8859_16	UTF8	LATIN10
utf8_to_iso_8859_2	UTF8	LATIN2
utf8_to_iso_8859_3	UTF8	LATIN3
utf8_to_iso_8859_4	UTF8	LATIN4
utf8_to_iso_8859_5	UTF8	ISO_8859_5
utf8_to_iso_8859_6	UTF8	ISO_8859_6
utf8_to_iso_8859_7	UTF8	ISO_8859_7
utf8_to_iso_8859_8	UTF8	ISO_8859_8
utf8_to_iso_8859_9	UTF8	LATIN5
utf8_to_johab	UTF8	JOHAB
utf8_to_koi8_r	UTF8	KOI8R
utf8_to_koi8_u	UTF8	KOI8U
utf8_to_sjis	UTF8	SJIS
utf8_to_windows_1258	UTF8	WIN1258
utf8_to_uhc	UTF8	UHC
utf8_to_windows_1250	UTF8	WIN1250
utf8_to_windows_1251	UTF8	WIN1251
utf8_to_windows_1252	UTF8	WIN1252
utf8_to_windows_1253	UTF8	WIN1253
utf8_to_windows_1254	UTF8	WIN1254
utf8_to_windows_1255	UTF8	WIN1255
utf8_to_windows_1256	UTF8	WIN1256
utf8_to_windows_1257	UTF8	WIN1257
utf8_to_windows_866	UTF8	WIN866
utf8_to_windows_874	UTF8	WIN874
win-dows_1250_to_iso_8859_2	WIN1250	LATIN2
windows_1250_to_mic	WIN1250	MULE_INTERNAL
windows_1250_to_utf8	WIN1250	UTF8
win-dows_1251_to_iso_8859_5	WIN1251	ISO_8859_5
win-dows_1251_to_koi8_r	WIN1251	KOI8R
windows_1251_to_mic	WIN1251	MULE_INTERNAL
windows_1251_to_utf8	WIN1251	UTF8
windows_1251_to_win-dows_866	WIN1251	WIN866
windows_1252_to_utf8	WIN1252	UTF8

Conversion Name ^a	Source Encoding	Destination Encoding
windows_1256_to_utf8	WIN1256	UTF8
win-dows_866_to_iso_8859_5	WIN866	ISO_8859_5
windows_866_to_koi8_r	WIN866	KOI8R
windows_866_to_mic	WIN866	MULE_INTERNAL
windows_866_to_utf8	WIN866	UTF8
windows_866_to_win-dows_1251	WIN866	WIN
windows_874_to_utf8	WIN874	UTF8
euc_jis_2004_to_utf8	EUC_JIS_2004	UTF8
utf8_to_euc_jis_2004	UTF8	EUC_JIS_2004
shift_jis_2004_to_utf8	SHIFT_JIS_2004	UTF8
ut-f8_to_shift_jis_2004	UTF8	SHIFT_JIS_2004
eu-c_jis_2004_to_shift_jis_2004	EUC_JIS_2004	SHIFT_JIS_2004
shift_jis_2004_to_eu-c_jis_2004	SHIFT_JIS_2004	EUC_JIS_2004

^a The conversion names follow a standard naming scheme: The official name of the source encoding with all non-alphanumeric characters replaced by underscores, followed by `_to_`, followed by the similarly processed destination encoding name. Therefore, the names might deviate from the customary encoding names.

9.4.1. format

The function `format` produces output formatted according to a format string, in a style similar to the C function `sprintf`.

```
format(formatstr text [, formatarg "any" [, ...] ])
```

formatstr is a format string that specifies how the result should be formatted. Text in the format string is copied directly to the result, except where *format specifiers* are used. Format specifiers act as placeholders in the string, defining how subsequent function arguments should be formatted and inserted into the result. Each *formatarg* argument is converted to text according to the usual output rules for its data type, and then formatted and inserted into the result string according to the format specifier(s).

Format specifiers are introduced by a `%` character and have the form

```
%[position][flags][width]type
```

where the component fields are:

position (optional)

A string of the form `n$` where `n` is the index of the argument to print. Index 1 means the first argument after *formatstr*. If the *position* is omitted, the default is to use the next argument in sequence.

flags (optional)

Additional options controlling how the format specifier's output is formatted. Currently the only supported flag is a minus sign (`-`) which will cause the format specifier's output to be left-justified. This has no effect unless the *width* field is also specified.

width (optional)

Specifies the *minimum* number of characters to use to display the format specifier's output. The output is padded on the left or right (depending on the `-` flag) with spaces as needed to fill the width. A too-small width does not cause truncation of the output, but is simply ignored. The width may be specified using any of the following: a positive integer; an asterisk (`*`) to use the next function argument as the width; or a string of the form `*n$` to use the *n*th function argument as the width.

If the width comes from a function argument, that argument is consumed before the argument that is used for the format specifier's value. If the width argument is negative, the result is left aligned (as if the `-` flag had been specified) within a field of length `abs(width)`.

type (required)

The type of format conversion to use to produce the format specifier's output. The following types are supported:

- `s` formats the argument value as a simple string. A null value is treated as an empty string.
- `I` treats the argument value as an SQL identifier, double-quoting it if necessary. It is an error for the value to be null (equivalent to `quote_ident`).
- `L` quotes the argument value as an SQL literal. A null value is displayed as the string `NULL`, without quotes (equivalent to `quote_nullable`).

In addition to the format specifiers described above, the special sequence `%%` may be used to output a literal `%` character.

Here are some examples of the basic format conversions:

```
SELECT format('Hello %s', 'World');
Result: Hello World
```

```
SELECT format('Testing %s, %s, %s, %%', 'one', 'two', 'three');
Result: Testing one, two, three, %
```

```
SELECT format('INSERT INTO %I VALUES(%L)', 'Foo bar', E'O
\'Reilly');
Result: INSERT INTO "Foo bar" VALUES('O\'Reilly')
```

```
SELECT format('INSERT INTO %I VALUES(%L)', 'locations', 'C:\Program
Files');
Result: INSERT INTO locations VALUES('C:\Program Files')
```

Here are examples using *width* fields and the `-` flag:

```
SELECT format('|%10s|', 'foo');
Result: |          foo|
```

```
SELECT format('|%-10s|', 'foo');
Result: |foo          |
```

```
SELECT format('|%*s|', 10, 'foo');
Result: |          foo|
```

```
SELECT format('|%*s|', -10, 'foo');
Result: |foo          |
```

```
SELECT format('|%-*s|', 10, 'foo');
```

```
Result: |foo      |
SELECT format('|%-*s|', -10, 'foo');
Result: |foo      |
```

These examples show use of *position* fields:

```
SELECT format('Testing %3$s, %2$s, %1$s', 'one', 'two', 'three');
Result: Testing three, two, one
```

```
SELECT format('|%*2$s|', 'foo', 10, 'bar');
Result: |          bar|
```

```
SELECT format('|%1$*2$s|', 'foo', 10, 'bar');
Result: |          foo|
```

Unlike the standard C function `sprintf`, PostgreSQL's `format` function allows format specifiers with and without *position* fields to be mixed in the same format string. A format specifier without a *position* field always uses the next argument after the last argument consumed. In addition, the `format` function does not require all function arguments to be used in the format string. For example:

```
SELECT format('Testing %3$s, %2$s, %s', 'one', 'two', 'three');
Result: Testing three, two, three
```

The `%I` and `%L` format specifiers are particularly useful for safely constructing dynamic SQL statements. See Example 42.1.

9.5. Binary String Functions and Operators

This section describes functions and operators for examining and manipulating values of type `bytea`.

SQL defines some string functions that use key words, rather than commas, to separate arguments. Details are in Table 9.12. PostgreSQL also provides versions of these functions that use the regular function invocation syntax (see Table 9.13).

Note

The sample results shown on this page assume that the server parameter `bytea_output` is set to `escape` (the traditional PostgreSQL format).

Table 9.12. SQL Binary String Functions and Operators

Function	Return Type	Description	Example	Result
<code>string string</code>	<code>bytea</code>	String concatenation	<code>'\Post'::bytea '\047gres\000'::bytea</code>	<code>\\Post'gres\000</code>
<code>octet_length(string)</code>	<code>int</code>	Number of bytes in binary string	<code>octet_length('5jo\000se'::bytea)</code>	5
<code>overlay(string placing string from int [for int])</code>	<code>bytea</code>	Replace substring	<code>overlay('Th\000omas'::bytea placing '\002\003'::bytea from 2 for 3)</code>	<code>T\002\003mas\000</code>

Function	Return Type	Description	Example	Result
<code>position(substring in string)</code>	int	Location of specified substring	<code>position('\000om'::bytea in 'Th\000omas'::bytea)</code>	3
<code>substring(string [from int] [for int])</code>	bytea	Extract substring	<code>substring('Th\000omas'::bytea from 2 for 3)</code>	h\000o
<code>trim([both] bytes from string)</code>	bytea	Remove the longest string containing only bytes appearing in <i>bytes</i> from the start and end of <i>string</i>	<code>trim('\000\000Tom\001'::bytea)</code>	Tom bytea

Additional binary string manipulation functions are available and are listed in Table 9.13. Some of them are used internally to implement the SQL-standard string functions listed in Table 9.12.

Table 9.13. Other Binary String Functions

Function	Return Type	Description	Example	Result
<code>btrim(string bytea, bytes bytea)</code>	bytea	Remove the longest string containing only bytes appearing in <i>bytes</i> from the start and end of <i>string</i>	<code>btrim('\000trim\001'::bytea, '\000\001'::bytea)</code>	trim
<code>decode(string text, format text)</code>	bytea	Decode binary data from textual representation in <i>string</i> . Options for <i>format</i> are same as in encode.	<code>decode('123\000456', 'escape')</code>	123\000456
<code>encode(data bytea, format text)</code>	text	Encode binary data into a textual representation. Supported formats are: base64, hex, escape. escape converts zero bytes and high-bit-set bytes to octal sequences (<code>\nnn</code>) and doubles backslashes.	<code>encode('123\000456', 'escape')</code>	123\000456
<code>get_bit(string, offset)</code>	int	Extract bit from string	<code>get_bit('Th\000omas'::bytea, 45)</code>	1
<code>get_byte(string, offset)</code>	int	Extract byte from string	<code>get_byte('Th\000omas'::bytea, 4)</code>	109

Function	Return Type	Description	Example	Result
<code>length(string)</code>	int	Length of binary string	<code>length('jose')</code>	5
<code>md5(string)</code>	text	Calculates the MD5 hash of <i>string</i> , returning the result in hexadecimal	<code>md5('Thomas')</code>	8ab2d3c9689aaf184958c334c82d8b1
<code>set_bit(string, offset, new-value)</code>	bytea	Set bit in string	<code>set_bit('Thomas', 45, 0)</code>	Th\000omAs
<code>set_byte(string, offset, new-value)</code>	bytea	Set byte in string	<code>set_byte('Thomas', 4, 64)</code>	Th\000o@as
<code>sha224(bytea)</code>	bytea	SHA-224 hash	<code>sha224('abc')</code>	\x23097d223405d8228642a7da255b32aad-bce4b-da0b3f7e36c9da7
<code>sha256(bytea)</code>	bytea	SHA-256 hash	<code>sha256('abc')</code>	\xba7816bf8f01cfea414140db00361a396177a9cb410ff61f20015ad
<code>sha384(bytea)</code>	bytea	SHA-384 hash	<code>sha384('abc')</code>	\xcb00753f45a35e8b-b5a03d699ac65007272c32ab0ed-ed1631a8b605a43ff5bed8086072ba1e7cc2358bae-ca134c825a7
<code>sha512(bytea)</code>	bytea	SHA-512 hash	<code>sha512('abc')</code>	\xddaf35a193617abacc417349ae20413112e6fa4e89a97ea20a9eeee642192992a274fc1a836ba3c23a454d4423643ce80e2a9ac94fa

`get_byte` and `set_byte` number the first byte of a binary string as byte 0. `get_bit` and `set_bit` number bits from the right within each byte; for example bit 0 is the least significant bit of the first byte, and bit 15 is the most significant bit of the second byte.

Note that for historic reasons, the function `md5` returns a hex-encoded value of type `text` whereas the SHA-2 functions return type `bytea`. Use the functions `encode` and `decode` to convert between the two, for example `encode(sha256('abc'), 'hex')` to get a hex-encoded text representation.

See also the aggregate function `string_agg` in Section 9.20 and the large object functions in Section 34.4.

9.6. Bit String Functions and Operators

This section describes functions and operators for examining and manipulating bit strings, that is values of the types `bit` and `bit varying`. Aside from the usual comparison operators, the operators shown in Table 9.14 can be used. Bit string operands of `&`, `|`, and `#` must be of equal length. When bit shifting, the original length of the string is preserved, as shown in the examples.

Table 9.14. Bit String Operators

Operator	Description	Example	Result
	concatenation	B'10001' B'011'	10001011
&	bitwise AND	B'10001' & B'01101'	00001
	bitwise OR	B'10001' B'01101'	11101
#	bitwise XOR	B'10001' # B'01101'	11100
~	bitwise NOT	~ B'10001'	01110
<<	bitwise shift left	B'10001' << 3	01000
>>	bitwise shift right	B'10001' >> 2	00100

The following SQL-standard functions work on bit strings as well as character strings: `length`, `bit_length`, `octet_length`, `position`, `substring`, `overlay`.

The following functions work on bit strings as well as binary strings: `get_bit`, `set_bit`. When working with a bit string, these functions number the first (leftmost) bit of the string as bit 0.

In addition, it is possible to cast integral values to and from type `bit`. Some examples:

```
44::bit(10)           0000101100
44::bit(3)           100
cast(-44 as bit(12)) 111111010100
'1110'::bit(4)::integer 14
```

Note that casting to just “bit” means casting to `bit(1)`, and so will deliver only the least significant bit of the integer.

Note

Casting an integer to `bit(n)` copies the rightmost *n* bits. Casting an integer to a bit string width wider than the integer itself will sign-extend on the left.

9.7. Pattern Matching

There are three separate approaches to pattern matching provided by PostgreSQL: the traditional SQL `LIKE` operator, the more recent `SIMILAR TO` operator (added in SQL:1999), and POSIX-style regular expressions. Aside from the basic “does this string match this pattern?” operators, functions are available to extract or replace matching substrings and to split a string at matching locations.

Tip

If you have pattern matching needs that go beyond this, consider writing a user-defined function in Perl or Tcl.

Caution

While most regular-expression searches can be executed very quickly, regular expressions can be contrived that take arbitrary amounts of time and memory to process. Be

wary of accepting regular-expression search patterns from hostile sources. If you must do so, it is advisable to impose a statement timeout.

Searches using `SIMILAR TO` patterns have the same security hazards, since `SIMILAR TO` provides many of the same capabilities as POSIX-style regular expressions.

`LIKE` searches, being much simpler than the other two options, are safer to use with possibly-hostile pattern sources.

The pattern matching operators of all three kinds do not support nondeterministic collations. If required, apply a different collation to the expression to work around this limitation.

9.7.1. LIKE

```
string LIKE pattern [ESCAPE escape-character]
string NOT LIKE pattern [ESCAPE escape-character]
```

The `LIKE` expression returns true if the *string* matches the supplied *pattern*. (As expected, the `NOT LIKE` expression returns false if `LIKE` returns true, and vice versa. An equivalent expression is `NOT (string LIKE pattern)`.)

If *pattern* does not contain percent signs or underscores, then the pattern only represents the string itself; in that case `LIKE` acts like the equals operator. An underscore (`_`) in *pattern* stands for (matches) any single character; a percent sign (`%`) matches any sequence of zero or more characters.

Some examples:

```
'abc' LIKE 'abc'      true
'abc' LIKE 'a%'      true
'abc' LIKE '_b_'     true
'abc' LIKE 'c'       false
```

`LIKE` pattern matching always covers the entire string. Therefore, if it's desired to match a sequence anywhere within a string, the pattern must start and end with a percent sign.

To match a literal underscore or percent sign without matching other characters, the respective character in *pattern* must be preceded by the escape character. The default escape character is the backslash but a different one can be selected by using the `ESCAPE` clause. To match the escape character itself, write two escape characters.

Note

If you have `standard_conforming_strings` turned off, any backslashes you write in literal string constants will need to be doubled. See Section 4.1.2.1 for more information.

It's also possible to select no escape character by writing `ESCAPE ''`. This effectively disables the escape mechanism, which makes it impossible to turn off the special meaning of underscore and percent signs in the pattern.

The key word `ILIKE` can be used instead of `LIKE` to make the match case-insensitive according to the active locale. This is not in the SQL standard but is a PostgreSQL extension.

The operator `~~` is equivalent to `LIKE`, and `~~*` corresponds to `ILIKE`. There are also `!~~` and `!~~*` operators that represent `NOT LIKE` and `NOT ILIKE`, respectively. All of these operators are PostgreSQL-specific.

There is also the prefix operator `^@` and corresponding `starts_with` function which covers cases when only searching by beginning of the string is needed.

9.7.2. SIMILAR TO Regular Expressions

```
string SIMILAR TO pattern [ESCAPE escape-character]
string NOT SIMILAR TO pattern [ESCAPE escape-character]
```

The `SIMILAR TO` operator returns true or false depending on whether its pattern matches the given string. It is similar to `LIKE`, except that it interprets the pattern using the SQL standard's definition of a regular expression. SQL regular expressions are a curious cross between `LIKE` notation and common regular expression notation.

Like `LIKE`, the `SIMILAR TO` operator succeeds only if its pattern matches the entire string; this is unlike common regular expression behavior where the pattern can match any part of the string. Also like `LIKE`, `SIMILAR TO` uses `_` and `%` as wildcard characters denoting any single character and any string, respectively (these are comparable to `.` and `.*` in POSIX regular expressions).

In addition to these facilities borrowed from `LIKE`, `SIMILAR TO` supports these pattern-matching metacharacters borrowed from POSIX regular expressions:

- `|` denotes alternation (either of two alternatives).
- `*` denotes repetition of the previous item zero or more times.
- `+` denotes repetition of the previous item one or more times.
- `?` denotes repetition of the previous item zero or one time.
- `{m}` denotes repetition of the previous item exactly *m* times.
- `{m, }` denotes repetition of the previous item *m* or more times.
- `{m, n}` denotes repetition of the previous item at least *m* and not more than *n* times.
- Parentheses `()` can be used to group items into a single logical item.
- A bracket expression `[. . .]` specifies a character class, just as in POSIX regular expressions.

Notice that the period `(.)` is not a metacharacter for `SIMILAR TO`.

As with `LIKE`, a backslash disables the special meaning of any of these metacharacters; or a different escape character can be specified with `ESCAPE`.

Some examples:

```
'abc' SIMILAR TO 'abc'      true
'abc' SIMILAR TO 'a'        false
'abc' SIMILAR TO '%(b|d)%' true
'abc' SIMILAR TO '(b|c)%'  false
```

The `substring` function with three parameters provides extraction of a substring that matches an SQL regular expression pattern. The function can be written according to SQL99 syntax:

```
substring(string from pattern for escape-character)
```

or as a plain three-argument function:

`substring(string, pattern, escape-character)`

As with `SIMILAR TO`, the specified pattern must match the entire data string, or else the function fails and returns null. To indicate the part of the pattern for which the matching data sub-string is of interest, the pattern should contain two occurrences of the escape character followed by a double quote ("). The text matching the portion of the pattern between these separators is returned when the match is successful.

The escape-double-quote separators actually divide `substring`'s pattern into three independent regular expressions; for example, a vertical bar (|) in any of the three sections affects only that section. Also, the first and third of these regular expressions are defined to match the smallest possible amount of text, not the largest, when there is any ambiguity about how much of the data string matches which pattern. (In POSIX parlance, the first and third regular expressions are forced to be non-greedy.)

As an extension to the SQL standard, PostgreSQL allows there to be just one escape-double-quote separator, in which case the third regular expression is taken as empty; or no separators, in which case the first and third regular expressions are taken as empty.

Some examples, with `#` delimiting the return string:

```
substring('foobar' from '%#"o_b#"%' for '#')    oob
substring('foobar' from '#"o_b#"%' for '#')    NULL
```

9.7.3. POSIX Regular Expressions

Table 9.15 lists the available operators for pattern matching using POSIX regular expressions.

Table 9.15. Regular Expression Match Operators

Operator	Description	Example
<code>~</code>	Matches regular expression, case sensitive	'thomas' ~ '.*thomas.*'
<code>~*</code>	Matches regular expression, case insensitive	'thomas' ~* '.*Thomas.*'
<code>!~</code>	Does not match regular expression, case sensitive	'thomas' !~ '.*Thomas.*'
<code>!~*</code>	Does not match regular expression, case insensitive	'thomas' !~* '.*vadim.*'

POSIX regular expressions provide a more powerful means for pattern matching than the `LIKE` and `SIMILAR TO` operators. Many Unix tools such as `egrep`, `sed`, or `awk` use a pattern matching language that is similar to the one described here.

A regular expression is a character sequence that is an abbreviated definition of a set of strings (a *regular set*). A string is said to match a regular expression if it is a member of the regular set described by the regular expression. As with `LIKE`, pattern characters match string characters exactly unless they are special characters in the regular expression language — but regular expressions use different special characters than `LIKE` does. Unlike `LIKE` patterns, a regular expression is allowed to match anywhere within a string, unless the regular expression is explicitly anchored to the beginning or end of the string.

Some examples:

```
'abc' ~ 'abc'      true
'abc' ~ '^a'       true
'abc' ~ '(b|d)'    true
```

```
'abc' ~ '^(b|c)' false
```

The POSIX pattern language is described in much greater detail below.

The `substring` function with two parameters, `substring(string from pattern)`, provides extraction of a substring that matches a POSIX regular expression pattern. It returns null if there is no match, otherwise the portion of the text that matched the pattern. But if the pattern contains any parentheses, the portion of the text that matched the first parenthesized subexpression (the one whose left parenthesis comes first) is returned. You can put parentheses around the whole expression if you want to use parentheses within it without triggering this exception. If you need parentheses in the pattern before the subexpression you want to extract, see the non-capturing parentheses described below.

Some examples:

```
substring('foobar' from 'o.b')      oob
substring('foobar' from 'o(.)b')    o
```

The `regexp_replace` function provides substitution of new text for substrings that match POSIX regular expression patterns. It has the syntax `regexp_replace(source, pattern, replacement [, flags])`. The `source` string is returned unchanged if there is no match to the `pattern`. If there is a match, the `source` string is returned with the `replacement` string substituted for the matching substring. The `replacement` string can contain `\n`, where `n` is 1 through 9, to indicate that the source substring matching the `n`'th parenthesized subexpression of the pattern should be inserted, and it can contain `&` to indicate that the substring matching the entire pattern should be inserted. Write `\\` if you need to put a literal backslash in the replacement text. The `flags` parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. Flag `i` specifies case-insensitive matching, while flag `g` specifies replacement of each matching substring rather than only the first one. Supported flags (though not `g`) are described in Table 9.23.

Some examples:

```
regexp_replace('foobarbaz', 'b..', 'X')
                                fooXbaz
regexp_replace('foobarbaz', 'b..', 'X', 'g')
                                fooXX
regexp_replace('foobarbaz', 'b(..)', 'X\1Y', 'g')
                                fooXarYXazY
```

The `regexp_match` function returns a text array of captured substring(s) resulting from the first match of a POSIX regular expression pattern to a string. It has the syntax `regexp_match(string, pattern [, flags])`. If there is no match, the result is NULL. If a match is found, and the `pattern` contains no parenthesized subexpressions, then the result is a single-element text array containing the substring matching the whole pattern. If a match is found, and the `pattern` contains parenthesized subexpressions, then the result is a text array whose `n`'th element is the substring matching the `n`'th parenthesized subexpression of the `pattern` (not counting “non-capturing” parentheses; see below for details). The `flags` parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. Supported flags are described in Table 9.23.

Some examples:

```
SELECT regexp_match('foobarbequebaz', 'bar.*que');
       regexp_match
-----
 {barbeque}
(1 row)

SELECT regexp_match('foobarbequebaz', '(bar)(beque)');
```

```

regexp_match
-----
{bar,beque}
(1 row)

```

In the common case where you just want the whole matching substring or NULL for no match, write something like

```

SELECT (regexp_match('foobarbequebaz', 'bar.*que'))[1];
 regexp_match
-----
barbeque
(1 row)

```

The `regexp_matches` function returns a set of text arrays of captured substring(s) resulting from matching a POSIX regular expression pattern to a string. It has the same syntax as `regexp_match`. This function returns no rows if there is no match, one row if there is a match and the `g` flag is not given, or *N* rows if there are *N* matches and the `g` flag is given. Each returned row is a text array containing the whole matched substring or the substrings matching parenthesized subexpressions of the *pattern*, just as described above for `regexp_match`. `regexp_matches` accepts all the flags shown in Table 9.23, plus the `g` flag which commands it to return all matches, not just the first one.

Some examples:

```

SELECT regexp_matches('foo', 'not there');
 regexp_matches
-----
(0 rows)

```

```

SELECT regexp_matches('foobarbequebazilbarfbonk', '(b[^b]+)
(b[^b]+)', 'g');
 regexp_matches
-----
{bar,beque}
{bazil,barf}
(2 rows)

```

Tip

In most cases `regexp_matches()` should be used with the `g` flag, since if you only want the first match, it's easier and more efficient to use `regexp_match()`. However, `regexp_match()` only exists in PostgreSQL version 10 and up. When working in older versions, a common trick is to place a `regexp_matches()` call in a sub-select, for example:

```

SELECT col1, (SELECT regexp_matches(col2, '(bar)
(beque)')) FROM tab;

```

This produces a text array if there's a match, or NULL if not, the same as `regexp_match()` would do. Without the sub-select, this query would produce no output at all for table rows without a match, which is typically not the desired behavior.

The `regexp_split_to_table` function splits a string using a POSIX regular expression pattern as a delimiter. It has the syntax `regexp_split_to_table(string, pattern [, flags])`. If

there is no match to the *pattern*, the function returns the *string*. If there is at least one match, for each match it returns the text from the end of the last match (or the beginning of the string) to the beginning of the match. When there are no more matches, it returns the text from the end of the last match to the end of the string. The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. `regexp_split_to_table` supports the flags described in Table 9.23.

The `regexp_split_to_array` function behaves the same as `regexp_split_to_table`, except that `regexp_split_to_array` returns its result as an array of text. It has the syntax `regexp_split_to_array(string, pattern [, flags])`. The parameters are the same as for `regexp_split_to_table`.

Some examples:

```
SELECT foo FROM regexp_split_to_table('the quick brown fox jumps
over the lazy dog', '\s+') AS foo;
foo
```

```
the
quick
brown
fox
jumps
over
the
lazy
dog
```

(9 rows)

```
SELECT regexp_split_to_array('the quick brown fox jumps over the
lazy dog', '\s+');
          regexp_split_to_array
```

```
{the,quick,brown,fox,jumps,over,the,lazy,dog}
```

(1 row)

```
SELECT foo FROM regexp_split_to_table('the quick brown fox', '\s*')
AS foo;
foo
```

```
t
h
e
q
u
i
c
k
b
r
o
w
n
f
o
x
```

(16 rows)

As the last example demonstrates, the `regexp` split functions ignore zero-length matches that occur at the start or end of the string or immediately after a previous match. This is contrary to the strict definition of `regexp` matching that is implemented by `regexp_match` and `regexp_matches`, but is usually the most convenient behavior in practice. Other software systems such as Perl use similar definitions.

9.7.3.1. Regular Expression Details

PostgreSQL's regular expressions are implemented using a software package written by Henry Spencer. Much of the description of regular expressions below is copied verbatim from his manual.

Regular expressions (REs), as defined in POSIX 1003.2, come in two forms: *extended* REs or EREs (roughly those of `egrep`), and *basic* REs or BREs (roughly those of `ed`). PostgreSQL supports both forms, and also implements some extensions that are not in the POSIX standard, but have become widely used due to their availability in programming languages such as Perl and Tcl. REs using these non-POSIX extensions are called *advanced* REs or AREs in this documentation. AREs are almost an exact superset of EREs, but BREs have several notational incompatibilities (as well as being much more limited). We first describe the ARE and ERE forms, noting features that apply only to AREs, and then describe how BREs differ.

Note

PostgreSQL always initially presumes that a regular expression follows the ARE rules. However, the more limited ERE or BRE rules can be chosen by prepending an *embedded option* to the RE pattern, as described in Section 9.7.3.4. This can be useful for compatibility with applications that expect exactly the POSIX 1003.2 rules.

A regular expression is defined as one or more *branches*, separated by `|`. It matches anything that matches one of the branches.

A branch is zero or more *quantified atoms* or *constraints*, concatenated. It matches a match for the first, followed by a match for the second, etc; an empty branch matches the empty string.

A quantified atom is an *atom* possibly followed by a single *quantifier*. Without a quantifier, it matches a match for the atom. With a quantifier, it can match some number of matches of the atom. An *atom* can be any of the possibilities shown in Table 9.16. The possible quantifiers and their meanings are shown in Table 9.17.

A *constraint* matches an empty string, but matches only when specific conditions are met. A constraint can be used where an atom could be used, except it cannot be followed by a quantifier. The simple constraints are shown in Table 9.18; some more constraints are described later.

Table 9.16. Regular Expression Atoms

Atom	Description
<code>(re)</code>	(where <i>re</i> is any regular expression) matches a match for <i>re</i> , with the match noted for possible reporting
<code>(? : re)</code>	as above, but the match is not noted for reporting (a “non-capturing” set of parentheses) (AREs only)
<code>.</code>	matches any single character
<code>[chars]</code>	a <i>bracket expression</i> , matching any one of the <i>chars</i> (see Section 9.7.3.2 for more detail)

Atom	Description
<code>\k</code>	(where <i>k</i> is a non-alphanumeric character) matches that character taken as an ordinary character, e.g., <code>\\</code> matches a backslash character
<code>\c</code>	where <i>c</i> is alphanumeric (possibly followed by other characters) is an <i>escape</i> , see Section 9.7.3.3 (AREs only; in EREs and BREs, this matches <i>c</i>)
<code>{</code>	when followed by a character other than a digit, matches the left-brace character <code>{</code> ; when followed by a digit, it is the beginning of a <i>bound</i> (see below)
<code>x</code>	where <i>x</i> is a single character with no other significance, matches that character

An RE cannot end with a backslash (`\`).

Note

If you have `standard_conforming_strings` turned off, any backslashes you write in literal string constants will need to be doubled. See Section 4.1.2.1 for more information.

Table 9.17. Regular Expression Quantifiers

Quantifier	Matches
<code>*</code>	a sequence of 0 or more matches of the atom
<code>+</code>	a sequence of 1 or more matches of the atom
<code>?</code>	a sequence of 0 or 1 matches of the atom
<code>{m}</code>	a sequence of exactly <i>m</i> matches of the atom
<code>{m, }</code>	a sequence of <i>m</i> or more matches of the atom
<code>{m, n}</code>	a sequence of <i>m</i> through <i>n</i> (inclusive) matches of the atom; <i>m</i> cannot exceed <i>n</i>
<code>*?</code>	non-greedy version of <code>*</code>
<code>+?</code>	non-greedy version of <code>+</code>
<code>??</code>	non-greedy version of <code>?</code>
<code>{m}?</code>	non-greedy version of <code>{m}</code>
<code>{m, }?</code>	non-greedy version of <code>{m, }</code>
<code>{m, n}?</code>	non-greedy version of <code>{m, n}</code>

The forms using `{ . . . }` are known as *bounds*. The numbers *m* and *n* within a bound are unsigned decimal integers with permissible values from 0 to 255 inclusive.

Non-greedy quantifiers (available in AREs only) match the same possibilities as their corresponding normal (*greedy*) counterparts, but prefer the smallest number rather than the largest number of matches. See Section 9.7.3.5 for more detail.

Note

A quantifier cannot immediately follow another quantifier, e.g., `**` is invalid. A quantifier cannot begin an expression or subexpression or follow `^` or `|`.

Table 9.18. Regular Expression Constraints

Constraint	Description
<code>^</code>	matches at the beginning of the string
<code>\$</code>	matches at the end of the string
<code>(?=re)</code>	<i>positive lookahead</i> matches at any point where a substring matching <i>re</i> begins (AREs only)
<code>(?!re)</code>	<i>negative lookahead</i> matches at any point where no substring matching <i>re</i> begins (AREs only)
<code>(?<=re)</code>	<i>positive lookbehind</i> matches at any point where a substring matching <i>re</i> ends (AREs only)
<code>(?<!re)</code>	<i>negative lookbehind</i> matches at any point where no substring matching <i>re</i> ends (AREs only)

Lookahead and lookbehind constraints cannot contain *back references* (see Section 9.7.3.3), and all parentheses within them are considered non-capturing.

9.7.3.2. Bracket Expressions

A *bracket expression* is a list of characters enclosed in `[]`. It normally matches any single character from the list (but see below). If the list begins with `^`, it matches any single character *not* from the rest of the list. If two characters in the list are separated by `-`, this is shorthand for the full range of characters between those two (inclusive) in the collating sequence, e.g., `[0-9]` in ASCII matches any decimal digit. It is illegal for two ranges to share an endpoint, e.g., `a-c-e`. Ranges are very collating-sequence-dependent, so portable programs should avoid relying on them.

To include a literal `]` in the list, make it the first character (after `^`, if that is used). To include a literal `-`, make it the first or last character, or the second endpoint of a range. To use a literal `-` as the first endpoint of a range, enclose it in `[. and .]` to make it a collating element (see below). With the exception of these characters, some combinations using `[` (see next paragraphs), and escapes (AREs only), all other special characters lose their special significance within a bracket expression. In particular, `\` is not special when following ERE or BRE rules, though it is special (as introducing an escape) in AREs.

Within a bracket expression, a collating element (a character, a multiple-character sequence that collates as if it were a single character, or a collating-sequence name for either) enclosed in `[. and .]` stands for the sequence of characters of that collating element. The sequence is treated as a single element of the bracket expression's list. This allows a bracket expression containing a multiple-character collating element to match more than one character, e.g., if the collating sequence includes a `ch` collating element, then the RE `[[. ch .]] *c` matches the first five characters of `chchcc`.

Note

PostgreSQL currently does not support multi-character collating elements. This information describes possible future behavior.

Within a bracket expression, a collating element enclosed in `[= and =]` is an *equivalence class*, standing for the sequences of characters of all collating elements equivalent to that one, including itself. (If there are no other equivalent collating elements, the treatment is as if the enclosing delimiters were `[. and .]`.) For example, if `o` and `^` are the members of an equivalence class, then `[[=o=]`, `[[=^=]`, and `[o^]` are all synonymous. An equivalence class cannot be an endpoint of a range.

Within a bracket expression, the name of a character class enclosed in `[: and :]` stands for the list of all characters belonging to that class. A character class cannot be used as an endpoint of a range. The POSIX standard defines these character class names: `a1num` (letters and numeric digits), `a1pha` (let-

ters), `blank` (space and tab), `cntrl` (control characters), `digit` (numeric digits), `graph` (printable characters except space), `lower` (lower-case letters), `print` (printable characters including space), `punct` (punctuation), `space` (any white space), `upper` (upper-case letters), and `xdigit` (hexadecimal digits). The behavior of these standard character classes is generally consistent across platforms for characters in the 7-bit ASCII set. Whether a given non-ASCII character is considered to belong to one of these classes depends on the *collation* that is used for the regular-expression function or operator (see Section 23.2), or by default on the database's `LC_CTYPE` locale setting (see Section 23.1). The classification of non-ASCII characters can vary across platforms even in similarly-named locales. (But the `C` locale never considers any non-ASCII characters to belong to any of these classes.) In addition to these standard character classes, PostgreSQL defines the `ascii` character class, which contains exactly the 7-bit ASCII set.

There are two special cases of bracket expressions: the bracket expressions `[[:<:]]` and `[[:>:]]` are constraints, matching empty strings at the beginning and end of a word respectively. A word is defined as a sequence of word characters that is neither preceded nor followed by word characters. A word character is an `alnum` character (as defined by the POSIX character class described above) or an underscore. This is an extension, compatible with but not specified by POSIX 1003.2, and should be used with caution in software intended to be portable to other systems. The constraint escapes described below are usually preferable; they are no more standard, but are easier to type.

9.7.3.3. Regular Expression Escapes

Escapes are special sequences beginning with `\` followed by an alphanumeric character. Escapes come in several varieties: character entry, class shorthands, constraint escapes, and back references. A `\` followed by an alphanumeric character but not constituting a valid escape is illegal in AREs. In EREs, there are no escapes: outside a bracket expression, a `\` followed by an alphanumeric character merely stands for that character as an ordinary character, and inside a bracket expression, `\` is an ordinary character. (The latter is the one actual incompatibility between EREs and AREs.)

Character-entry escapes exist to make it easier to specify non-printing and other inconvenient characters in REs. They are shown in Table 9.19.

Class-shorthand escapes provide shorthands for certain commonly-used character classes. They are shown in Table 9.20.

A *constraint escape* is a constraint, matching the empty string if specific conditions are met, written as an escape. They are shown in Table 9.21.

A *back reference* (`\n`) matches the same string matched by the previous parenthesized subexpression specified by the number *n* (see Table 9.22). For example, `([bc])\1` matches `bb` or `cc` but not `bc` or `cb`. The subexpression must entirely precede the back reference in the RE. Subexpressions are numbered in the order of their leading parentheses. Non-capturing parentheses do not define subexpressions.

Table 9.19. Regular Expression Character-Entry Escapes

Escape	Description
<code>\a</code>	alert (bell) character, as in C
<code>\b</code>	backspace, as in C
<code>\B</code>	synonym for backslash (<code>\</code>) to help reduce the need for backslash doubling
<code>\cX</code>	(where <i>X</i> is any character) the character whose low-order 5 bits are the same as those of <i>X</i> , and whose other bits are all zero
<code>\e</code>	the character whose collating-sequence name is <code>ESC</code> , or failing that, the character with octal value <code>033</code>

Escape	Description
<code>\f</code>	form feed, as in C
<code>\n</code>	newline, as in C
<code>\r</code>	carriage return, as in C
<code>\t</code>	horizontal tab, as in C
<code>\uvwxyz</code>	(where <i>wxyz</i> is exactly four hexadecimal digits) the character whose hexadecimal value is <code>0xwxyz</code>
<code>\Ustuvwxyz</code>	(where <i>stuvwxyz</i> is exactly eight hexadecimal digits) the character whose hexadecimal value is <code>0x.stuvwxyz</code>
<code>\v</code>	vertical tab, as in C
<code>\xhhh</code>	(where <i>hhh</i> is any sequence of hexadecimal digits) the character whose hexadecimal value is <code>0xhhh</code> (a single character no matter how many hexadecimal digits are used)
<code>\0</code>	the character whose value is 0 (the null byte)
<code>\xy</code>	(where <i>xy</i> is exactly two octal digits, and is not a <i>back reference</i>) the character whose octal value is <code>0xy</code>
<code>\xyz</code>	(where <i>xyz</i> is exactly three octal digits, and is not a <i>back reference</i>) the character whose octal value is <code>0xyz</code>

Hexadecimal digits are 0-9, a-f, and A-F. Octal digits are 0-7.

Numeric character-entry escapes specifying values outside the ASCII range (0-127) have meanings dependent on the database encoding. When the encoding is UTF-8, escape values are equivalent to Unicode code points, for example `\u1234` means the character U+1234. For other multibyte encodings, character-entry escapes usually just specify the concatenation of the byte values for the character. If the escape value does not correspond to any legal character in the database encoding, no error will be raised, but it will never match any data.

The character-entry escapes are always taken as ordinary characters. For example, `\135` is `]` in ASCII, but `\135` does not terminate a bracket expression.

Table 9.20. Regular Expression Class-Shorthand Escapes

Escape	Description
<code>\d</code>	<code>[[:digit:]]</code>
<code>\s</code>	<code>[[:space:]]</code>
<code>\w</code>	<code>[[:alnum:]_]</code> (note underscore is included)
<code>\D</code>	<code>[^[:digit:]]</code>
<code>\S</code>	<code>[^[:space:]]</code>
<code>\W</code>	<code>[^[:alnum:]_]</code> (note underscore is included)

Within bracket expressions, `\d`, `\s`, and `\w` lose their outer brackets, and `\D`, `\S`, and `\W` are illegal. (So, for example, `[a-c\d]` is equivalent to `[a-c[:digit:]]`. Also, `[a-c\D]`, which is equivalent to `[a-c^[[:digit:]]]`, is illegal.)

Table 9.21. Regular Expression Constraint Escapes

Escape	Description
\A	matches only at the beginning of the string (see Section 9.7.3.5 for how this differs from ^)
\m	matches only at the beginning of a word
\M	matches only at the end of a word
\y	matches only at the beginning or end of a word
\Y	matches only at a point that is not the beginning or end of a word
\Z	matches only at the end of the string (see Section 9.7.3.5 for how this differs from \$)

A word is defined as in the specification of [[:<:]] and [[:>:]] above. Constraint escapes are illegal within bracket expressions.

Table 9.22. Regular Expression Back References

Escape	Description
\m	(where <i>m</i> is a nonzero digit) a back reference to the <i>m</i> 'th subexpression
\mnn	(where <i>m</i> is a nonzero digit, and <i>nn</i> is some more digits, and the decimal value <i>mnn</i> is not greater than the number of closing capturing parentheses seen so far) a back reference to the <i>mnn</i> 'th subexpression

Note

There is an inherent ambiguity between octal character-entry escapes and back references, which is resolved by the following heuristics, as hinted at above. A leading zero always indicates an octal escape. A single non-zero digit, not followed by another digit, is always taken as a back reference. A multi-digit sequence not starting with a zero is taken as a back reference if it comes after a suitable subexpression (i.e., the number is in the legal range for a back reference), and otherwise is taken as octal.

9.7.3.4. Regular Expression Metasyntax

In addition to the main syntax described above, there are some special forms and miscellaneous syntactic facilities available.

An RE can begin with one of two special *director* prefixes. If an RE begins with `***:`, the rest of the RE is taken as an ARE. (This normally has no effect in PostgreSQL, since REs are assumed to be AREs; but it does have an effect if ERE or BRE mode had been specified by the *flags* parameter to a regex function.) If an RE begins with `***=`, the rest of the RE is taken to be a literal string, with all characters considered ordinary characters.

An ARE can begin with *embedded options*: a sequence `(?xyz)` (where *xyz* is one or more alphabetic characters) specifies options affecting the rest of the RE. These options override any previously determined options — in particular, they can override the case-sensitivity behavior implied by a regex operator, or the *flags* parameter to a regex function. The available option letters are shown in Table 9.23. Note that these same option letters are used in the *flags* parameters of regex functions.

Table 9.23. ARE Embedded-Option Letters

Option	Description
b	rest of RE is a BRE
c	case-sensitive matching (overrides operator type)
e	rest of RE is an ERE
i	case-insensitive matching (see Section 9.7.3.5) (overrides operator type)
m	historical synonym for n
n	newline-sensitive matching (see Section 9.7.3.5)
p	partial newline-sensitive matching (see Section 9.7.3.5)
q	rest of RE is a literal (“quoted”) string, all ordinary characters
s	non-newline-sensitive matching (default)
t	tight syntax (default; see below)
w	inverse partial newline-sensitive (“weird”) matching (see Section 9.7.3.5)
x	expanded syntax (see below)

Embedded options take effect at the) terminating the sequence. They can appear only at the start of an ARE (after the *** : director if any).

In addition to the usual (*tight*) RE syntax, in which all characters are significant, there is an *expanded* syntax, available by specifying the embedded x option. In the expanded syntax, white-space characters in the RE are ignored, as are all characters between a # and the following newline (or the end of the RE). This permits paragraphing and commenting a complex RE. There are three exceptions to that basic rule:

- a white-space character or # preceded by \ is retained
- white space or # within a bracket expression is retained
- white space and comments cannot appear within multi-character symbols, such as (? :

For this purpose, white-space characters are blank, tab, newline, and any character that belongs to the *space* character class.

Finally, in an ARE, outside bracket expressions, the sequence (?#*ttt*) (where *ttt* is any text not containing a) is a comment, completely ignored. Again, this is not allowed between the characters of multi-character symbols, like (? : . Such comments are more a historical artifact than a useful facility, and their use is deprecated; use the expanded syntax instead.

None of these metasyntax extensions is available if an initial *** = director has specified that the user's input be treated as a literal string rather than as an RE.

9.7.3.5. Regular Expression Matching Rules

In the event that an RE could match more than one substring of a given string, the RE matches the one starting earliest in the string. If the RE could match more than one substring starting at that point, either the longest possible match or the shortest possible match will be taken, depending on whether the RE is *greedy* or *non-greedy*.

Whether an RE is greedy or not is determined by the following rules:

- Most atoms, and all constraints, have no greediness attribute (because they cannot match variable amounts of text anyway).
- Adding parentheses around an RE does not change its greediness.
- A quantified atom with a fixed-repetition quantifier ($\{m\}$ or $\{m\}?$) has the same greediness (possibly none) as the atom itself.
- A quantified atom with other normal quantifiers (including $\{m, n\}$ with m equal to n) is greedy (prefers longest match).
- A quantified atom with a non-greedy quantifier (including $\{m, n\}?$ with m equal to n) is non-greedy (prefers shortest match).
- A branch — that is, an RE that has no top-level `|` operator — has the same greediness as the first quantified atom in it that has a greediness attribute.
- An RE consisting of two or more branches connected by the `|` operator is always greedy.

The above rules associate greediness attributes not only with individual quantified atoms, but with branches and entire REs that contain quantified atoms. What that means is that the matching is done in such a way that the branch, or whole RE, matches the longest or shortest possible substring *as a whole*. Once the length of the entire match is determined, the part of it that matches any particular subexpression is determined on the basis of the greediness attribute of that subexpression, with subexpressions starting earlier in the RE taking priority over ones starting later.

An example of what this means:

```
SELECT SUBSTRING('XY1234Z', 'Y*([0-9]{1,3})');
Result: 123
SELECT SUBSTRING('XY1234Z', 'Y?*([0-9]{1,3})');
Result: 1
```

In the first case, the RE as a whole is greedy because `Y*` is greedy. It can match beginning at the `Y`, and it matches the longest possible string starting there, i.e., `Y123`. The output is the parenthesized part of that, or `123`. In the second case, the RE as a whole is non-greedy because `Y*?` is non-greedy. It can match beginning at the `Y`, and it matches the shortest possible string starting there, i.e., `Y1`. The subexpression `[0-9]{1,3}` is greedy but it cannot change the decision as to the overall match length; so it is forced to match just `1`.

In short, when an RE contains both greedy and non-greedy subexpressions, the total match length is either as long as possible or as short as possible, according to the attribute assigned to the whole RE. The attributes assigned to the subexpressions only affect how much of that match they are allowed to “eat” relative to each other.

The quantifiers $\{1, 1\}$ and $\{1, 1\}?$ can be used to force greediness or non-greediness, respectively, on a subexpression or a whole RE. This is useful when you need the whole RE to have a greediness attribute different from what's deduced from its elements. As an example, suppose that we are trying to separate a string containing some digits into the digits and the parts before and after them. We might try to do that like this:

```
SELECT regexp_match('abc01234xyz', '(.*)(\d+)(.*)');
Result: {abc0123,4,xyz}
```

That didn't work: the first `.*` is greedy so it “eats” as much as it can, leaving the `\d+` to match at the last possible place, the last digit. We might try to fix that by making it non-greedy:

```
SELECT regexp_match('abc01234xyz', '(.*?)(\d+)(.*)');
```

```
Result: {abc,0,""}
```

That didn't work either, because now the RE as a whole is non-greedy and so it ends the overall match as soon as possible. We can get what we want by forcing the RE as a whole to be greedy:

```
SELECT regexp_match('abc01234xyz', '(?: .*?)(\d+)(.*){1,1}');
Result: {abc,01234,xyz}
```

Controlling the RE's overall greediness separately from its components' greediness allows great flexibility in handling variable-length patterns.

When deciding what is a longer or shorter match, match lengths are measured in characters, not collating elements. An empty string is considered longer than no match at all. For example: `bb*` matches the three middle characters of `abbbc`; `(week|wee)(night|knights)` matches all ten characters of `weeknights`; when `(.)*.*` is matched against `abc` the parenthesized subexpression matches all three characters; and when `(a*)*` is matched against `bc` both the whole RE and the parenthesized subexpression match an empty string.

If case-independent matching is specified, the effect is much as if all case distinctions had vanished from the alphabet. When an alphabetic that exists in multiple cases appears as an ordinary character outside a bracket expression, it is effectively transformed into a bracket expression containing both cases, e.g., `x` becomes `[xX]`. When it appears inside a bracket expression, all case counterparts of it are added to the bracket expression, e.g., `[x]` becomes `[xX]` and `[^x]` becomes `[^xX]`.

If newline-sensitive matching is specified, `.` and bracket expressions using `^` will never match the newline character (so that matches will never cross newlines unless the RE explicitly arranges it) and `^` and `$` will match the empty string after and before a newline respectively, in addition to matching at beginning and end of string respectively. But the ARE escapes `\A` and `\Z` continue to match beginning or end of string *only*.

If partial newline-sensitive matching is specified, this affects `.` and bracket expressions as with newline-sensitive matching, but not `^` and `$`.

If inverse partial newline-sensitive matching is specified, this affects `^` and `$` as with newline-sensitive matching, but not `.` and bracket expressions. This isn't very useful but is provided for symmetry.

9.7.3.6. Limits and Compatibility

No particular limit is imposed on the length of REs in this implementation. However, programs intended to be highly portable should not employ REs longer than 256 bytes, as a POSIX-compliant implementation can refuse to accept such REs.

The only feature of AREs that is actually incompatible with POSIX EREs is that `\` does not lose its special significance inside bracket expressions. All other ARE features use syntax which is illegal or has undefined or unspecified effects in POSIX EREs; the `***` syntax of directors likewise is outside the POSIX syntax for both BREs and EREs.

Many of the ARE extensions are borrowed from Perl, but some have been changed to clean them up, and a few Perl extensions are not present. Incompatibilities of note include `\b`, `\B`, the lack of special treatment for a trailing newline, the addition of complemented bracket expressions to the things affected by newline-sensitive matching, the restrictions on parentheses and back references in lookahead/lookbehind constraints, and the longest/shortest-match (rather than first-match) matching semantics.

Two significant incompatibilities exist between AREs and the ERE syntax recognized by pre-7.4 releases of PostgreSQL:

- In AREs, `\` followed by an alphanumeric character is either an escape or an error, while in previous releases, it was just another way of writing the alphanumeric. This should not be much of a problem because there was no reason to write such a sequence in earlier releases.

- In AREs, `\` remains a special character within `[]`, so a literal `\` within a bracket expression must be written `\\`.

9.7.3.7. Basic Regular Expressions

BREs differ from EREs in several respects. In BREs, `|`, `+`, and `?` are ordinary characters and there is no equivalent for their functionality. The delimiters for bounds are `\{` and `\}`, with `{` and `}` by themselves ordinary characters. The parentheses for nested subexpressions are `\(` and `\)`, with `(` and `)` by themselves ordinary characters. `^` is an ordinary character except at the beginning of the RE or the beginning of a parenthesized subexpression, `$` is an ordinary character except at the end of the RE or the end of a parenthesized subexpression, and `*` is an ordinary character if it appears at the beginning of the RE or the beginning of a parenthesized subexpression (after a possible leading `^`). Finally, single-digit back references are available, and `\<` and `\>` are synonyms for `[[:<:]]` and `[[:>:]]` respectively; no other escapes are available in BREs.

9.7.3.8. Differences From XQuery (`LIKE_REGEX`)

Since SQL:2008, the SQL standard includes a `LIKE_REGEX` operator that performs pattern matching according to the XQuery regular expression standard. PostgreSQL does not yet implement this operator, but you can get very similar behavior using the `regexp_match()` function, since XQuery regular expressions are quite close to the ARE syntax described above.

Notable differences between the existing POSIX-based regular-expression feature and XQuery regular expressions include:

- XQuery character class subtraction is not supported. An example of this feature is using the following to match only English consonants: `[a-z-[aeiou]]`.
- XQuery character class shorthands `\c`, `\C`, `\i`, and `\I` are not supported.
- XQuery character class elements using `\p{UnicodeProperty}` or the inverse `\P{UnicodeProperty}` are not supported.
- POSIX interprets character classes such as `\w` (see Table 9.20) according to the prevailing locale (which you can control by attaching a `COLLATE` clause to the operator or function). XQuery specifies these classes by reference to Unicode character properties, so equivalent behavior is obtained only with a locale that follows the Unicode rules.
- The SQL standard (not XQuery itself) attempts to cater for more variants of “newline” than POSIX does. The newline-sensitive matching options described above consider only ASCII NL (`\n`) to be a newline, but SQL would have us treat CR (`\r`), CRLF (`\r\n`) (a Windows-style newline), and some Unicode-only characters like LINE SEPARATOR (U+2028) as newlines as well. Notably, `.` and `\s` should count `\r\n` as one character not two according to SQL.
- Of the character-entry escapes described in Table 9.19, XQuery supports only `\n`, `\r`, and `\t`.
- XQuery does not support the `[:name :]` syntax for character classes within bracket expressions.
- XQuery does not have lookahead or lookbehind constraints, nor any of the constraint escapes described in Table 9.21.
- The metasyntax forms described in Section 9.7.3.4 do not exist in XQuery.
- The regular expression flag letters defined by XQuery are related to but not the same as the option letters for POSIX (Table 9.23). While the `i` and `q` options behave the same, others do not:
 - XQuery's `s` (allow dot to match newline) and `m` (allow `^` and `$` to match at newlines) flags provide access to the same behaviors as POSIX's `n`, `p` and `w` flags, but they do *not* match the behavior of POSIX's `s` and `m` flags. Note in particular that dot-matches-newline is the default behavior in POSIX but not XQuery.

- XQuery's `x` (ignore whitespace in pattern) flag is noticeably different from POSIX's expanded-mode flag. POSIX's `x` flag also allows `#` to begin a comment in the pattern, and POSIX will not ignore a whitespace character after a backslash.

9.8. Data Type Formatting Functions

The PostgreSQL formatting functions provide a powerful set of tools for converting various data types (date/time, integer, floating point, numeric) to formatted strings and for converting from formatted strings to specific data types. Table 9.24 lists them. These functions all follow a common calling convention: the first argument is the value to be formatted and the second argument is a template that defines the output or input format.

Table 9.24. Formatting Functions

Function	Return Type	Description	Example
<code>to_char(timestamp, text)</code>	text	convert time stamp to string	<code>to_char(current_timestamp, 'HH12:MI:SS')</code>
<code>to_char(interval, text)</code>	text	convert interval to string	<code>to_char(interval '15h 2m 12s', 'HH24:MI:SS')</code>
<code>to_char(int, text)</code>	text	convert integer to string	<code>to_char(125, '999')</code>
<code>to_char(double precision, text)</code>	text	convert real/double precision to string	<code>to_char(125.8::real, '999D9')</code>
<code>to_char(numeric, text)</code>	text	convert numeric to string	<code>to_char(-125.8, '999D99S')</code>
<code>to_date(text, text)</code>	date	convert string to date	<code>to_date('0000', 'DD Mon YYYY')</code>
<code>to_number(text, text)</code>	numeric	convert string to numeric	<code>to_number('12,454.8-', '99G999D9S')</code>
<code>to_timestamp(text, text)</code>	timestamp with time zone	convert string to timestamp	<code>to_timestamp('05 Dec 2000', 'DD Mon YYYY')</code>

Note

There is also a single-argument `to_timestamp` function; see Table 9.31.

Tip

`to_timestamp` and `to_date` exist to handle input formats that cannot be converted by simple casting. For most standard date/time formats, simply casting the source string to the required data type works, and is much easier. Similarly, `to_number` is unnecessary for standard numeric representations.

In a `to_char` output template string, there are certain patterns that are recognized and replaced with appropriately-formatted data based on the given value. Any text that is not a template pattern is simply copied verbatim. Similarly, in an input template string (for the other functions), template patterns

identify the values to be supplied by the input data string. If there are characters in the template string that are not template patterns, the corresponding characters in the input data string are simply skipped over (whether or not they are equal to the template string characters).

Table 9.25 shows the template patterns available for formatting date and time values.

Table 9.25. Template Patterns for Date/Time Formatting

Pattern	Description
HH	hour of day (01-12)
HH12	hour of day (01-12)
HH24	hour of day (00-23)
MI	minute (00-59)
SS	second (00-59)
MS	millisecond (000-999)
US	microsecond (000000-999999)
SSSS	seconds past midnight (0-86399)
AM, am, PM or pm	meridiem indicator (without periods)
A.M., a.m., P.M. or p.m.	meridiem indicator (with periods)
Y, YYY	year (4 or more digits) with comma
YYYY	year (4 or more digits)
YYY	last 3 digits of year
YY	last 2 digits of year
Y	last digit of year
IYYY	ISO 8601 week-numbering year (4 or more digits)
IYY	last 3 digits of ISO 8601 week-numbering year
IY	last 2 digits of ISO 8601 week-numbering year
I	last digit of ISO 8601 week-numbering year
BC, bc, AD or ad	era indicator (without periods)
B.C., b.c., A.D. or a.d.	era indicator (with periods)
MONTH	full upper case month name (blank-padded to 9 chars)
Month	full capitalized month name (blank-padded to 9 chars)
month	full lower case month name (blank-padded to 9 chars)
MON	abbreviated upper case month name (3 chars in English, localized lengths vary)
Mon	abbreviated capitalized month name (3 chars in English, localized lengths vary)
mon	abbreviated lower case month name (3 chars in English, localized lengths vary)
MM	month number (01-12)
DAY	full upper case day name (blank-padded to 9 chars)
Day	full capitalized day name (blank-padded to 9 chars)

Pattern	Description
day	full lower case day name (blank-padded to 9 chars)
DY	abbreviated upper case day name (3 chars in English, localized lengths vary)
Dy	abbreviated capitalized day name (3 chars in English, localized lengths vary)
dy	abbreviated lower case day name (3 chars in English, localized lengths vary)
DDD	day of year (001-366)
IDDD	day of ISO 8601 week-numbering year (001-371; day 1 of the year is Monday of the first ISO week)
DD	day of month (01-31)
D	day of the week, Sunday (1) to Saturday (7)
ID	ISO 8601 day of the week, Monday (1) to Sunday (7)
W	week of month (1-5) (the first week starts on the first day of the month)
WW	week number of year (1-53) (the first week starts on the first day of the year)
IW	week number of ISO 8601 week-numbering year (01-53; the first Thursday of the year is in week 1)
CC	century (2 digits) (the twenty-first century starts on 2001-01-01)
J	Julian Day (integer days since November 24, 4714 BC at midnight UTC)
Q	quarter
RM	month in upper case Roman numerals (I-XII; I=January)
rm	month in lower case Roman numerals (i-xii; i=January)
TZ	upper case time-zone abbreviation (only supported in to_char)
tz	lower case time-zone abbreviation (only supported in to_char)
TZH	time-zone hours
TZM	time-zone minutes
OF	time-zone offset from UTC (only supported in to_char)

Modifiers can be applied to any template pattern to alter its behavior. For example, FMMonth is the Month pattern with the FM modifier. Table 9.26 shows the modifier patterns for date/time formatting.

Table 9.26. Template Pattern Modifiers for Date/Time Formatting

Modifier	Description	Example
FM prefix	fill mode (suppress leading zeroes and padding blanks)	FMMonth
TH suffix	upper case ordinal number suffix	DDTH, e.g., 12TH

Modifier	Description	Example
th suffix	lower case ordinal number suffix	DDth, e.g., 12th
FX prefix	fixed format global option (see usage notes)	FX Month DD Day
TM prefix	translation mode (print localized day and month names based on <code>lc_time</code>)	TMMonth
SP suffix	spell mode (not implemented)	DDSP

Usage notes for date/time formatting:

- FM suppresses leading zeroes and trailing blanks that would otherwise be added to make the output of a pattern be fixed-width. In PostgreSQL, FM modifies only the next specification, while in Oracle FM affects all subsequent specifications, and repeated FM modifiers toggle fill mode on and off.
- TM does not include trailing blanks. `to_timestamp` and `to_date` ignore the TM modifier.
- `to_timestamp` and `to_date` skip multiple blank spaces at the beginning of the input string and around date and time values unless the FX option is used. For example, `to_timestamp(' 2000 JUN', 'YYYY MON')` and `to_timestamp('2000 - JUN', 'YYYY-MON')` work, but `to_timestamp('2000 JUN', 'FXYYYY MON')` returns an error because `to_timestamp` expects only a single space. FX must be specified as the first item in the template.
- A separator (a space or non-letter/non-digit character) in the template string of `to_timestamp` and `to_date` matches any single separator in the input string or is skipped, unless the FX option is used. For example, `to_timestamp('2000JUN', 'YYYY//MON')` and `to_timestamp('2000/JUN', 'YYYY MON')` work, but `to_timestamp('2000//JUN', 'YYYY/MON')` returns an error because the number of separators in the input string exceeds the number of separators in the template.

If FX is specified, a separator in the template string matches exactly one character in the input string. But note that the input string character is not required to be the same as the separator from the template string. For example, `to_timestamp('2000/JUN', 'FXYYYY MON')` works, but `to_timestamp('2000/JUN', 'FXYYYY MON')` returns an error because the second space in the template string consumes the letter J from the input string.

- A TZH template pattern can match a signed number. Without the FX option, minus signs may be ambiguous, and could be interpreted as a separator. This ambiguity is resolved as follows: If the number of separators before TZH in the template string is less than the number of separators before the minus sign in the input string, the minus sign is interpreted as part of TZH. Otherwise, the minus sign is considered to be a separator between values. For example, `to_timestamp('2000 -10', 'YYYY TZH')` matches -10 to TZH, but `to_timestamp('2000 -10', 'YYYY TZH')` matches 10 to TZH.
- Ordinary text is allowed in `to_char` templates and will be output literally. You can put a substring in double quotes to force it to be interpreted as literal text even if it contains template patterns. For example, in `"Hello Year "YYYY"`, the YYYY will be replaced by the year data, but the single Y in Year will not be. In `to_date`, `to_number`, and `to_timestamp`, literal text and double-quoted strings result in skipping the number of characters contained in the string; for example `"XX"` skips two input characters (whether or not they are XX).

Tip

Prior to PostgreSQL 12, it was possible to skip arbitrary text in the input string using non-letter or non-digit characters. For example, `to_timestamp('2000y6m1d', 'YYYY-MM-DD')` used to work. Now you can only use let-

ter characters for this purpose. For example, `to_timestamp('2000y6m1d', 'yyyytMMtDDt')` and `to_timestamp('2000y6m1d', 'yyyy"y"M-M"m"DD"d')` skip `y`, `m`, and `d`.

- If you want to have a double quote in the output you must precede it with a backslash, for example `'\"YYYY Month\"'`. Backslashes are not otherwise special outside of double-quoted strings. Within a double-quoted string, a backslash causes the next character to be taken literally, whatever it is (but this has no special effect unless the next character is a double quote or another backslash).
- In `to_timestamp` and `to_date`, if the year format specification is less than four digits, e.g. `YYY`, and the supplied year is less than four digits, the year will be adjusted to be nearest to the year 2020, e.g. 95 becomes 1995.
- In `to_timestamp` and `to_date`, the `YYYY` conversion has a restriction when processing years with more than 4 digits. You must use some non-digit character or template after `YYYY`, otherwise the year is always interpreted as 4 digits. For example (with the year 20000): `to_date('200001131', 'YYYYMMDD')` will be interpreted as a 4-digit year; instead use a non-digit separator after the year, like `to_date('20000-1131', 'YYYY-MMDD')` or `to_date('20000Nov31', 'YYYYMonDD')`.
- In `to_timestamp` and `to_date`, the `CC` (century) field is accepted but ignored if there is a `YYY`, `YYYY` or `Y,YYY` field. If `CC` is used with `YY` or `Y` then the result is computed as that year in the specified century. If the century is specified but the year is not, the first year of the century is assumed.
- In `to_timestamp` and `to_date`, weekday names or numbers (`DAY`, `D`, and related field types) are accepted but are ignored for purposes of computing the result. The same is true for quarter (`Q`) fields.
- In `to_timestamp` and `to_date`, an ISO 8601 week-numbering date (as distinct from a Gregorian date) can be specified in one of two ways:
 - Year, week number, and weekday: for example `to_date('2006-42-4', 'IYYY-IW-ID')` returns the date 2006-10-19. If you omit the weekday it is assumed to be 1 (Monday).
 - Year and day of year: for example `to_date('2006-291', 'IYYY-IDDD')` also returns 2006-10-19.

Attempting to enter a date using a mixture of ISO 8601 week-numbering fields and Gregorian date fields is nonsensical, and will cause an error. In the context of an ISO 8601 week-numbering year, the concept of a “month” or “day of month” has no meaning. In the context of a Gregorian year, the ISO week has no meaning.

Caution

While `to_date` will reject a mixture of Gregorian and ISO week-numbering date fields, `to_char` will not, since output format specifications like `YYYY-MM-DD (IYYY-IDDD)` can be useful. But avoid writing something like `IYYY-MM-DD`; that would yield surprising results near the start of the year. (See Section 9.9.1 for more information.)

- In `to_timestamp`, millisecond (`MS`) or microsecond (`US`) fields are used as the seconds digits after the decimal point. For example `to_timestamp('12.3', 'SS.MS')` is not 3 milliseconds, but 300, because the conversion treats it as 12 + 0.3 seconds. So, for the format `SS.MS`, the input values 12.3, 12.30, and 12.300 specify the same number of milliseconds. To get three milliseconds, one must write 12.003, which the conversion treats as 12 + 0.003 = 12.003 seconds.

Here is a more complex example: `to_timestamp('15:12:02.020.001230', 'HH24:MI:SS.MS.US')` is 15 hours, 12 minutes, and 2 seconds + 20 milliseconds + 1230 microseconds = 2.021230 seconds.

- `to_char(..., 'ID')`'s day of the week numbering matches the `extract(isodow from ...)` function, but `to_char(..., 'D')`'s does not match `extract(dow from ...)`'s day numbering.
- `to_char(interval)` formats HH and HH12 as shown on a 12-hour clock, for example zero hours and 36 hours both output as 12, while HH24 outputs the full hour value, which can exceed 23 in an interval value.

Table 9.27 shows the template patterns available for formatting numeric values.

Table 9.27. Template Patterns for Numeric Formatting

Pattern	Description
9	digit position (can be dropped if insignificant)
0	digit position (will not be dropped, even if insignificant)
. (period)	decimal point
, (comma)	group (thousands) separator
PR	negative value in angle brackets
S	sign anchored to number (uses locale)
L	currency symbol (uses locale)
D	decimal point (uses locale)
G	group separator (uses locale)
MI	minus sign in specified position (if number < 0)
PL	plus sign in specified position (if number > 0)
SG	plus/minus sign in specified position
RN	Roman numeral (input between 1 and 3999)
TH or th	ordinal number suffix
V	shift specified number of digits (see notes)
EEEE	exponent for scientific notation

Usage notes for numeric formatting:

- 0 specifies a digit position that will always be printed, even if it contains a leading/trailing zero. 9 also specifies a digit position, but if it is a leading zero then it will be replaced by a space, while if it is a trailing zero and fill mode is specified then it will be deleted. (For `to_number()`, these two pattern characters are equivalent.)
- The pattern characters S, L, D, and G represent the sign, currency symbol, decimal point, and thousands separator characters defined by the current locale (see `lc_monetary` and `lc_numeric`). The pattern characters period and comma represent those exact characters, with the meanings of decimal point and thousands separator, regardless of locale.
- If no explicit provision is made for a sign in `to_char()`'s pattern, one column will be reserved for the sign, and it will be anchored to (appear just left of) the number. If S appears just left of some 9's, it will likewise be anchored to the number.
- A sign formatted using SG, PL, or MI is not anchored to the number; for example, `to_char(-12, 'MI9999')` produces '- 12' but `to_char(-12, 'S9999')` produces '-12'. (The Oracle implementation does not allow the use of MI before 9, but rather requires that 9 precede MI.)

- TH does not convert values less than zero and does not convert fractional numbers.
- PL, SG, and TH are PostgreSQL extensions.
- In `to_number`, if non-data template patterns such as L or TH are used, the corresponding number of input characters are skipped, whether or not they match the template pattern, unless they are data characters (that is, digits, sign, decimal point, or comma). For example, TH would skip two non-data characters.
- V with `to_char` multiplies the input values by 10^n , where n is the number of digits following V. V with `to_number` divides in a similar manner. `to_char` and `to_number` do not support the use of V combined with a decimal point (e.g., `99.9V99` is not allowed).
- EEEE (scientific notation) cannot be used in combination with any of the other formatting patterns or modifiers other than digit and decimal point patterns, and must be at the end of the format string (e.g., `9.99EEEE` is a valid pattern).

Certain modifiers can be applied to any template pattern to alter its behavior. For example, `FM99.99` is the `99.99` pattern with the FM modifier. Table 9.28 shows the modifier patterns for numeric formatting.

Table 9.28. Template Pattern Modifiers for Numeric Formatting

Modifier	Description	Example
FM prefix	fill mode (suppress trailing zeroes and padding blanks)	FM99.99
TH suffix	upper case ordinal number suffix	999TH
th suffix	lower case ordinal number suffix	999th

Table 9.29 shows some examples of the use of the `to_char` function.

Table 9.29. to_char Examples

Expression	Result
<code>to_char(current_timestamp, 'Day, DD HH12:MI:SS')</code>	'Tuesday , 06 05:39:18'
<code>to_char(current_timestamp, 'FM-Day, FMDD HH12:MI:SS')</code>	'Tuesday, 6 05:39:18'
<code>to_char(-0.1, '99.99')</code>	' -.10'
<code>to_char(-0.1, 'FM9.99')</code>	'-.1'
<code>to_char(-0.1, 'FM90.99')</code>	'-0.1'
<code>to_char(0.1, '0.9')</code>	' 0.1'
<code>to_char(12, '9990999.9')</code>	' 0012.0'
<code>to_char(12, 'FM9990999.9')</code>	'0012.'
<code>to_char(485, '999')</code>	' 485'
<code>to_char(-485, '999')</code>	'-485'
<code>to_char(485, '9 9 9')</code>	' 4 8 5'
<code>to_char(1485, '9,999')</code>	' 1,485'
<code>to_char(1485, '9G999')</code>	' 1 485'
<code>to_char(148.5, '999.999')</code>	' 148.500'
<code>to_char(148.5, 'FM999.999')</code>	'148.5'
<code>to_char(148.5, 'FM999.990')</code>	'148.500'

Expression	Result
to_char(148.5, '999D999')	' 148,500'
to_char(3148.5, '9G999D999')	' 3 148,500'
to_char(-485, '999S')	'485-'
to_char(-485, '999MI')	'485-'
to_char(485, '999MI')	'485 '
to_char(485, 'FM999MI')	'485'
to_char(485, 'PL999')	'+485'
to_char(485, 'SG999')	'+485'
to_char(-485, 'SG999')	'-485'
to_char(-485, '9SG99')	'4-85'
to_char(-485, '999PR')	'<485>'
to_char(485, 'L999')	'DM 485'
to_char(485, 'RN')	' CDLXXXV'
to_char(485, 'FMRN')	'CDLXXXV'
to_char(5.2, 'FMRN')	'V'
to_char(482, '999th')	' 482nd'
to_char(485, '"Good number:"999')	'Good number: 485'
to_char(485.8, 'Pre:"999" Post:" .999')	'Pre: 485 Post: .800'
to_char(12, '99V999')	' 12000'
to_char(12.4, '99V999')	' 12400'
to_char(12.45, '99V9')	' 125'
to_char(0.0004859, '9.99EEEE')	' 4.86e-04'

9.9. Date/Time Functions and Operators

Table 9.31 shows the available functions for date/time value processing, with details appearing in the following subsections. Table 9.30 illustrates the behaviors of the basic arithmetic operators (+, *, etc.). For formatting functions, refer to Section 9.8. You should be familiar with the background information on date/time data types from Section 8.5.

All the functions and operators described below that take time or timestamp inputs actually come in two variants: one that takes time with time zone or timestamp with time zone, and one that takes time without time zone or timestamp without time zone. For brevity, these variants are not shown separately. Also, the + and * operators come in commutative pairs (for example both date + integer and integer + date); we show only one of each such pair.

Table 9.30. Date/Time Operators

Operator	Example	Result
+	date '2001-09-28' + integer '7'	date '2001-10-05'
+	date '2001-09-28' + interval '1 hour'	timestamp '2001-09-28 01:00:00'
+	date '2001-09-28' + time '03:00'	timestamp '2001-09-28 03:00:00'

Operator	Example	Result
+	interval '1 day' + interval '1 hour'	interval '1 day 01:00:00'
+	timestamp '2001-09-28 01:00' + interval '23 hours'	timestamp '2001-09-29 00:00:00'
+	time '01:00' + interval '3 hours'	time '04:00:00'
-	- interval '23 hours'	interval '-23:00:00'
-	date '2001-10-01' - date '2001-09-28'	integer '3' (days)
-	date '2001-10-01' - integer '7'	date '2001-09-24'
-	date '2001-09-28' - interval '1 hour'	timestamp '2001-09-27 23:00:00'
-	time '05:00' - time '03:00'	interval '02:00:00'
-	time '05:00' - interval '2 hours'	time '03:00:00'
-	timestamp '2001-09-28 23:00' - interval '23 hours'	timestamp '2001-09-28 00:00:00'
-	interval '1 day' - interval '1 hour'	interval '1 day -01:00:00'
-	timestamp '2001-09-29 03:00' - timestamp '2001-09-27 12:00'	interval '1 day 15:00:00'
*	900 * interval '1 second'	interval '00:15:00'
*	21 * interval '1 day'	interval '21 days'
*	double precision '3.5' * interval '1 hour'	interval '03:30:00'
/	interval '1 hour' / double precision '1.5'	interval '00:40:00'

Table 9.31. Date/Time Functions

Function	Return Type	Description	Example	Result
age(timestamp, timestamp)	interval	Subtract arguments, producing a “symbolic” result that uses years and months, rather than just days	age(timestamp '2001-04-10', timestamp '1957-06-13')	43 years 9 mons 27 days
age(timestamp)	interval	Subtract from current_date (at midnight)	age(timestamp '1957-06-13')	43 years 8 mons 3 days
clock_timestamp()	timestamp with time zone	Current date and time (changes during statement ex-		

Function	Return Type	Description	Example	Result
		ecution); see Section 9.9.4		
current_date	date	Current date; see Section 9.9.4		
current_time	time with time zone	Current time of day; see Section 9.9.4		
current_timestamp	timestamp with time zone	Current date and time (start of current transaction); see Section 9.9.4		
date_part(text, timestamp)	double precision	Get subfield (equivalent to extract); see Section 9.9.1	date_part('hour', timestamp '2001-02-16 20:38:40')	20
date_part(text, interval)	double precision	Get subfield (equivalent to extract); see Section 9.9.1	date_part('month', interval '2 years 3 months')	3
date_trunc(text, timestamp)	timestamp	Truncate to specified precision; see Section 9.9.2	date_trunc('hour', timestamp '2001-02-16 20:38:40')	2001-02-16 20:00:00
date_trunc(text, timestamp with time zone, text)	timestamp with time zone	Truncate to specified precision in the specified time zone; see Section 9.9.2	date_trunc('day', timestamptz '2001-02-16 20:38:40+00', 'Australia/Sydney')	2001-02-16 13:00:00+00
date_trunc(text, interval)	interval	Truncate to specified precision; see Section 9.9.2	date_trunc('hour', interval '2 days 3 hours 40 minutes')	2 days 03:00:00
extract(field from timestamp)	double precision	Get subfield; see Section 9.9.1	extract(hour from timestamp '2001-02-16 20:38:40')	20
extract(field from interval)	double precision	Get subfield; see Section 9.9.1	extract(month from interval '2 years 3 months')	3
isfinite(date)	boolean	Test for finite date (not +/-infinity)	isfinite(date '2001-02-16')	true
isfinite(timestamp)	boolean	Test for finite timestamp (not +/-infinity)	isfinite(timestamp '2001-02-16 21:28:30')	true

Function	Return Type	Description	Example	Result
<code>isfinite(interval)</code>	boolean	Test for finite interval	<code>isfinite(interval '4 hours')</code>	true
<code>justify_days(interval)</code>	interval	Adjust interval so 30-day time periods are represented as months	<code>justify_days(interval '35 days')</code>	1 mon 5 days
<code>justify_hours(interval)</code>	interval	Adjust interval so 24-hour time periods are represented as days	<code>justify_hours(interval '27 hours')</code>	1 day 03:00:00
<code>justify_interval(interval)</code>	interval	Adjust interval using <code>justify_days</code> and <code>justify_hours</code> , with additional sign adjustments	<code>justify_interval(interval '1 mon -1 hour')</code>	29 days 23:00:00
<code>localtime</code>	time	Current time of day; see Section 9.9.4		
<code>localtime-stamp</code>	timestamp	Current date and time (start of current transaction); see Section 9.9.4		
<code>make_date(year int, month int, day int)</code>	date	Create date from year, month and day fields	<code>make_date(2013, 7, 15)</code>	2013-07-15
<code>make_interval(years int DEFAULT 0, months int DEFAULT 0, weeks int DEFAULT 0, days int DEFAULT 0, hours int DEFAULT 0, mins int DEFAULT 0, secs double precision DEFAULT 0.0)</code>	interval	Create interval from years, months, weeks, days, hours, minutes and seconds fields	<code>make_interval(days => 10)</code>	10 days
<code>make_time(hour int, min int, sec double precision)</code>	time	Create time from hour, minute and seconds fields	<code>make_time(8, 15, 23.5)</code>	08:15:23.5
<code>make_timestamp(year int, month int, day int,</code>	timestamp	Create timestamp from year, month, day, hour, minute and seconds fields	<code>make_timestamp(2013, 7, 15, 8, 15, 23.5)</code>	2013-07-15 08:15:23.5

Function	Return Type	Description	Example	Result
<i>hour int, min int, sec double precision</i>)				
<code>make_time- stampz(year int, month int, day int, hour int, min int, sec double precision, [time- zone text])</code>	timestamp with time zone	Create timestamp with time zone from year, month, day, hour, minute and seconds fields; if <i>timezone</i> is not specified, the current time zone is used	<code>make_time- stampz(2013, 7, 15, 8, 15, 23.5)</code>	2013-07-15 08:15:23.5+01
<code>now()</code>	timestamp with time zone	Current date and time (start of current transaction); see Section 9.9.4		
<code>statemen- t_time-stam- p()</code>	timestamp with time zone	Current date and time (start of current statement); see Section 9.9.4		
<code>timeofday()</code>	text	Current date and time (like <code>clock_time-stamp</code> , but as a text string); see Section 9.9.4		
<code>transac- tion_time- stamp()</code>	timestamp with time zone	Current date and time (start of current transaction); see Section 9.9.4		
<code>to_time-stam- p(double pre- cision)</code>	timestamp with time zone	Convert Unix epoch (seconds since 1970-01-01 00:00:00+00) to timestamp	<code>to_time-stam- p(1284352323)</code>	2010-09-13 04:32:03+00

In addition to these functions, the SQL OVERLAPS operator is supported:

```
(start1, end1) OVERLAPS (start2, end2)
(start1, length1) OVERLAPS (start2, length2)
```

This expression yields true when two time periods (defined by their endpoints) overlap, false when they do not overlap. The endpoints can be specified as pairs of dates, times, or time stamps; or as a date, time, or time stamp followed by an interval. When a pair of values is provided, either the start or the end can be written first; OVERLAPS automatically takes the earlier value of the pair as the start. Each time period is considered to represent the half-open interval $start \leq time < end$, unless *start* and *end* are equal in which case it represents that single time instant. This means for instance that two time periods with only an endpoint in common do not overlap.

```
SELECT (DATE '2001-02-16', DATE '2001-12-21') OVERLAPS
       (DATE '2001-10-30', DATE '2002-10-30');
Result: true
```

```
SELECT (DATE '2001-02-16', INTERVAL '100 days') OVERLAPS
       (DATE '2001-10-30', DATE '2002-10-30');
Result: false
SELECT (DATE '2001-10-29', DATE '2001-10-30') OVERLAPS
       (DATE '2001-10-30', DATE '2001-10-31');
Result: false
SELECT (DATE '2001-10-30', DATE '2001-10-30') OVERLAPS
       (DATE '2001-10-30', DATE '2001-10-31');
Result: true
```

When adding an interval value to (or subtracting an interval value from) a timestamp with time zone value, the days component advances or decrements the date of the timestamp with time zone by the indicated number of days. Across daylight saving time changes (when the session time zone is set to a time zone that recognizes DST), this means interval '1 day' does not necessarily equal interval '24 hours'. For example, with the session time zone set to CST7CDT, timestamp with time zone '2005-04-02 12:00-07' + interval '1 day' will produce timestamp with time zone '2005-04-03 12:00-06', while adding interval '24 hours' to the same initial timestamp with time zone produces timestamp with time zone '2005-04-03 13:00-06', as there is a change in daylight saving time at 2005-04-03 02:00 in time zone CST7CDT.

Note there can be ambiguity in the months field returned by `age` because different months have different numbers of days. PostgreSQL's approach uses the month from the earlier of the two dates when calculating partial months. For example, `age('2004-06-01', '2004-04-30')` uses April to yield `1 mon 1 day`, while using May would yield `1 mon 2 days` because May has 31 days, while April has only 30.

Subtraction of dates and timestamps can also be complex. One conceptually simple way to perform subtraction is to convert each value to a number of seconds using `EXTRACT(EPOCH FROM ...)`, then subtract the results; this produces the number of *seconds* between the two values. This will adjust for the number of days in each month, timezone changes, and daylight saving time adjustments. Subtraction of date or timestamp values with the “-” operator returns the number of days (24-hours) and hours/minutes/seconds between the values, making the same adjustments. The `age` function returns years, months, days, and hours/minutes/seconds, performing field-by-field subtraction and then adjusting for negative field values. The following queries illustrate the differences in these approaches. The sample results were produced with `timezone = 'US/Eastern'`; there is a daylight saving time change between the two dates used:

```
SELECT EXTRACT(EPOCH FROM timestampz '2013-07-01 12:00:00') -
       EXTRACT(EPOCH FROM timestampz '2013-03-01 12:00:00');
Result: 10537200
SELECT (EXTRACT(EPOCH FROM timestampz '2013-07-01 12:00:00') -
       EXTRACT(EPOCH FROM timestampz '2013-03-01 12:00:00'))
       / 60 / 60 / 24;
Result: 121.95833333333333
SELECT timestampz '2013-07-01 12:00:00' - timestampz '2013-03-01
       12:00:00';
Result: 121 days 23:00:00
SELECT age(timestampz '2013-07-01 12:00:00', timestampz
       '2013-03-01 12:00:00');
Result: 4 mons
```

9.9.1. EXTRACT, date_part

```
EXTRACT(field FROM source)
```

The `extract` function retrieves subfields such as year or hour from date/time values. *source* must be a value expression of type `timestamp`, `time`, or `interval`. (Expressions of type `date` are cast to `timestamp` and can therefore be used as well.) *field* is an identifier or string that selects what field to extract from the source value. The `extract` function returns values of type double precision. The following are valid field names:

century

The century

```
SELECT EXTRACT(CENTURY FROM TIMESTAMP '2000-12-16 12:21:13');
Result: 20
SELECT EXTRACT(CENTURY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 21
```

The first century starts at 0001-01-01 00:00:00 AD, although they did not know it at the time. This definition applies to all Gregorian calendar countries. There is no century number 0, you go from -1 century to 1 century. If you disagree with this, please write your complaint to: Pope, Cathedral Saint-Peter of Roma, Vatican.

day

For `timestamp` values, the day (of the month) field (1 - 31); for `interval` values, the number of days

```
SELECT EXTRACT(DAY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 16

SELECT EXTRACT(DAY FROM INTERVAL '40 days 1 minute');
Result: 40
```

decade

The year field divided by 10

```
SELECT EXTRACT(DECADE FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 200
```

dow

The day of the week as Sunday (0) to Saturday (6)

```
SELECT EXTRACT(DOW FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 5
```

Note that `extract`'s day of the week numbering differs from that of the `to_char(..., 'D')` function.

doy

The day of the year (1 - 365/366)

```
SELECT EXTRACT(DOY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 47
```

epoch

For timestamp with time zone values, the number of seconds since 1970-01-01 00:00:00 UTC (can be negative); for date and timestamp values, the number of seconds since 1970-01-01 00:00:00 local time; for interval values, the total number of seconds in the interval

```
SELECT EXTRACT(EPOCH FROM TIMESTAMP WITH TIME ZONE '2001-02-16
20:38:40.12-08');
Result: 982384720.12
```

```
SELECT EXTRACT(EPOCH FROM INTERVAL '5 days 3 hours');
Result: 442800
```

You can convert an epoch value back to a time stamp with `to_timestamp`:

```
SELECT to_timestamp(982384720.12);
Result: 2001-02-17 04:38:40.12+00
```

hour

The hour field (0 - 23)

```
SELECT EXTRACT(HOUR FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 20
```

isodow

The day of the week as Monday (1) to Sunday (7)

```
SELECT EXTRACT(ISODOW FROM TIMESTAMP '2001-02-18 20:38:40');
Result: 7
```

This is identical to `dow` except for Sunday. This matches the ISO 8601 day of the week numbering.

isoyear

The ISO 8601 week-numbering year that the date falls in (not applicable to intervals)

```
SELECT EXTRACT(ISOYEAR FROM DATE '2006-01-01');
Result: 2005
SELECT EXTRACT(ISOYEAR FROM DATE '2006-01-02');
Result: 2006
```

Each ISO 8601 week-numbering year begins with the Monday of the week containing the 4th of January, so in early January or late December the ISO year may be different from the Gregorian year. See the `week` field for more information.

This field is not available in PostgreSQL releases prior to 8.3.

microseconds

The seconds field, including fractional parts, multiplied by 1 000 000; note that this includes full seconds

```
SELECT EXTRACT(MICROSECONDS FROM TIME '17:12:28.5');
Result: 28500000
```

millennium

The millennium

```
SELECT EXTRACT(MILLENNIUM FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 3
```

Years in the 1900s are in the second millennium. The third millennium started January 1, 2001.

milliseconds

The seconds field, including fractional parts, multiplied by 1000. Note that this includes full seconds.

```
SELECT EXTRACT(MILLISECONDS FROM TIME '17:12:28.5');  
Result: 28500
```

minute

The minutes field (0 - 59)

```
SELECT EXTRACT(MINUTE FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 38
```

month

For timestamp values, the number of the month within the year (1 - 12); for interval values, the number of months, modulo 12 (0 - 11)

```
SELECT EXTRACT(MONTH FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 2
```

```
SELECT EXTRACT(MONTH FROM INTERVAL '2 years 3 months');  
Result: 3
```

```
SELECT EXTRACT(MONTH FROM INTERVAL '2 years 13 months');  
Result: 1
```

quarter

The quarter of the year (1 - 4) that the date is in

```
SELECT EXTRACT(QUARTER FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 1
```

second

The seconds field, including fractional parts (0 - 59¹)

```
SELECT EXTRACT(SECOND FROM TIMESTAMP '2001-02-16 20:38:40');  
Result: 40
```

```
SELECT EXTRACT(SECOND FROM TIME '17:12:28.5');  
Result: 28.5
```

¹60 if leap seconds are implemented by the operating system

`timezone`

The time zone offset from UTC, measured in seconds. Positive values correspond to time zones east of UTC, negative values to zones west of UTC. (Technically, PostgreSQL does not use UTC because leap seconds are not handled.)

`timezone_hour`

The hour component of the time zone offset

`timezone_minute`

The minute component of the time zone offset

`week`

The number of the ISO 8601 week-numbering week of the year. By definition, ISO weeks start on Mondays and the first week of a year contains January 4 of that year. In other words, the first Thursday of a year is in week 1 of that year.

In the ISO week-numbering system, it is possible for early-January dates to be part of the 52nd or 53rd week of the previous year, and for late-December dates to be part of the first week of the next year. For example, 2005-01-01 is part of the 53rd week of year 2004, and 2006-01-01 is part of the 52nd week of year 2005, while 2012-12-31 is part of the first week of 2013. It's recommended to use the `isoyear` field together with `week` to get consistent results.

```
SELECT EXTRACT(WEEK FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 7
```

`year`

The year field. Keep in mind there is no 0 AD, so subtracting BC years from AD years should be done with care.

```
SELECT EXTRACT(YEAR FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 2001
```

Note

When the input value is +/-Infinity, `extract` returns +/-Infinity for monotonically-increasing fields (`epoch`, `julian`, `year`, `isoyear`, `decade`, `century`, and `millennium`). For other fields, NULL is returned. PostgreSQL versions before 9.6 returned zero for all cases of infinite input.

The `extract` function is primarily intended for computational processing. For formatting date/time values for display, see Section 9.8.

The `date_part` function is modeled on the traditional Ingres equivalent to the SQL-standard function `extract`:

```
date_part('field', source)
```

Note that here the `field` parameter needs to be a string value, not a name. The valid field names for `date_part` are the same as for `extract`.

```
SELECT date_part('day', TIMESTAMP '2001-02-16 20:38:40');
```

Result: 16

```
SELECT date_part('hour', INTERVAL '4 hours 3 minutes');
```

Result: 4

9.9.2. date_trunc

The function `date_trunc` is conceptually similar to the `trunc` function for numbers.

```
date_trunc(field, source [, time_zone ])
```

source is a value expression of type `timestamp`, `timestamp with time zone`, or `interval`. (Values of type `date` and `time` are cast automatically to `timestamp` or `interval`, respectively.) *field* selects to which precision to truncate the input value. The return value is likewise of type `timestamp`, `timestamp with time zone`, or `interval`, and it has all fields that are less significant than the selected one set to zero (or one, for day and month).

Valid values for *field* are:

```
microseconds
milliseconds
second
minute
hour
day
week
month
quarter
year
decade
century
millennium
```

When the input value is of type `timestamp with time zone`, the truncation is performed with respect to a particular time zone; for example, truncation to `day` produces a value that is midnight in that zone. By default, truncation is done with respect to the current `TimeZone` setting, but the optional *time_zone* argument can be provided to specify a different time zone. The time zone name can be specified in any of the ways described in Section 8.5.3.

A time zone cannot be specified when processing `timestamp without time zone` or `interval` inputs. These are always taken at face value.

Examples (assuming the local time zone is `America/New_York`):

```
SELECT date_trunc('hour', TIMESTAMP '2001-02-16 20:38:40');
```

Result: 2001-02-16 20:00:00

```
SELECT date_trunc('year', TIMESTAMP '2001-02-16 20:38:40');
```

Result: 2001-01-01 00:00:00

```
SELECT date_trunc('day', TIMESTAMP WITH TIME ZONE '2001-02-16
20:38:40+00');
```

Result: 2001-02-16 00:00:00-05

```
SELECT date_trunc('day', TIMESTAMP WITH TIME ZONE '2001-02-16
20:38:40+00', 'Australia/Sydney');
```

Result: 2001-02-16 08:00:00-05

```
SELECT date_trunc('hour', INTERVAL '3 days 02:47:33');
Result: 3 days 02:00:00
```

9.9.3. AT TIME ZONE

The `AT TIME ZONE` converts time stamp *without time zone* to/from time stamp *with time zone*, and *time* values to different time zones. Table 9.32 shows its variants.

Table 9.32. AT TIME ZONE Variants

Expression	Return Type	Description
timestamp without time zone AT TIME ZONE zone	timestamp with time zone	Treat given time stamp <i>without time zone</i> as located in the specified time zone
timestamp with time zone AT TIME ZONE zone	timestamp without time zone	Convert given time stamp <i>with time zone</i> to the new time zone, with no time zone designation
time with time zone AT TIME ZONE zone	time with time zone	Convert given time <i>with time zone</i> to the new time zone

In these expressions, the desired time zone *zone* can be specified either as a text string (e.g., 'America/Los_Angeles') or as an interval (e.g., INTERVAL '-08:00'). In the text case, a time zone name can be specified in any of the ways described in Section 8.5.3.

Examples (assuming the local time zone is America/Los_Angeles):

```
SELECT TIMESTAMP '2001-02-16 20:38:40' AT TIME ZONE 'America/Denver';
Result: 2001-02-16 19:38:40-08
```

```
SELECT TIMESTAMP WITH TIME ZONE '2001-02-16 20:38:40-05' AT TIME ZONE 'America/Denver';
Result: 2001-02-16 18:38:40
```

```
SELECT TIMESTAMP '2001-02-16 20:38:40-05' AT TIME ZONE 'Asia/Tokyo' AT TIME ZONE 'America/Chicago';
Result: 2001-02-16 05:38:40
```

The first example adds a time zone to a value that lacks it, and displays the value using the current TimeZone setting. The second example shifts the time stamp with time zone value to the specified time zone, and returns the value without a time zone. This allows storage and display of values different from the current TimeZone setting. The third example converts Tokyo time to Chicago time. Converting *time* values to other time zones uses the currently active time zone rules since no date is supplied.

The function `timezone(zone, timestamp)` is equivalent to the SQL-conforming construct `timestamp AT TIME ZONE zone`.

9.9.4. Current Date/Time

PostgreSQL provides a number of functions that return values related to the current date and time. These SQL-standard functions all return values based on the start time of the current transaction:

```
CURRENT_DATE
CURRENT_TIME
CURRENT_TIMESTAMP
```

```
CURRENT_TIME(precision)
CURRENT_TIMESTAMP(precision)
LOCALTIME
LOCALTIMESTAMP
LOCALTIME(precision)
LOCALTIMESTAMP(precision)
```

CURRENT_TIME and CURRENT_TIMESTAMP deliver values with time zone; LOCALTIME and LOCALTIMESTAMP deliver values without time zone.

CURRENT_TIME, CURRENT_TIMESTAMP, LOCALTIME, and LOCALTIMESTAMP can optionally take a precision parameter, which causes the result to be rounded to that many fractional digits in the seconds field. Without a precision parameter, the result is given to the full available precision.

Some examples:

```
SELECT CURRENT_TIME;
Result: 14:39:53.662522-05
```

```
SELECT CURRENT_DATE;
Result: 2001-12-23
```

```
SELECT CURRENT_TIMESTAMP;
Result: 2001-12-23 14:39:53.662522-05
```

```
SELECT CURRENT_TIMESTAMP(2);
Result: 2001-12-23 14:39:53.66-05
```

```
SELECT LOCALTIMESTAMP;
Result: 2001-12-23 14:39:53.662522
```

Since these functions return the start time of the current transaction, their values do not change during the transaction. This is considered a feature: the intent is to allow a single transaction to have a consistent notion of the “current” time, so that multiple modifications within the same transaction bear the same time stamp.

Note

Other database systems might advance these values more frequently.

PostgreSQL also provides functions that return the start time of the current statement, as well as the actual current time at the instant the function is called. The complete list of non-SQL-standard time functions is:

```
transaction_timestamp()
statement_timestamp()
clock_timestamp()
timeofday()
now()
```

transaction_timestamp() is equivalent to CURRENT_TIMESTAMP, but is named to clearly reflect what it returns. statement_timestamp() returns the start time of the current statement (more specifically, the time of receipt of the latest command message from the client). statement_timestamp() and transaction_timestamp() return the same value during the first command of a transaction, but might differ during subsequent commands. clock_timestamp() returns the actual current time, and therefore its value changes even within a single SQL command.

`timeofday()` is a historical PostgreSQL function. Like `clock_timestamp()`, it returns the actual current time, but as a formatted text string rather than a timestamp with time zone value. `now()` is a traditional PostgreSQL equivalent to `transaction_timestamp()`.

All the date/time data types also accept the special literal value `now` to specify the current date and time (again, interpreted as the transaction start time). Thus, the following three all return the same result:

```
SELECT CURRENT_TIMESTAMP;
SELECT now();
SELECT TIMESTAMP 'now'; -- incorrect for use with DEFAULT
```

Tip

You do not want to use the third form when specifying a `DEFAULT` clause while creating a table. The system will convert `now` to a timestamp as soon as the constant is parsed, so that when the default value is needed, the time of the table creation would be used! The first two forms will not be evaluated until the default value is used, because they are function calls. Thus they will give the desired behavior of defaulting to the time of row insertion.

9.9.5. Delaying Execution

The following functions are available to delay execution of the server process:

```
pg_sleep(seconds)
pg_sleep_for(interval)
pg_sleep_until(timestamp with time zone)
```

`pg_sleep` makes the current session's process sleep until *seconds* seconds have elapsed. *seconds* is a value of type `double precision`, so fractional-second delays can be specified. `pg_sleep_for` is a convenience function for larger sleep times specified as an `interval`. `pg_sleep_until` is a convenience function for when a specific wake-up time is desired. For example:

```
SELECT pg_sleep(1.5);
SELECT pg_sleep_for('5 minutes');
SELECT pg_sleep_until('tomorrow 03:00');
```

Note

The effective resolution of the sleep interval is platform-specific; 0.01 seconds is a common value. The sleep delay will be at least as long as specified. It might be longer depending on factors such as server load. In particular, `pg_sleep_until` is not guaranteed to wake up exactly at the specified time, but it will not wake up any earlier.

Warning

Make sure that your session does not hold more locks than necessary when calling `pg_sleep` or its variants. Otherwise other sessions might have to wait for your sleeping process, slowing down the entire system.

9.10. Enum Support Functions

For enum types (described in Section 8.7), there are several functions that allow cleaner programming without hard-coding particular values of an enum type. These are listed in Table 9.33. The examples assume an enum type created as:

```
CREATE TYPE rainbow AS ENUM ('red', 'orange', 'yellow', 'green',
    'blue', 'purple');
```

Table 9.33. Enum Support Functions

Function	Description	Example	Example Result
<code>enum_first(anyenum)</code>	Returns the first value of the input enum type	<code>enum_first(NULL::rainbow)</code>	red
<code>enum_last(anyenum)</code>	Returns the last value of the input enum type	<code>enum_last(NULL::rainbow)</code>	purple
<code>enum_range(anyenum)</code>	Returns all values of the input enum type in an ordered array	<code>enum_range(NULL::rainbow)</code>	{red, orange, yellow, green, blue, purple}
<code>enum_range(anyenum, anyenum)</code>	Returns the range between the two given enum values, as an ordered array. The values must be from the same enum type. If the first parameter is null, the result will start with the first value of the enum type. If the second parameter is null, the result will end with the last value of the enum type.	<code>enum_range('orange'::rainbow, 'green'::rainbow)</code>	{orange, yellow, green}
		<code>enum_range(NULL, 'green'::rainbow)</code>	{red, orange, yellow, green}
		<code>enum_range('orange'::rainbow, NULL)</code>	{orange, yellow, green, blue, purple}

Notice that except for the two-argument form of `enum_range`, these functions disregard the specific value passed to them; they care only about its declared data type. Either null or a specific value of the type can be passed, with the same result. It is more common to apply these functions to a table column or function argument than to a hardwired type name as suggested by the examples.

9.11. Geometric Functions and Operators

The geometric types `point`, `box`, `lseg`, `line`, `path`, `polygon`, and `circle` have a large set of native support functions and operators, shown in Table 9.34, Table 9.35, and Table 9.36.

Caution

Note that the “same as” operator, `~=`, represents the usual notion of equality for the `point`, `box`, `polygon`, and `circle` types. Some of these types also have an `=` operator, but `=` compares for equal *areas* only. The other scalar comparison operators (`<=` and so on) likewise compare areas for these types.

Table 9.34. Geometric Operators

Operator	Description	Example
+	Translation	box '((0,0),(1,1))' + point '(2.0,0)'
-	Translation	box '((0,0),(1,1))' - point '(2.0,0)'
*	Scaling/rotation	box '((0,0),(1,1))' * point '(2.0,0)'
/	Scaling/rotation	box '((0,0),(2,2))' / point '(2.0,0)'
#	Point or box of intersection	box '((1,-1),(-1,1))' # box '((1,1),(-2,-2))'
#	Number of points in path or polygon	# path '((1,0),(0,1),(-1,0))'
@-@	Length or circumference	@-@ path '((0,0),(1,0))'
@@	Center	@@ circle '((0,0),10)'
##	Closest point to first operand on second operand	point '(0,0)' ## lseg '((2,0),(0,2))'
<->	Distance between	circle '((0,0),1)' <-> circle '((5,0),1)'
&&	Overlaps? (One point in common makes this true.)	box '((0,0),(1,1))' && box '((0,0),(2,2))'
<<	Is strictly left of?	circle '((0,0),1)' << circle '((5,0),1)'
>>	Is strictly right of?	circle '((5,0),1)' >> circle '((0,0),1)'
&<	Does not extend to the right of?	box '((0,0),(1,1))' &< box '((0,0),(2,2))'
&>	Does not extend to the left of?	box '((0,0),(3,3))' &> box '((0,0),(2,2))'
<<	Is strictly below?	box '((0,0),(3,3))' << box '((3,4),(5,5))'
>>	Is strictly above?	box '((3,4),(5,5))' >> box '((0,0),(3,3))'
&<	Does not extend above?	box '((0,0),(1,1))' &< box '((0,0),(2,2))'
&>	Does not extend below?	box '((0,0),(3,3))' &> box '((0,0),(2,2))'
<^	Is below (allows touching)?	circle '((0,0),1)' <^ circle '((0,5),1)'
>^	Is above (allows touching)?	circle '((0,5),1)' >^ circle '((0,0),1)'

Operator	Description	Example
?#	Intersects?	<code>lseg '((-1,0),(1,0))' ?# box '((-2,-2),(2,2))'</code>
?-	Is horizontal?	<code>?- lseg '((-1,0),(1,0))'</code>
?-	Are horizontally aligned?	<code>point '(1,0)' ?- point '(0,0)'</code>
?	Is vertical?	<code>? lseg '((-1,0),(1,0))'</code>
?	Are vertically aligned?	<code>point '(0,1)' ? point '(0,0)'</code>
?-	Is perpendicular?	<code>lseg '((0,0),(0,1))' ?- lseg '((0,0),(1,0))'</code>
?	Are parallel?	<code>lseg '((-1,0),(1,0))' ? lseg '((-1,2),(1,2))'</code>
@>	Contains?	<code>circle '((0,0),2)' @> point '(1,1)'</code>
<@	Contained in or on?	<code>point '(1,1)' <@ circle '((0,0),2)'</code>
~=	Same as?	<code>polygon '((0,0),(1,1))' ~= polygon '((1,1),(0,0))'</code>

Note

Before PostgreSQL 8.2, the containment operators @> and <@ were respectively called ~ and @. These names are still available, but are deprecated and will eventually be removed.

Table 9.35. Geometric Functions

Function	Return Type	Description	Example
<code>area(object)</code>	double precision	area	<code>area(box '((0,0),(1,1))')</code>
<code>center(object)</code>	point	center	<code>center(box '((0,0),(1,2))')</code>
<code>diameter(circle)</code>	double precision	diameter of circle	<code>diameter(circle '((0,0),2.0)')</code>
<code>height(box)</code>	double precision	vertical size of box	<code>height(box '((0,0),(1,1))')</code>
<code>isclosed(path)</code>	boolean	a closed path?	<code>isclosed(path '((0,0),(1,1),(2,0))')</code>
<code>isopen(path)</code>	boolean	an open path?	<code>isopen(path '[(0,0),(1,1),(2,0)]')</code>

Function	Return Type	Description	Example
<code>length(object)</code>	double precision	length	<code>length(path '((-1,0),(1,0))')</code>
<code>npoints(path)</code>	int	number of points	<code>npoints(path '[(0,0),(1,1),(2,0)]')</code>
<code>npoints(polygon)</code>	int	number of points	<code>npoints(polygon '((1,1),(0,0))')</code>
<code>pclose(path)</code>	path	convert path to closed	<code>pclose(path '[(0,0),(1,1),(2,0)]')</code>
<code>popen(path)</code>	path	convert path to open	<code>popen(path '((0,0),(1,1),(2,0))')</code>
<code>radius(circle)</code>	double precision	radius of circle	<code>radius(circle '((0,0),2.0)')</code>
<code>width(box)</code>	double precision	horizontal size of box	<code>width(box '((0,0),(1,1))')</code>

Table 9.36. Geometric Type Conversion Functions

Function	Return Type	Description	Example
<code>box(circle)</code>	box	circle to box	<code>box(circle '((0,0),2.0)')</code>
<code>box(point)</code>	box	point to empty box	<code>box(point '(0,0)')</code>
<code>box(point, point)</code>	box	points to box	<code>box(point '(0,0)', point '(1,1)')</code>
<code>box(polygon)</code>	box	polygon to box	<code>box(polygon '((0,0),(1,1),(2,0))')</code>
<code>bound_box(box, box)</code>	box	boxes to bounding box	<code>bound_box(box '((0,0),(1,1))', box '((3,3),(4,4))')</code>
<code>circle(box)</code>	circle	box to circle	<code>circle(box '((0,0),(1,1))')</code>
<code>circle(point, double precision)</code>	circle	center and radius to circle	<code>circle(point '(0,0)', 2.0)</code>
<code>circle(polygon)</code>	circle	polygon to circle	<code>circle(polygon '((0,0),(1,1),(2,0))')</code>
<code>line(point, point)</code>	line	points to line	<code>line(point '(-1,0)', point '(1,0)')</code>
<code>lseg(box)</code>	lseg	box diagonal to line segment	<code>lseg(box '((-1,0),(1,0))')</code>

Function	Return Type	Description	Example
<code>lseg(point, point)</code>	<code>lseg</code>	points to line segment	<code>lseg(point '(-1,0)', point '(1,0)')</code>
<code>path(polygon)</code>	<code>path</code>	polygon to path	<code>path(polygon '((0,0),(1,1),(2,0))')</code>
<code>point(double precision, double precision)</code>	<code>point</code>	construct point	<code>point(23.4, -44.5)</code>
<code>point(box)</code>	<code>point</code>	center of box	<code>point(box '((-1,0),(1,0))')</code>
<code>point(circle)</code>	<code>point</code>	center of circle	<code>point(circle '((0,0),2.0)')</code>
<code>point(lseg)</code>	<code>point</code>	center of line segment	<code>point(lseg '((-1,0),(1,0))')</code>
<code>point(polygon)</code>	<code>point</code>	center of polygon	<code>point(polygon '((0,0),(1,1),(2,0))')</code>
<code>polygon(box)</code>	<code>polygon</code>	box to 4-point polygon	<code>polygon(box '((0,0),(1,1))')</code>
<code>polygon(circle)</code>	<code>polygon</code>	circle to 12-point polygon	<code>polygon(circle '((0,0),2.0)')</code>
<code>polygon(npts, circle)</code>	<code>polygon</code>	circle to <i>npts</i> -point polygon	<code>polygon(12, circle '((0,0),2.0)')</code>
<code>polygon(path)</code>	<code>polygon</code>	path to polygon	<code>polygon(path '((0,0),(1,1),(2,0))')</code>

It is possible to access the two component numbers of a `point` as though the point were an array with indexes 0 and 1. For example, if `t.p` is a `point` column then `SELECT p[0] FROM t` retrieves the X coordinate and `UPDATE t SET p[1] = ...` changes the Y coordinate. In the same way, a value of type `box` or `lseg` can be treated as an array of two `point` values.

The `area` function works for the types `box`, `circle`, and `path`. The `area` function only works on the `path` data type if the points in the `path` are non-intersecting. For example, the `path '((0,0),(0,1),(2,1),(2,2),(1,2),(1,0),(0,0))'::PATH` will not work; however, the following visually identical `path '((0,0),(0,1),(1,1),(1,2),(2,2),(2,1),(1,1),(1,0),(0,0))'::PATH` will work. If the concept of an intersecting versus non-intersecting `path` is confusing, draw both of the above `paths` side by side on a piece of graph paper.

9.12. Network Address Functions and Operators

Table 9.37 shows the operators available for the `cidr` and `inet` types. The operators `<<`, `<<=`, `>>`, `>>=`, and `&&` test for subnet inclusion. They consider only the network parts of the two addresses (ignoring any host part) and determine whether one network is identical to or a subnet of the other.

Table 9.37. cidr and inet Operators

Operator	Description	Example
<	is less than	inet '192.168.1.5' < inet '192.168.1.6'
<=	is less than or equal	inet '192.168.1.5' <= inet '192.168.1.5'
=	equals	inet '192.168.1.5' = inet '192.168.1.5'
>=	is greater or equal	inet '192.168.1.5' >= inet '192.168.1.5'
>	is greater than	inet '192.168.1.5' > inet '192.168.1.4'
<>	is not equal	inet '192.168.1.5' <> inet '192.168.1.4'
<<	is contained by	inet '192.168.1.5' << inet '192.168.1/24'
<<=	is contained by or equals	inet '192.168.1/24' <<= inet '192.168.1/24'
>>	contains	inet '192.168.1/24' >> inet '192.168.1.5'
>>=	contains or equals	inet '192.168.1/24' >>= inet '192.168.1/24'
&&	contains or is contained by	inet '192.168.1/24' && inet '192.168.1.80/28'
~	bitwise NOT	~ inet '192.168.1.6'
&	bitwise AND	inet '192.168.1.6' & inet '0.0.0.255'
	bitwise OR	inet '192.168.1.6' inet '0.0.0.255'
+	addition	inet '192.168.1.6' + 25
-	subtraction	inet '192.168.1.43' - 36
-	subtraction	inet '192.168.1.43' - inet '192.168.1.19'

Table 9.38 shows the functions available for use with the cidr and inet types. The abbrev, host, and text functions are primarily intended to offer alternative display formats.

Table 9.38. cidr and inet Functions

Function	Return Type	Description	Example	Result
abbrev(inet)	text	abbreviated display format as text	abbrev(inet '10.1.0.0/16')	10.1.0.0/16
abbrev(cidr)	text	abbreviated display format as text	abbrev(cidr '10.1.0.0/16')	10.1/16

Function	Return Type	Description	Example	Result
<code>broadcast(inet)</code>	<code>inet</code>	broadcast address for network	<code>broadcast('192.168.1.5/24')</code>	192.168.1.255/24
<code>family(inet)</code>	<code>int</code>	extract family of address; 4 for IPv4, 6 for IPv6	<code>family('::1')</code>	6
<code>host(inet)</code>	<code>text</code>	extract IP address as text	<code>host('192.168.1.5')</code>	192.168.1.5
<code>hostmask(inet)</code>	<code>inet</code>	construct host mask for network	<code>hostmask('192.168.23.20/30')</code>	0.0.0.3
<code>masklen(inet)</code>	<code>int</code>	extract netmask length	<code>masklen('192.168.1.5/24')</code>	24
<code>netmask(inet)</code>	<code>inet</code>	construct netmask for network	<code>netmask('192.168.1.5/24')</code>	255.255.255.0
<code>network(inet)</code>	<code>cidr</code>	extract network part of address	<code>network('192.168.1.5/24')</code>	192.168.1.0/24
<code>set_masklen(inet, int)</code>	<code>inet</code>	set netmask length for inet value	<code>set_masklen('192.168.1.5/24', 16)</code>	192.168.1.0/16
<code>set_masklen(cidr, int)</code>	<code>cidr</code>	set netmask length for cidr value	<code>set_masklen('192.168.10.0/24', 16)::cidr</code>	192.168.10.0/16
<code>text(inet)</code>	<code>text</code>	extract IP address and netmask length as text	<code>text(inet '192.168.1.5')</code>	192.168.1.5/32
<code>inet_same_family(inet, inet)</code>	<code>boolean</code>	are the addresses from the same family?	<code>inet_same_family('192.168.1.5/24', '::1')</code>	false
<code>inet_merge(inet, inet)</code>	<code>cidr</code>	the smallest network which includes both of the given networks	<code>inet_merge('192.168.1.5/24', '192.168.2.5/24')</code>	192.168.0.0/22

Any `cidr` value can be cast to `inet` implicitly or explicitly; therefore, the functions shown above as operating on `inet` also work on `cidr` values. (Where there are separate functions for `inet` and `cidr`, it is because the behavior should be different for the two cases.) Also, it is permitted to cast an `inet` value to `cidr`. When this is done, any bits to the right of the netmask are silently zeroed to create a valid `cidr` value. In addition, you can cast a text value to `inet` or `cidr` using normal casting syntax: for example, `inet(expression)` or `colname::cidr`.

Table 9.39 shows the functions available for use with the `macaddr` type. The function `trunc(macaddr)` returns a MAC address with the last 3 bytes set to zero. This can be used to associate the remaining prefix with a manufacturer.

Table 9.39. macaddr Functions

Function	Return Type	Description	Example	Result
<code>trunc(macaddr)</code>	<code>macaddr</code>	set last 3 bytes to zero	<code>trunc(macaddr '12:34:56:78:90:ab')</code>	12:34:56:00:00:00

The `macaddr` type also supports the standard relational operators (>, <=, etc.) for lexicographical ordering, and the bitwise arithmetic operators (~, & and |) for NOT, AND and OR.

Table 9.40 shows the functions available for use with the `macaddr8` type. The function `trunc(macaddr8)` returns a MAC address with the last 5 bytes set to zero. This can be used to associate the remaining prefix with a manufacturer.

Table 9.40. macaddr8 Functions

Function	Return Type	Description	Example	Result
<code>trunc(macaddr8)</code>	<code>macaddr8</code>	set last 5 bytes to zero	<code>trunc(macaddr8 '12:34:56:78:90:ab:cd:ef')</code>	12:34:56:00:00:00:00:00
<code>macaddr8_set7bit(macaddr8)</code>	<code>macaddr8</code>	set 7th bit to one, also known as modified EUI-64, for inclusion in an IPv6 address	<code>macaddr8_set7bit(macaddr8 '00:34:56:ab:cd:ef')</code>	02:34:56:ff:fe:ab:cd:ef

The `macaddr8` type also supports the standard relational operators (`>`, `<=`, etc.) for ordering, and the bitwise arithmetic operators (`~`, `&` and `|`) for NOT, AND and OR.

9.13. Text Search Functions and Operators

Table 9.41, Table 9.42 and Table 9.43 summarize the functions and operators that are provided for full text searching. See Chapter 12 for a detailed explanation of PostgreSQL's text search facility.

Table 9.41. Text Search Operators

Operator	Return Type	Description	Example	Result
<code>@@</code>	boolean	tsvector matches query?	<code>to_tsvector('fat cats ate rats')</code> <code>@@ to_tsquery('cat & rat')</code>	t
<code>@@@</code>	boolean	deprecated synonym for @@	<code>to_tsvector('fat cats ate rats')</code> <code>@@@ to_tsquery('cat & rat')</code>	t
<code> </code>	tsvector	concatenate tsvectors	'a:1 b:2'::tsvector 'c:1 d:2 b:3'::tsvector	'a':1 'b':2,5 'c':3 'd':4
<code>&&</code>	tsquery	AND tsqueries together	'fat rat'::tsquery && 'cat'::tsquery	('fat' 'rat') & 'cat'
<code> </code>	tsquery	OR tsqueries together	'fat rat'::tsquery 'cat'	('fat' 'rat') 'cat'

Operator	Return Type	Description	Example	Result
			'cat'::tsquery	
!!	tsquery	negate a tsquery	!! 'cat'::tsquery	!'cat'
<->	tsquery	tsquery followed by tsquery	to_tsquery('fat') <-> to_tsquery('rat')	'fat' <-> 'rat'
@>	boolean	tsquery contains another ?	'cat'::tsquery @> 'cat & rat'::tsquery	f
<@	boolean	tsquery is contained in ?	'cat'::tsquery <@ 'cat & rat'::tsquery	t

Note

The tsquery containment operators consider only the lexemes listed in the two queries, ignoring the combining operators.

In addition to the operators shown in the table, the ordinary B-tree comparison operators (=, <, etc) are defined for types tsvector and tsquery. These are not very useful for text searching but allow, for example, unique indexes to be built on columns of these types.

Table 9.42. Text Search Functions

Function	Return Type	Description	Example	Result
array_to_tsvector(text[])	tsvector	convert array of lexemes to tsvector	array_to_tsvector({'fat,cat,rat'}::text[])	'cat' 'fat' 'rat'
get_current_ts_config()	regconfig	get default text search configuration	get_current_ts_config()	english
length(tsvector)	integer	number of lexemes in tsvector	length('fat:2,cat:3,rat:5A'::tsvector)	3
numnode(tsquery)	integer	number of lexemes plus operators in tsquery	numnode('(fat & rat) cat'::tsquery)	5
plainto_tsquery([config regconfig ,] query text)	tsquery	produce tsquery ignoring punctuation	plainto_tsquery('english', 'The Fat Rats')	'fat' & 'rat'
phraseto_tsquery([config regcon-	tsquery	produce tsquery that searches for	phraseto_tsquery('eng-	'fat' <-> 'rat'

Function	Return Type	Description	Example	Result
<code>fig ,] query text)</code>		a phrase, ignoring punctuation	<code>lish', 'The Fat Rats')</code>	
<code>web-search_to_tsquery([config regconfig ,] query text)</code>	tsquery	produce tsquery from a web search style query	<code>web-search_to_tsquery('english', '"fat rat" or rat')</code>	<code>'fat' <-> 'rat' 'rat'</code>
<code>query-tree(query tsquery)</code>	text	get indexable part of a tsquery	<code>query-tree('foo & ! bar'::tsquery)</code>	<code>'foo'</code>
<code>setweight(vector tsvector, weight "char")</code>	tsvector	assign <i>weight</i> to each element of vector	<code>setweight('fat:2A cat:3 rat:5B'::tsvector, 'A')</code>	<code>'cat':3A 'fat':2A,4A 'rat':5A</code>
<code>setweight(vector tsvector, weight "char", lexemes text[])</code>	tsvector	assign <i>weight</i> to elements of vector that are listed in <i>lexemes</i>	<code>setweight('fat:2A cat:3 rat:5B'::tsvector, 'A', '{cat,rat}')</code>	<code>'cat':3A 'fat':2,4 'rat':5A</code>
<code>strip(tsvector)</code>	tsvector	remove positions and weights from tsvector	<code>strip('fat:2,4cat:3 rat:5A'::tsvector)</code>	<code>'fat' 'rat'</code>
<code>to_tsquery([config regconfig ,] query text)</code>	tsquery	normalize words and convert to tsquery	<code>to_tsquery('english', 'The & Fat & Rats')</code>	<code>'fat' & 'rat'</code>
<code>to_tsvector([config regconfig ,] document text)</code>	tsvector	reduce document text to tsvector	<code>to_tsvector('english', 'The Fat Rats')</code>	<code>'fat':2 'rat':3</code>
<code>to_tsvector([config regconfig ,] document json(b))</code>	tsvector	reduce each string value in the document to a tsvector, and then concatenate those in document order to produce a single tsvector	<code>to_tsvector('english', '{"a": "The Fat Rats"}'::json)</code>	<code>'fat':2 'rat':3</code>
<code>json(b)_to_tsvector([config regconfig ,] document json(b), filter json(b))</code>	tsvector	reduce each value in the document, specified by <i>filter</i> to a tsvector, and then concatenate those in document order to produce a single tsvec-	<code>json_to_tsvector('english', '{"a": "The Fat Rats", "b": 123}'::json, ['string', 'numeric'])</code>	<code>'123':5 'fat':2 'rat':3</code>

Function	Return Type	Description	Example	Result
		<i>tor.filter</i> is a jsonb array, that enumerates what kind of elements need to be included into the resulting <i>tsvector</i> . Possible values for <i>filter</i> are "string" (to include all string values), "numeric" (to include all numeric values in the string format), "boolean" (to include all Boolean values in the string format "true"/"false"), "key" (to include all keys) or "all" (to include all above). These values can be combined together to include, e.g. all string and numeric values.		
<code>ts_delete(vector tsvector, lexeme text)</code>	tsvector	remove given <i>lexeme</i> from <i>vector</i>	<code>ts_delete('fat:3 cat:3 rat:5A'::tsvector, 'fat')</code>	<code>'cat':3 'rat':5A</code>
<code>ts_delete(vector tsvector, lexemes text[])</code>	tsvector	remove any occurrence of lexemes in <i>lexemes</i> from <i>vector</i>	<code>ts_delete('fat:3 cat:3 rat:5A'::tsvector, ARRAY['fat', 'rat'])</code>	<code>'cat':3</code>
<code>ts_filter(vector tsvector, weights "char"[])</code>	tsvector	select only elements with given <i>weights</i> from <i>vector</i>	<code>ts_filter('fat:2,4 cat:3b rat:5A'::tsvector, '{a,b}')</code>	<code>'cat':3B 'rat':5A</code>
<code>ts_headline([config regconfig,] document text, query tsquery [, options text])</code>	text	display a query match	<code>ts_headline('x y z', 'z'::tsquery)</code>	<code>x y z</code>
<code>ts_headline([config regconfig</code>	text	display a query match	<code>ts_headline('{ "a": "x y z" }'::j-</code>	<code>{ "a": "x y z" }</code>

Function	Return Type	Description	Example	Result
<code>fig,] document json(b), query tsquery [, options text])</code>			<code>son, 'z'::tsquery)</code>	
<code>ts_rank([weights float4[],] vector tsvector, query tsquery [, normalization integer])</code>	float4	rank document for query	<code>ts_rank(textsearch, query)</code>	0.1818
<code>ts_rank_cd([weights float4[],] vector tsvector, query tsquery [, normalization integer])</code>	float4	rank document for query using cover density	<code>ts_rank_cd('{0.2, 0.4, 1.0}', textsearch, query)</code>	0.101317
<code>ts_rewrite(query tsquery, target tsquery, substitute tsquery)</code>	tsquery	replace <i>target</i> with <i>substitute</i> within query	<code>ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'foo bar'::tsquery)</code>	'b' & ('foo' 'bar')
<code>ts_rewrite(query tsquery, select text)</code>	tsquery	replace using targets and substitutes from a SELECT command	<code>SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases')</code>	'b' & ('foo' 'bar')
<code>ts_query_phrase(query1 tsquery, query2 tsquery)</code>	tsquery	make query that searches for <i>query1</i> followed by <i>query2</i> (same as <-> operator)	<code>ts_query_phrase(to_tsquery('fat'), to_tsquery('cat'))</code>	'fat' <-> 'cat'
<code>ts_query_phrase(query1 tsquery, query2 tsquery, distance integer)</code>	tsquery	make query that searches for <i>query1</i> followed by <i>query2</i> at distance <i>distance</i>	<code>ts_query_phrase(to_tsquery('fat'), to_tsquery('cat'), 10)</code>	'fat' <10> 'cat'
<code>tsvector_to_array(tsvector)</code>	text[]	convert tsvector to array of lexemes	<code>tsvector_to_array('fat:2,4 cat:3')</code>	{cat,fat, rat}

Function	Return Type	Description	Example	Result
			rat:5A'::tsvector)	
tsvector_update_trigger()	trigger	trigger function for automatic tsvector column update	CREATE TRIGGER ... tsvector_update_trigger(tsvcol, 'pg_catalog.swedish', title, body)	
tsvector_update_trigger_column()	trigger	trigger function for automatic tsvector column update	CREATE TRIGGER ... tsvector_update_trigger_column(tsvcol, configcol, title, body)	
unnest(tsvector, OUT lexeme text, OUT positions smallint[], OUT weights text)	setof record	expand a tsvector to a set of rows	unnest('fat:2,cat:3 rat:5A'::tsvector)	(fat,{3}, {D}) ...

Note

All the text search functions that accept an optional `regconfig` argument will use the configuration specified by `default_text_search_config` when that argument is omitted.

The functions in Table 9.43 are listed separately because they are not usually used in everyday text searching operations. They are helpful for development and debugging of new text search configurations.

Table 9.43. Text Search Debugging Functions

Function	Return Type	Description	Example	Result
ts_debug([config regconfig, document text, alias text, OUT description text, OUT token text, OUT dictionaries regdictionary[],	setof record	test a configuration	ts_debug('english', 'The Brightest supernovaes')	(ascii-word, "Word, all ASCII", The, {english_stem}, english_stem, { }) ...

Function	Return Type	Description	Example	Result
OUT <i>dictionary</i> regdictionary, OUT <i>lexemes</i> text[])				
<i>ts_lexize</i> (<i>dict</i> regdictionary, <i>token</i> text)	text[]	test a dictionary	<i>ts_lexize</i> ('english_stem', 'stars')	{star}
<i>ts_parse</i> (<i>parser_name</i> text, <i>document</i> text, OUT <i>tokid</i> integer, OUT <i>token</i> text)	setof record	test a parser	<i>ts_parse</i> ('default', 'foo - bar')	(1,foo) ...
<i>ts_parse</i> (<i>parser_oid</i> oid, <i>document</i> text, OUT <i>tokid</i> integer, OUT <i>token</i> text)	setof record	test a parser	<i>ts_parse</i> (3722, 'foo - bar')	(1,foo) ...
<i>ts_token_type</i> (<i>parser_name</i> text, OUT <i>tokid</i> integer, OUT <i>alias</i> text, OUT <i>description</i> text)	setof record	get token types defined by parser	<i>ts_token_type</i> ('default')	(1,ascii-word, "Word, all ASCII") ...
<i>ts_token_type</i> (<i>parser_oid</i> oid, OUT <i>tokid</i> integer, OUT <i>alias</i> text, OUT <i>description</i> text)	setof record	get token types defined by parser	<i>ts_token_type</i> (3722)	(1,ascii-word, "Word, all ASCII") ...
<i>ts_stat</i> (<i>sql_query</i> text, [<i>weights</i> text,] OUT <i>word</i> text, OUT <i>ndoc</i> integer, OUT <i>nentry</i> integer)	setof record	get statistics of a tsvector column	<i>ts_stat</i> ('SELECT vector from apod')	(foo,10,15) ...

9.14. XML Functions

The functions and function-like expressions described in this section operate on values of type `xml`. See Section 8.13 for information about the `xml` type. The function-like expressions `xmlparse` and `xmlserialize` for converting to and from type `xml` are documented there, not in this section.

Use of most of these functions requires PostgreSQL to have been built with `configure --with-libxml`.

9.14.1. Producing XML Content

A set of functions and function-like expressions are available for producing XML content from SQL data. As such, they are particularly suitable for formatting query results into XML documents for processing in client applications.

9.14.1.1. `xmlcomment`

`xmlcomment (text)`

The function `xmlcomment` creates an XML value containing an XML comment with the specified text as content. The text cannot contain “--” or end with a “-” so that the resulting construct is a valid XML comment. If the argument is null, the result is null.

Example:

```
SELECT xmlcomment('hello');
```

```
xmlcomment
-----
<!--hello-->
```

9.14.1.2. `xmlconcat`

`xmlconcat (xml [, ...])`

The function `xmlconcat` concatenates a list of individual XML values to create a single value containing an XML content fragment. Null values are omitted; the result is only null if there are no non-null arguments.

Example:

```
SELECT xmlconcat(' <abc/>', ' <bar>foo</bar>' );
```

```
xmlconcat
-----
<abc/><bar>foo</bar>
```

XML declarations, if present, are combined as follows. If all argument values have the same XML version declaration, that version is used in the result, else no version is used. If all argument values have the standalone declaration value “yes”, then that value is used in the result. If all argument values have a standalone declaration value and at least one is “no”, then that is used in the result. Else the result will have no standalone declaration. If the result is determined to require a standalone declaration but no version declaration, a version declaration with version 1.0 will be used because XML requires an XML declaration to contain a version declaration. Encoding declarations are ignored and removed in all cases.

Example:

```
SELECT xmlconcat('<?xml version="1.1"?><foo/>', '<?xml
version="1.1" standalone="no"?><bar/>');
```

```
          xmlconcat
-----
<?xml version="1.1"?><foo/><bar/>
```

9.14.1.3. xmlelement

```
xmlelement(name name [, xmlattributes(value [AS attname] [, ... ])]
[, content, ...])
```

The `xmlelement` expression produces an XML element with the given name, attributes, and content.

Examples:

```
SELECT xmlelement(name foo);
```

```
          xmlelement
-----
<foo/>
```

```
SELECT xmlelement(name foo, xmlattributes('xyz' as bar));
```

```
          xmlelement
-----
<foo bar="xyz"/>
```

```
SELECT xmlelement(name foo, xmlattributes(current_date as bar),
'cont', 'ent');
```

```
          xmlelement
-----
<foo bar="2007-01-26">content</foo>
```

Element and attribute names that are not valid XML names are escaped by replacing the offending characters by the sequence `_xHHHH_`, where `HHHH` is the character's Unicode codepoint in hexadecimal notation. For example:

```
SELECT xmlelement(name "foo$bar", xmlattributes('xyz' as "a&b"));
```

```
          xmlelement
-----
<foo_x0024_bar a_x0026_b="xyz"/>
```

An explicit attribute name need not be specified if the attribute value is a column reference, in which case the column's name will be used as the attribute name by default. In other cases, the attribute must be given an explicit name. So this example is valid:

```
CREATE TABLE test (a xml, b xml);
SELECT xmlelement(name test, xmlattributes(a, b)) FROM test;
```

But these are not:

```
SELECT xmlelement(name test, xmlattributes('constant'), a, b) FROM
test;
SELECT xmlelement(name test, xmlattributes(func(a, b))) FROM test;
```

Element content, if specified, will be formatted according to its data type. If the content is itself of type xml, complex XML documents can be constructed. For example:

```
SELECT xmlelement(name foo, xmlattributes('xyz' as bar),
xmlelement(name abc),
xmlcomment('test'),
xmlelement(name xyz));
```

xmlelement

```
-----
<foo bar="xyz"><abc/><!--test--><xyz/></foo>
```

Content of other types will be formatted into valid XML character data. This means in particular that the characters <, >, and & will be converted to entities. Binary data (data type bytea) will be represented in base64 or hex encoding, depending on the setting of the configuration parameter xmlbinary. The particular behavior for individual data types is expected to evolve in order to align the PostgreSQL mappings with those specified in SQL:2006 and later, as discussed in Section D.3.1.3.

9.14.1.4. xmlforest

```
xmlforest(content [AS name] [, ...])
```

The xmlforest expression produces an XML forest (sequence) of elements using the given names and content.

Examples:

```
SELECT xmlforest('abc' AS foo, 123 AS bar);
```

xmlforest

```
-----
<foo>abc</foo><bar>123</bar>
```

```
SELECT xmlforest(table_name, column_name)
FROM information_schema.columns
WHERE table_schema = 'pg_catalog';
```

xmlforest

```
-----
<table_name>pg_authid</table_name><column_name>rolname</
column_name>
<table_name>pg_authid</table_name><column_name>rolsuper</
column_name>
...
```

As seen in the second example, the element name can be omitted if the content value is a column reference, in which case the column name is used by default. Otherwise, a name must be specified.

Element names that are not valid XML names are escaped as shown for xmlelement above. Similarly, content data is escaped to make valid XML content, unless it is already of type xml.

Note that XML forests are not valid XML documents if they consist of more than one element, so it might be useful to wrap `xmlforest` expressions in `xmlelement`.

9.14.1.5. `xmlpi`

```
xmlpi(name target [, content])
```

The `xmlpi` expression creates an XML processing instruction. The content, if present, must not contain the character sequence `?>`.

Example:

```
SELECT xmlpi(name php, 'echo "hello world";');

          xmlpi
-----
<?php echo "hello world";?>
```

9.14.1.6. `xmlroot`

```
xmlroot(xml, version text | no value [, standalone yes|no|no
value])
```

The `xmlroot` expression alters the properties of the root node of an XML value. If a version is specified, it replaces the value in the root node's version declaration; if a standalone setting is specified, it replaces the value in the root node's standalone declaration.

```
SELECT xmlroot(xmlparse(document '<?xml version="1.1"?
><content>abc</content>'),
          version '1.0', standalone yes);

          xmlroot
-----
<?xml version="1.0" standalone="yes"?>
<content>abc</content>
```

9.14.1.7. `xmlagg`

```
xmlagg(xml)
```

The function `xmlagg` is, unlike the other functions described here, an aggregate function. It concatenates the input values to the aggregate function call, much like `xmlconcat` does, except that concatenation occurs across rows rather than across expressions in a single row. See Section 9.20 for additional information about aggregate functions.

Example:

```
CREATE TABLE test (y int, x xml);
INSERT INTO test VALUES (1, '<foo>abc</foo>');
INSERT INTO test VALUES (2, '<bar/>');
SELECT xmlagg(x) FROM test;

          xmlagg
-----
```

```
<foo>abc</foo><bar/>
```

To determine the order of the concatenation, an `ORDER BY` clause may be added to the aggregate call as described in Section 4.2.7. For example:

```
SELECT xmlagg(x ORDER BY y DESC) FROM test;
       xmlagg
-----
<bar/><foo>abc</foo>
```

The following non-standard approach used to be recommended in previous versions, and may still be useful in specific cases:

```
SELECT xmlagg(x) FROM (SELECT * FROM test ORDER BY y DESC) AS tab;
       xmlagg
-----
<bar/><foo>abc</foo>
```

9.14.2. XML Predicates

The expressions described in this section check properties of `xml` values.

9.14.2.1. IS DOCUMENT

```
xml IS DOCUMENT
```

The expression `IS DOCUMENT` returns true if the argument XML value is a proper XML document, false if it is not (that is, it is a content fragment), or null if the argument is null. See Section 8.13 about the difference between documents and content fragments.

9.14.2.2. IS NOT DOCUMENT

```
xml IS NOT DOCUMENT
```

The expression `IS NOT DOCUMENT` returns false if the argument XML value is a proper XML document, true if it is not (that is, it is a content fragment), or null if the argument is null.

9.14.2.3. XMLEXISTS

```
XMLEXISTS(text PASSING [BY { REF | VALUE }] xml [BY { REF |
VALUE }])
```

The function `xmlexists` evaluates an XPath 1.0 expression (the first argument), with the passed XML value as its context item. The function returns false if the result of that evaluation yields an empty node-set, true if it yields any other value. The function returns null if any argument is null. A nonnull value passed as the context item must be an XML document, not a content fragment or any non-XML value.

Example:

```
SELECT xmlexists('//town[text() = ''Toronto'']' PASSING BY VALUE
'<towns><town>Toronto</town><town>Ottawa</town></towns>');

xmlexists
```

```
-----
t
(1 row)
```

The `BY REF` and `BY VALUE` clauses are accepted in PostgreSQL, but are ignored, as discussed in Section D.3.2. In the SQL standard, the `xml_exists` function evaluates an expression in the XML Query language, but PostgreSQL allows only an XPath 1.0 expression, as discussed in Section D.3.1.

9.14.2.4. `xml_is_well_formed`

```
xml_is_well_formed(text)
xml_is_well_formed_document(text)
xml_is_well_formed_content(text)
```

These functions check whether a `text` string is well-formed XML, returning a Boolean result. `xml_is_well_formed_document` checks for a well-formed document, while `xml_is_well_formed_content` checks for well-formed content. `xml_is_well_formed` does the former if the `xmloption` configuration parameter is set to `DOCUMENT`, or the latter if it is set to `CONTENT`. This means that `xml_is_well_formed` is useful for seeing whether a simple cast to type `xml` will succeed, whereas the other two functions are useful for seeing whether the corresponding variants of `XMLPARSE` will succeed.

Examples:

```
SET xmloption TO DOCUMENT;
SELECT xml_is_well_formed('<>');
xml_is_well_formed
```

```
-----
f
(1 row)
```

```
SELECT xml_is_well_formed('<abc/>');
xml_is_well_formed
```

```
-----
t
(1 row)
```

```
SET xmloption TO CONTENT;
SELECT xml_is_well_formed('abc');
xml_is_well_formed
```

```
-----
t
(1 row)
```

```
SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://
postgresql.org/stuff">bar</pg:foo>');
xml_is_well_formed_document
```

```
-----
t
(1 row)
```

```
SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://
postgresql.org/stuff">bar</my:foo>');
xml_is_well_formed_document
```

```
-----
f
(1 row)
```

The last example shows that the checks include whether namespaces are correctly matched.

9.14.3. Processing XML

To process values of data type `xml`, PostgreSQL offers the functions `xpath` and `xpath_exists`, which evaluate XPath 1.0 expressions, and the `XMLTABLE` table function.

9.14.3.1. `xpath`

```
xpath(xpath, xml [, nsarray])
```

The function `xpath` evaluates the XPath 1.0 expression `xpath` (a `text` value) against the XML value `xml`. It returns an array of XML values corresponding to the node-set produced by the XPath expression. If the XPath expression returns a scalar value rather than a node-set, a single-element array is returned.

The second argument must be a well formed XML document. In particular, it must have a single root node element.

The optional third argument of the function is an array of namespace mappings. This array should be a two-dimensional `text` array with the length of the second axis being equal to 2 (i.e., it should be an array of arrays, each of which consists of exactly 2 elements). The first element of each array entry is the namespace name (alias), the second the namespace URI. It is not required that aliases provided in this array be the same as those being used in the XML document itself (in other words, both in the XML document and in the `xpath` function context, aliases are *local*).

Example:

```
SELECT xpath('/my:a/text()', '<my:a xmlns:my="http://
example.com">test</my:a>',
           ARRAY[ARRAY['my', 'http://example.com']]);
```

```
xpath
-----
 {test}
(1 row)
```

To deal with default (anonymous) namespaces, do something like this:

```
SELECT xpath('//mydefns:b/text()', '<a xmlns="http://
example.com"><b>test</b></a>',
           ARRAY[ARRAY['mydefns', 'http://example.com']]);
```

```
xpath
-----
 {test}
(1 row)
```

9.14.3.2. `xpath_exists`

```
xpath_exists(xpath, xml [, nsarray])
```

The function `xpath_exists` is a specialized form of the `xpath` function. Instead of returning the individual XML values that satisfy the XPath 1.0 expression, this function returns a Boolean indicating whether the query was satisfied or not (specifically, whether it produced any value other than an empty

node-set). This function is equivalent to the `XMLEXISTS` predicate, except that it also offers support for a namespace mapping argument.

Example:

```
SELECT xpath_exists('/my:a/text()', '<my:a xmlns:my="http://
example.com">test</my:a>',
                ARRAY[ARRAY['my', 'http://example.com']]);
```

```
xpath_exists
-----
t
(1 row)
```

9.14.3.3. `xmltable`

```
xmltable( [XMLNAMESPACES(namespace uri AS namespace name[, ...]), ]
         row_expression PASSING [BY { REF |
VALUE }] document_expression [BY { REF | VALUE }]
         COLUMNS name { type [PATH column_expression]
[DEFAULT default_expression] [NOT NULL | NULL]
| FOR ORDINALITY }
         [, ...]
)
```

The `xmltable` function produces a table based on the given XML value, an XPath filter to extract rows, and a set of column definitions.

The optional `XMLNAMESPACES` clause is a comma-separated list of namespaces. It specifies the XML namespaces used in the document and their aliases. A default namespace specification is not currently supported.

The required `row_expression` argument is an XPath 1.0 expression that is evaluated, passing the `document_expression` as its context item, to obtain a set of XML nodes. These nodes are what `xmltable` transforms into output rows. No rows will be produced if the `document_expression` is null, nor if the `row_expression` produces an empty node-set or any value other than a node-set.

`document_expression` provides the context item for the `row_expression`. It must be a well-formed XML document; fragments/forests are not accepted. The `BY REF` and `BY VALUE` clauses are accepted but ignored, as discussed in Section D.3.2. In the SQL standard, the `xmltable` function evaluates expressions in the XML Query language, but PostgreSQL allows only XPath 1.0 expressions, as discussed in Section D.3.1.

The mandatory `COLUMNS` clause specifies the list of columns in the output table. Each entry describes a single column. See the syntax summary above for the format. The column name and type are required; the path, default and nullability clauses are optional.

A column marked `FOR ORDINALITY` will be populated with row numbers, starting with 1, in the order of nodes retrieved from the `row_expression`'s result node-set. At most one column may be marked `FOR ORDINALITY`.

Note

XPath 1.0 does not specify an order for nodes in a node-set, so code that relies on a particular order of the results will be implementation-dependent. Details can be found in Section D.3.1.2.

The *column_expression* for a column is an XPath 1.0 expression that is evaluated for each row, with the current node from the *row_expression* result as its context item, to find the value of the column. If no *column_expression* is given, then the column name is used as an implicit path.

If a column's XPath expression returns a non-XML value (limited to string, boolean, or double in XPath 1.0) and the column has a PostgreSQL type other than `xml`, the column will be set as if by assigning the value's string representation to the PostgreSQL type. (If the value is a boolean, its string representation is taken to be 1 or 0 if the output column's type category is numeric, otherwise `true` or `false`.)

If a column's XPath expression returns a non-empty set of XML nodes and the column's PostgreSQL type is `xml`, the column will be assigned the expression result exactly, if it is of document or content form.²

A non-XML result assigned to an `xml` output column produces content, a single text node with the string value of the result. An XML result assigned to a column of any other type may not have more than one node, or an error is raised. If there is exactly one node, the column will be set as if by assigning the node's string value (as defined for the XPath 1.0 `string` function) to the PostgreSQL type.

The string value of an XML element is the concatenation, in document order, of all text nodes contained in that element and its descendants. The string value of an element with no descendant text nodes is an empty string (not NULL). Any `xsi:nil` attributes are ignored. Note that the whitespace-only `text()` node between two non-text elements is preserved, and that leading whitespace on a `text()` node is not flattened. The XPath 1.0 `string` function may be consulted for the rules defining the string value of other XML node types and non-XML values.

The conversion rules presented here are not exactly those of the SQL standard, as discussed in Section D.3.1.3.

If the path expression returns an empty node-set (typically, when it does not match) for a given row, the column will be set to NULL, unless a *default_expression* is specified; then the value resulting from evaluating that expression is used.

Columns may be marked NOT NULL. If the *column_expression* for a NOT NULL column does not match anything and there is no DEFAULT or the *default_expression* also evaluates to null, an error is reported.

A *default_expression*, rather than being evaluated immediately when `xmltable` is called, is evaluated each time a default is needed for the column. If the expression qualifies as stable or immutable, the repeat evaluation may be skipped. This means that you can usefully use volatile functions like `nextval` in *default_expression*.

Examples:

```
CREATE TABLE xmldata AS SELECT
xml $$
<ROWS>
  <ROW id="1">
    <COUNTRY_ID>AU</COUNTRY_ID>
    <COUNTRY_NAME>Australia</COUNTRY_NAME>
  </ROW>
  <ROW id="5">
    <COUNTRY_ID>JP</COUNTRY_ID>
    <COUNTRY_NAME>Japan</COUNTRY_NAME>
    <PREMIER_NAME>Shinzo Abe</PREMIER_NAME>
    <SIZE unit="sq_mi">145935</SIZE>

```

² A result containing more than one element node at the top level, or non-whitespace text outside of an element, is an example of content form. An XPath result can be of neither form, for example if it returns an attribute node selected from the element that contains it. Such a result will be put into content form with each such disallowed node replaced by its string value, as defined for the XPath 1.0 `string` function.

```

</ROW>
<ROW id="6">
  <COUNTRY_ID>SG</COUNTRY_ID>
  <COUNTRY_NAME>Singapore</COUNTRY_NAME>
  <SIZE unit="sq_km">697</SIZE>
</ROW>
</ROWS>
$$ AS data;

SELECT xmltable.*
  FROM xmldata,
       XMLTABLE('//ROWS/ROW'
                PASSING data
                COLUMNS id int PATH '@id',
                        ordinality FOR ORDINALITY,
                        "COUNTRY_NAME" text,
                        country_id text PATH 'COUNTRY_ID',
                        size_sq_km float PATH 'SIZE[@unit =
"sq_km"]',
                        size_other text PATH
                        'concat(SIZE[@unit!="sq_km"], " ",
SIZE[@unit!="sq_km"]/@unit)',
                        premier_name text PATH 'PREMIER_NAME'
DEFAULT 'not specified') ;

```

id	ordinality	COUNTRY_NAME	country_id	size_sq_km	size_other	premier_name
1	1	Australia	AU			not specified
5	2	Japan	JP		145935	Shinzo Abe
6	3	Singapore	SG	697		not specified

The following example shows concatenation of multiple text() nodes, usage of the column name as XPath filter, and the treatment of whitespace, XML comments and processing instructions:

```

CREATE TABLE xmlelements AS SELECT
xml $$
  <root>
    <element> Hello<!-- xyxxz -->2a2<?aaaaa?> <!--x--> bbb<x>xxx</
x>CC </element>
  </root>
$$ AS data;

SELECT xmltable.*
  FROM xmlelements, XMLTABLE('/root' PASSING data COLUMNS element
text);
      element
-----
Hello2a2  bbbxxxCC

```

The following example illustrates how the XMLNAMESPACES clause can be used to specify a list of namespaces used in the XML document as well as in the XPath expressions:

```

WITH xmldata(data) AS (VALUES (
<example xmlns="http://example.com/myns" xmlns:B="http://
example.com/b">
  <item foo="1" B:bar="2"/>
  <item foo="3" B:bar="4"/>
  <item foo="4" B:bar="5"/>
</example>'::xml)
)
SELECT xmltable.*
  FROM XMLTABLE(XMLNAMESPACES('http://example.com/myns' AS x,
                              'http://example.com/b' AS "B"),
                '/x:example/x:item'
                PASSING (SELECT data FROM xmldata)
                COLUMNS foo int PATH '@foo',
                          bar int PATH '@B:bar');

```

foo	bar
1	2
3	4
4	5

(3 rows)

9.14.4. Mapping Tables to XML

The following functions map the contents of relational tables to XML values. They can be thought of as XML export functionality:

```

table_to_xml(tbl regclass, nulls boolean, tableforest boolean,
             targetns text)
query_to_xml(query text, nulls boolean, tableforest boolean,
             targetns text)
cursor_to_xml(cursor refcursor, count int, nulls boolean,
              tableforest boolean, targetns text)

```

The return type of each function is xml.

`table_to_xml` maps the content of the named table, passed as parameter `tbl`. The `regclass` type accepts strings identifying tables using the usual notation, including optional schema qualifications and double quotes. `query_to_xml` executes the query whose text is passed as parameter `query` and maps the result set. `cursor_to_xml` fetches the indicated number of rows from the cursor specified by the parameter `cursor`. This variant is recommended if large tables have to be mapped, because the result value is built up in memory by each function.

If `tableforest` is false, then the resulting XML document looks like this:

```

<tablename>
  <row>
    <columnname1>data</columnname1>
    <columnname2>data</columnname2>
  </row>

  <row>
    ...
  </row>

  ...
</tablename>

```

If *tableforest* is true, the result is an XML content fragment that looks like this:

```
<tablename>
  <columnname1>data</columnname1>
  <columnname2>data</columnname2>
</tablename>
```

```
<tablename>
  ...
</tablename>
```

```
...
```

If no table name is available, that is, when mapping a query or a cursor, the string *table* is used in the first format, *row* in the second format.

The choice between these formats is up to the user. The first format is a proper XML document, which will be important in many applications. The second format tends to be more useful in the *cursor_to_xml* function if the result values are to be reassembled into one document later on. The functions for producing XML content discussed above, in particular *xmlElement*, can be used to alter the results to taste.

The data values are mapped in the same way as described for the function *xmlElement* above.

The parameter *nulls* determines whether null values should be included in the output. If true, null values in columns are represented as:

```
<columnname xsi:nil="true"/>
```

where *xsi* is the XML namespace prefix for XML Schema Instance. An appropriate namespace declaration will be added to the result value. If false, columns containing null values are simply omitted from the output.

The parameter *targetns* specifies the desired XML namespace of the result. If no particular namespace is wanted, an empty string should be passed.

The following functions return XML Schema documents describing the mappings performed by the corresponding functions above:

```
table_to_xmlschema(tbl regclass, nulls boolean, tableforest
  boolean, targetns text)
query_to_xmlschema(query text, nulls boolean, tableforest boolean,
  targetns text)
cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest
  boolean, targetns text)
```

It is essential that the same parameters are passed in order to obtain matching XML data mappings and XML Schema documents.

The following functions produce XML data mappings and the corresponding XML Schema in one document (or forest), linked together. They can be useful where self-contained and self-describing results are wanted:

```
table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest
  boolean, targetns text)
query_to_xml_and_xmlschema(query text, nulls boolean, tableforest
  boolean, targetns text)
```

In addition, the following functions are available to produce analogous mappings of entire schemas or the entire current database:

```

schema_to_xml(schema name, nulls boolean, tableforest boolean,
  targetns text)
schema_to_xmlschema(schema name, nulls boolean, tableforest
  boolean, targetns text)
schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest
  boolean, targetns text)

database_to_xml(nulls boolean, tableforest boolean, targetns text)
database_to_xmlschema(nulls boolean, tableforest boolean, targetns
  text)
database_to_xml_and_xmlschema(nulls boolean, tableforest boolean,
  targetns text)

```

Note that these potentially produce a lot of data, which needs to be built up in memory. When requesting content mappings of large schemas or databases, it might be worthwhile to consider mapping the tables separately instead, possibly even through a cursor.

The result of a schema content mapping looks like this:

```

<schemaname>
  table1-mapping
  table2-mapping
  ...
</schemaname>

```

where the format of a table mapping depends on the *tableforest* parameter as explained above.

The result of a database content mapping looks like this:

```

<dbname>
  <schemaname1>
    ...
  </schemaname1>
  <schemaname2>
    ...
  </schemaname2>
  ...
</dbname>

```

where the schema mapping is as above.

As an example of using the output produced by these functions, Figure 9.1 shows an XSLT stylesheet that converts the output of *table_to_xml_and_xmlschema* to an HTML document containing a tabular rendition of the table data. In a similar manner, the results from these functions can be converted into other XML-based formats.

Figure 9.1. XSLT Stylesheet for Converting SQL/XML Output to HTML

```

<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
  xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns="http://www.w3.org/1999/xhtml"
>

  <xsl:output method="xml"
    doctype-system="http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"
    doctype-public="-//W3C/DTD XHTML 1.0 Strict//EN"
    indent="yes"/>

  <xsl:template match="/*">
    <xsl:variable name="schema" select="//xsd:schema"/>
    <xsl:variable name="tabletypename"
      select="$schema/
xsd:element[@name=name(current())]/@type"/>
    <xsl:variable name="rowtypename"
      select="$schema/xsd:complexType[@name=
$tabletypename]/xsd:sequence/xsd:element[@name='row']/@type"/>

    <html>
      <head>
        <title><xsl:value-of select="name(current())"/></title>
      </head>
      <body>
        <table>
          <tr>
            <xsl:for-each select="$schema/xsd:complexType[@name=
$rowtypename]/xsd:sequence/xsd:element/@name">
              <th><xsl:value-of select="."/></th>
            </xsl:for-each>
          </tr>

          <xsl:for-each select="row">
            <tr>
              <xsl:for-each select="*">
                <td><xsl:value-of select="."/></td>
              </xsl:for-each>
            </tr>
          </xsl:for-each>
        </table>
      </body>
    </html>
  </xsl:template>

</xsl:stylesheet>

```

9.15. JSON Functions and Operators

This section describes:

- functions and operators for processing and creating JSON data

- the SQL/JSON path language

To learn more about the SQL/JSON standard, see [sqltr-19075-6]. For details on JSON types supported in PostgreSQL, see Section 8.14.

9.15.1. Processing and Creating JSON Data

Table 9.44 shows the operators that are available for use with JSON data types (see Section 8.14).

Table 9.44. json and jsonb Operators

Operator	Right Operand Type	Return type	Description	Example	Example Result
->	int	json or jsonb	Get JSON array element (indexed from zero, negative integers count from the end)	'[{ "a": "foo", "b": "bar"}, {"c": "baz"}]'::json->2	{ "c": "baz" }
->	text	json or jsonb	Get JSON object field by key	'{ "a": "foo", "b": "bar"}'::json->'a'	{ "b": "bar" }
->>	int	text	Get JSON array element as text	'[1, 2, 3]'::json->>2	3
->>	text	text	Get JSON object field as text	'{ "a": 1, "b": 2}'::json->>'b'	2
#>	text[]	json or jsonb	Get JSON object at the specified path	'{ "a": { "b": { "c": "foo" } } }'::json#>'a,b'	{ "c": "foo" }
#>>	text[]	text	Get JSON object at the specified path as text	'{ "a": [1, 2, 3], "b": [4, 5, 6] }'::json#>>'a,2'	3

Note

There are parallel variants of these operators for both the json and jsonb types. The field/element/path extraction operators return the same type as their left-hand input (either json or jsonb), except for those specified as returning text, which coerce the value to text. The field/element/path extraction operators return NULL, rather than failing, if the JSON input does not have the right structure to match the request; for example if no such element exists. The field/element/path extraction operators that accept integer JSON array subscripts all support negative subscripting from the end of arrays.

The standard comparison operators shown in Table 9.1 are available for jsonb, but not for json. They follow the ordering rules for B-tree operations outlined at Section 8.14.4.

Some further operators also exist only for jsonb, as shown in Table 9.45. Many of these operators can be indexed by jsonb operator classes. For a full description of jsonb containment and existence

semantics, see Section 8.14.3. Section 8.14.4 describes how these operators can be used to effectively index `jsonb` data.

Table 9.45. Additional `jsonb` Operators

Operator	Right Operand Type	Description	Example
@>	<code>jsonb</code>	Does the left JSON value contain the right JSON path/value entries at the top level?	<code>'{"a":1, "b":2}'::jsonb @> '{"b":2}'::jsonb</code>
<@	<code>jsonb</code>	Are the left JSON path/value entries contained at the top level within the right JSON value?	<code>'{"b":2}'::jsonb <@ '{"a":1, "b":2}'::jsonb</code>
?	<code>text</code>	Does the <i>string</i> exist as a top-level key within the JSON value?	<code>'{"a":1, "b":2}'::jsonb ? 'b'</code>
?	<code>text[]</code>	Do any of these array <i>strings</i> exist as top-level keys?	<code>'{"a":1, "b":2, "c":3}'::jsonb ? array['b', 'c']</code>
?&	<code>text[]</code>	Do all of these array <i>strings</i> exist as top-level keys?	<code>'["a", "b"]'::jsonb ?& array['a', 'b']</code>
	<code>jsonb</code>	Concatenate two <code>jsonb</code> values into a new <code>jsonb</code> value	<code>'["a", "b"]'::jsonb '{"c", "d"}'::jsonb</code>
-	<code>text</code>	Delete key/value pair or <i>string</i> element from left operand. Key/value pairs are matched based on their key value.	<code>'{"a": "b"}'::jsonb - 'a'</code>
-	<code>text[]</code>	Delete multiple key/value pairs or <i>string</i> elements from left operand. Key/value pairs are matched based on their key value.	<code>'{"a": "b", "c": "d"}'::jsonb - '{a,c}'::text[]</code>
-	<code>integer</code>	Delete the array element with specified index (Negative integers count from the end). Throws an error if top level container is not an array.	<code>'["a", "b"]'::jsonb - 1</code>
#-	<code>text[]</code>	Delete the field or element with specified path (for JSON arrays, negative integers count from the end)	<code>'["a", {"b":1}]'::jsonb #- '{1,b}'</code>
@?	<code>jsonpath</code>	Does JSON path return any item for the specified JSON value?	<code>'{"a": [1,2,3,4,5]}'::jsonb @? '\$.a[*] ? (@ > 2)'</code>

Operator	Right Operand Type	Description	Example
@@	jsonpath	Returns the result of JSON path predicate check for the specified JSON value. Only the first item of the result is taken into account. If the result is not Boolean, then null is returned.	'{"a": [1,2,3,4,5]}'::jsonb @@ '\$.a[*] > 2'

Note

The || operator concatenates the elements at the top level of each of its operands. It does not operate recursively. For example, if both operands are objects with a common key field name, the value of the field in the result will just be the value from the right hand operand.

Note

The @? and @@ operators suppress the following errors: lacking object field or array element, unexpected JSON item type, and numeric errors. This behavior might be helpful while searching over JSON document collections of varying structure.

Table 9.46 shows the functions that are available for creating json and jsonb values. (There are no equivalent functions for jsonb, of the row_to_json and array_to_json functions. However, the to_jsonb function supplies much the same functionality as these functions would.)

Table 9.46. JSON Creation Functions

Function	Description	Example	Example Result
to_json(anyelement) to_jsonb(anyelement)	Returns the value as json or jsonb. Arrays and composites are converted (recursively) to arrays and objects; otherwise, if there is a cast from the type to json, the cast function will be used to perform the conversion; otherwise, a scalar value is produced. For any scalar type other than a number, a Boolean, or a null value, the text representation will be used, in such a fashion that it is a valid json or jsonb value.	to_json('Fred said "Hi."'::text)	"Fred said \"Hi.\\\""
array_to_json(anyarray [, pretty_bool])	Returns the array as a JSON array. A PostgreSQL multidimen-	array_to_json('{{1,5},{99,100}}'::int[])	[[1,5],[99,100]]

Function	Description	Example	Example Result
	sional array becomes a JSON array of arrays. Line feeds will be added between dimension-1 elements if <i>pretty_bool</i> is true.		
<code>row_to_json(record [, pretty_bool])</code>	Returns the row as a JSON object. Line feeds will be added between level-1 elements if <i>pretty_bool</i> is true.	<code>row_to_json(row(1, 'foo'))</code>	<code>{"f1":1,"f2":"foo"}</code>
<code>json_build_array(VARIADIC "any")</code> <code>jsonb_build_array(VARIADIC "any")</code>	Builds a possibly-heterogeneously-typed JSON array out of a variadic argument list.	<code>json_build_array(1,2,'3',4,5)</code>	<code>[1, 2, "3", 4, 5]</code>
<code>json_build_object(VARIADIC "any")</code> <code>jsonb_build_object(VARIADIC "any")</code>	Builds a JSON object out of a variadic argument list. By convention, the argument list consists of alternating keys and values.	<code>json_build_object('foo',1,'bar',2)</code>	<code>{"foo": 1, "bar": 2}</code>
<code>json_object(text[])</code> <code>jsonb_object(text[])</code>	Builds a JSON object out of a text array. The array must have either exactly one dimension with an even number of members, in which case they are taken as alternating key/value pairs, or two dimensions such that each inner array has exactly two elements, which are taken as a key/value pair.	<code>json_object('{a, 1, b, "def", c, 3.5}')</code> <code>json_object('{{a, 1}, {b, "def"} , {c, 3.5}}')</code>	<code>{"a": "1", "b": "def", "c": "3.5"}</code>
<code>json_object(keys text[], values text[])</code> <code>jsonb_object(keys text[], values text[])</code>	This form of <code>json_object</code> takes keys and values pairwise from two separate arrays. In all other respects it is identical to the one-argument form.	<code>json_object('{a, b}', '{1,2}')</code>	<code>{"a": "1", "b": "2"}</code>

Note

`array_to_json` and `row_to_json` have the same behavior as `to_json` except for offering a pretty-printing option. The behavior described for `to_json` likewise applies to each individual value converted by the other JSON creation functions.

Note

The `hstore` extension has a cast from `hstore` to `json`, so that `hstore` values converted via the JSON creation functions will be represented as JSON objects, not as primitive string values.

Table 9.47 shows the functions that are available for processing `json` and `jsonb` values.

Table 9.47. JSON Processing Functions

Function	Return Type	Description	Example	Example Result
<code>json_array_length(json)</code> <code>jsonb_array_length(jsonb)</code>	int	Returns the number of elements in the outermost JSON array.	<code>json_array_length('[[1,2,3,{\"f1\":1,\"f2\":[5,6]},4]')</code>	5
<code>json_each(json)</code> <code>jsonb_each(jsonb)</code>	setof text, json setof text, jsonb key value key value	Expands the outermost JSON object into a set of key/value pairs.	<code>select * from json_each('{\"a\":\"foo\",\"b\":\"bar\"}')</code>	<pre> key value ----- a "foo" b "bar" </pre>
<code>json_each_text(json)</code> <code>jsonb_each_text(jsonb)</code>	setof text, text key value key value	Expands the outermost JSON object into a set of key/value pairs. The returned values will be of type <code>text</code> .	<code>select * from json_each_text('{\"a\":\"foo\",\"b\":\"bar\"}')</code>	<pre> key value ----- a foo b bar </pre>
<code>json_extract_path(from_json json, VARIADIC path_elems text[])</code> <code>jsonb_extract_path(from_json jsonb, VARIADIC path_elems text[])</code>	json json, jsonb jsonb	Returns JSON value pointed to by <code>path_elems</code> (equivalent to <code>#></code> operator).	<code>json_extract_path('\"f2\":{\"f3\":1,\"f4\":{\"f5\":99,\"f6\":\"foo\"}}', 'f4')</code>	<pre> {\"f5\":99,\"f6\":\"foo\"} </pre>
<code>json_extract_path_text(from_json json, VARIADIC path_elems text[])</code> <code>jsonb_extract_path_text(from_json jsonb, VARIADIC path_elems text[])</code>	text	Returns JSON value pointed to by <code>path_elems</code> as <code>text</code> (equivalent to <code>#>></code> operator).	<code>json_extract_path_text('\"f2\":{\"f3\":1,\"f4\":{\"f5\":99,\"f6\":\"foo\"}}', 'f4', 'f6')</code>	<pre> foo </pre>

Function	Return Type	Description	Example	Example Result						
<code>t_path_text(from_json jsonb, VARIADIC path_elems text[])</code>										
<code>json_object_keys(json)</code> <code>jsonb_object_keys(jsonb)</code>	setof text	Returns set of keys in the outermost JSON object.	<code>json_object_keys('{ "f1": "foo", "f4": "b" })'</code>	<code>json_object_keys('{ "f1": "foo", "f2": "bar", "f4": "b" })'</code> ----- f1 f2						
<code>json_populate_record(base anyelement, from_json json)</code> <code>jsonb_populate_record(base anyelement, from_json jsonb)</code>	anyelement	Expands the object in <i>from_json</i> to a row whose columns match the record type defined by <i>base</i> (see note below).	<code>select * from json_populate_record(null::myrowtype, '{ "a": 1, "b": ["2", "a b"], "c": { "d": 4, "e": "a b c" } }')</code>	<table border="1"><tr><td>a</td><td>b</td></tr><tr><td></td><td>c</td></tr></table> ----- 1 {2,"a b"} (4,"a b c")	a	b		c		
a	b									
	c									
<code>json_populate_record_set(base anyelement, from_json json)</code> <code>jsonb_populate_record_set(base anyelement, from_json jsonb)</code>	setof anyelement	Expands the outermost array of objects in <i>from_json</i> to a set of rows whose columns match the record type defined by <i>base</i> (see note below).	<code>select * from json_populate_record_set(null::myrowtype, '[{ "a": 1, "b": 2 }, { "a": 3, "b": 4 }]')</code>	<table border="1"><tr><td>a</td><td>b</td></tr><tr><td>1</td><td>2</td></tr><tr><td>3</td><td>4</td></tr></table>	a	b	1	2	3	4
a	b									
1	2									
3	4									
<code>json_array_elements(json)</code> <code>jsonb_array_elements(jsonb)</code>	setof json setof jsonb	Expands a JSON array to a set of JSON values.	<code>select * from json_array_elements('[1,true,[2,false]]')</code>	value ----- 1 true [2,false]						
<code>json_array_elements_text(json)</code> <code>jsonb_array_elements_text(jsonb)</code>	setof text	Expands a JSON array to a set of text values.	<code>select * from json_array_elements_text('["foo","bar"]')</code>	value ----- foo bar						
<code>json_typeof(json)</code>	text	Returns the type of the outermost JSON value as a	<code>json_typeof('-123.4')</code>	number						

Function	Return Type	Description	Example	Example Result
jsonb_typeof(jsonb)		text string. Possible types are object, array, string, number, boolean, and null.		
json_to_record(json) jsonb_to_record(jsonb)	record	Builds an arbitrary record from a JSON object (see note below). As with all functions returning record, the caller must explicitly define the structure of the record with an AS clause.	select * from json_to_record('{"a":1,"b": [1,2,3],"c": [1,2,3],"e":"bar","r": { "a": 123, "b": "a b c"} }') as x(a int, b text, c int[], d text, r my- rowtype)	a b ----- d r bar r: +----- +----- +--- ----- 1 [1,2,3] {1,2,3} (123,"a b c")
json_to_record_set(json) jsonb_to_record_set(jsonb)	set of record	Builds an arbitrary set of records from a JSON array of objects (see note below). As with all functions returning record, the caller must explicitly define the structure of the record with an AS clause.	select * from json_to_record- set(' [{"a":1,"b":1}, {"a":2,"c":2 as x(a int, b text);	a b ----- -----
json_strip_nulls(from_json json) jsonb_strip_nulls(from_json jsonb)	json jsonb	Returns <i>from_json</i> with all object fields that have null values omitted. Other null values are untouched.	json_strip_nulls(' [{"f1":1,"f2":3}, {"f1":1}, {"f1":2}, {"f1":3}]')	[{"f1":1}, {"f1":2}, {"f1":3}]
jsonb_set(target jsonb, path text[], new_value jsonb [, create_missing boolean])	jsonb	Returns <i>target</i> with the section designated by <i>path</i> replaced by <i>new_value</i> , or with <i>new_value</i> added if <i>create_missing</i> is true (default is true) and the item designated by <i>path</i> does not exist. As with the path oriented operators, negative integers that appear	jsonb_set(' [{"f1":1}, {"f1":2}, {"f1":3}]', ['0,f1'], ' {0,f1}', true, false) jsonb_set(' [{"f1":1,"f2":null}, {"f1":2}, {"f1":3}]', ['0,f3'], ' {0,f3}', true, true)	[{"f1":1}, {"f1":2}, {"f1":3}] [{"f1":1, "f2": null, "f3": [2, 3, 4]}, {"f1":2}, {"f1":3}]

Function	Return Type	Description	Example	Example Result
		in <i>path</i> count from the end of JSON arrays.		
<code>jsonb_insert(target jsonb, path text[], new_value jsonb [, insert_after boolean])</code>	jsonb	Returns <i>target</i> with <i>new_value</i> inserted. If <i>target</i> section designated by <i>path</i> is in a JSONB array, <i>new_value</i> will be inserted before <i>target</i> or after if <i>insert_after</i> is true (default is false). If <i>target</i> section designated by <i>path</i> is in JSONB object, <i>new_value</i> will be inserted only if <i>target</i> does not exist. As with the path oriented operators, negative integers that appear in <i>path</i> count from the end of JSON arrays.	<code>jsonb_insert('{ "a": [0,1,2] }', '{ a, 1 }', "new_value")</code> <code>jsonb_insert('{ "a": [0,1,2] }', '{ a, 1 }', "new_value", true)</code>	<pre>{ "a": [0, "new_value", 1, 2] } { "a": [0, 1, "new_value", 2] }</pre>
<code>jsonb_pretty(from_json jsonb)</code>	text	Returns <i>from_json</i> as indented JSON text.	<code>jsonb_pretty(' [{"f1":1, 1}, 2, null, 1, 3]')</code>	<pre>[{ "f1": 1, "f2": null }, 2, null, 3]</pre>
<code>jsonb_path_exists(target jsonb, path jsonpath [, vars jsonb [, silent bool]])</code>	boolean	Checks whether JSON path returns any item for the specified JSON value.	<code>jsonb_path_exists('{ "a": [1,2,3,4,5] }', '\$.a[*] ? (@ >= \$min && @ <= \$max)', '{"min":2, "max":4}')</code>	true
<code>jsonb_path_match(target jsonb, path jsonpath [, vars jsonb])</code>	boolean	Returns the result of JSON path predicate check for the specified JSON value. Only the first item of the re-	<code>jsonb_path_match('{ "a": [1,2,3,4,5] }', 'exists(\$.a[*] ? (@ >= \$min && @ <=</code>	true

Function	Return Type	Description	Example	Example Result
<code>[, silent bool]])</code>		sult is taken into account. If the result is not Boolean, then null is returned.	<code>\$max))', '{"min":2,"max":4}'</code>	
<code>json- b_path_query(target jsonb, path jsonpath [, vars jsonb [, silent bool]])</code>	setof jsonb	Gets all JSON items returned by JSON path for the specified JSON value.	<code>select * from json- b_path_query('{"a":[1,2,3,4,5]}' , @ >= \$min && @ <= \$max)', '{"min":2,"max":4}');</code>	<code>jsonb_path_query '{"a":[1,2,3,4,5]}'</code>
<code>json- b_path_query_ar- ray(target jsonb, path jsonpath [, vars jsonb [, silent bool]])</code>	jsonb	Gets all JSON items returned by JSON path for the specified JSON value and wraps result into an array.	<code>json- b_path_query_ar- ray('{"a":[1,2,3,4,5]}' , @ >= \$min && @ <= \$max)', '{"min":2,"max":4}')</code>	<code>[2, 3, 4]</code>
<code>json- b_path_query_ri- st(target jsonb, path jsonpath [, vars jsonb [, silent bool]])</code>	jsonb	Gets the first JSON item returned by JSON path for the specified JSON value. Returns NULL on no results.	<code>json- b_path_query_ri- st('{"a":[1,2,3,4,5]}' , @ >= \$min && @ <= \$max)', '{"min":2,"max":4}')</code>	<code>2</code>

Note

Many of these functions and operators will convert Unicode escapes in JSON strings to the appropriate single character. This is a non-issue if the input is type `jsonb`, because the conversion was already done; but for `json` input, this may result in throwing an error, as noted in Section 8.14.

Note

The functions `json[b]_populate_record`, `json[b]_populate_recordset`, `json[b]_to_record` and `json[b]_to_recordset` operate on a JSON object, or array of objects, and extract the values associated with keys whose names match column names of the output row type. Object fields that do not correspond to any output column name are ignored, and output columns that do not match any object field will be filled with nulls. To convert a JSON value to the SQL type of an output column, the following rules are applied in sequence:

- A JSON null value is converted to a SQL null in all cases.
- If the output column is of type `json` or `jsonb`, the JSON value is just reproduced exactly.
- If the output column is a composite (row) type, and the JSON value is a JSON object, the fields of the object are converted to columns of the output row type by recursive application of these rules.

- Likewise, if the output column is an array type and the JSON value is a JSON array, the elements of the JSON array are converted to elements of the output array by recursive application of these rules.
- Otherwise, if the JSON value is a string literal, the contents of the string are fed to the input conversion function for the column's data type.
- Otherwise, the ordinary text representation of the JSON value is fed to the input conversion function for the column's data type.

While the examples for these functions use constants, the typical use would be to reference a table in the `FROM` clause and use one of its `json` or `jsonb` columns as an argument to the function. Extracted key values can then be referenced in other parts of the query, like `WHERE` clauses and target lists. Extracting multiple values in this way can improve performance over extracting them separately with per-key operators.

Note

All the items of the `path` parameter of `jsonb_set` as well as `jsonb_insert` except the last item must be present in the `target`. If `create_missing` is false, all items of the `path` parameter of `jsonb_set` must be present. If these conditions are not met the `target` is returned unchanged.

If the last path item is an object key, it will be created if it is absent and given the new value. If the last path item is an array index, if it is positive the item to set is found by counting from the left, and if negative by counting from the right - `-1` designates the rightmost element, and so on. If the item is out of the range `-array_length .. array_length - 1`, and `create_missing` is true, the new value is added at the beginning of the array if the item is negative, and at the end of the array if it is positive.

Note

The `json_typeof` function's `null` return value should not be confused with a SQL `NULL`. While calling `json_typeof('null'::json)` will return `null`, calling `json_typeof(NULL::json)` will return a SQL `NULL`.

Note

If the argument to `json_strip_nulls` contains duplicate field names in any object, the result could be semantically somewhat different, depending on the order in which they occur. This is not an issue for `jsonb_strip_nulls` since `jsonb` values never have duplicate object field names.

Note

The `jsonb_path_exists`, `jsonb_path_match`, `jsonb_path_query`, `jsonb_path_query_array`, and `jsonb_path_query_first` functions have optional `vars` and `silent` arguments.

If the `vars` argument is specified, it provides an object containing named variables to be substituted into a `jsonpath` expression.

If the *silent* argument is specified and has the `true` value, these functions suppress the same errors as the `@?` and `@@` operators.

See also Section 9.20 for the aggregate function `json_agg` which aggregates record values as JSON, and the aggregate function `json_object_agg` which aggregates pairs of values into a JSON object, and their `jsonb` equivalents, `jsonb_agg` and `jsonb_object_agg`.

9.15.2. The SQL/JSON Path Language

SQL/JSON path expressions specify the items to be retrieved from the JSON data, similar to XPath expressions used for SQL access to XML. In PostgreSQL, path expressions are implemented as the `jsonpath` data type and can use any elements described in Section 8.14.6.

JSON query functions and operators pass the provided path expression to the *path engine* for evaluation. If the expression matches the queried JSON data, the corresponding SQL/JSON item is returned. Path expressions are written in the SQL/JSON path language and can also include arithmetic expressions and functions. Query functions treat the provided expression as a text string, so it must be enclosed in single quotes.

A path expression consists of a sequence of elements allowed by the `jsonpath` data type. The path expression is evaluated from left to right, but you can use parentheses to change the order of operations. If the evaluation is successful, a sequence of SQL/JSON items (*SQL/JSON sequence*) is produced, and the evaluation result is returned to the JSON query function that completes the specified computation.

To refer to the JSON data to be queried (the *context item*), use the `$` sign in the path expression. It can be followed by one or more accessor operators, which go down the JSON structure level by level to retrieve the content of context item. Each operator that follows deals with the result of the previous evaluation step.

For example, suppose you have some JSON data from a GPS tracker that you would like to parse, such as:

```
{
  "track": {
    "segments": [
      {
        "location": [ 47.763, 13.4034 ],
        "start time": "2018-10-14 10:05:14",
        "HR": 73
      },
      {
        "location": [ 47.706, 13.2635 ],
        "start time": "2018-10-14 10:39:21",
        "HR": 135
      }
    ]
  }
}
```

To retrieve the available track segments, you need to use the `.key` accessor operator for all the preceding JSON objects:

```
'$.track.segments'
```

If the item to retrieve is an element of an array, you have to unnest this array using the `[*]` operator. For example, the following path will return location coordinates for all the available track segments:

```
'$.track.segments[*].location'
```

To return the coordinates of the first segment only, you can specify the corresponding subscript in the `[]` accessor operator. Note that the SQL/JSON arrays are 0-relative:

```
'$.track.segments[0].location'
```

The result of each path evaluation step can be processed by one or more `jsonpath` operators and methods listed in Section 9.15.2.3. Each method name must be preceded by a dot. For example, you can get an array size:

```
'$.track.segments.size()'
```

For more examples of using `jsonpath` operators and methods within path expressions, see Section 9.15.2.3.

When defining the path, you can also use one or more *filter expressions* that work similar to the `WHERE` clause in SQL. A filter expression begins with a question mark and provides a condition in parentheses:

```
? (condition)
```

Filter expressions must be specified right after the path evaluation step to which they are applied. The result of this step is filtered to include only those items that satisfy the provided condition. SQL/JSON defines three-valued logic, so the condition can be `true`, `false`, or `unknown`. The `unknown` value plays the same role as SQL `NULL` and can be tested for with the `is unknown` predicate. Further path evaluation steps use only those items for which filter expressions return `true`.

Functions and operators that can be used in filter expressions are listed in Table 9.49. The path evaluation result to be filtered is denoted by the `@` variable. To refer to a JSON element stored at a lower nesting level, add one or more accessor operators after `@`.

Suppose you would like to retrieve all heart rate values higher than 130. You can achieve this using the following expression:

```
'$.track.segments[*].HR ? (@ > 130)'
```

To get the start time of segments with such values instead, you have to filter out irrelevant segments before returning the start time, so the filter expression is applied to the previous step, and the path used in the condition is different:

```
'$.track.segments[*] ? (@.HR > 130). "start time"'
```

You can use several filter expressions on the same nesting level, if required. For example, the following expression selects all segments that contain locations with relevant coordinates and high heart rate values:

```
'$.track.segments[*] ? (@.location[1] < 13.4) ? (@.HR > 130). "start time"'
```

Using filter expressions at different nesting levels is also allowed. The following example first filters all segments by location, and then returns high heart rate values for these segments, if available:

```
'$.track.segments[*] ? (@.location[1] < 13.4).HR ? (@ > 130)'
```

You can also nest filter expressions within each other:

```
'$.track ? (exists(@.segments[*] ? (@.HR > 130)).segments.size()'
```

This expression returns the size of the track if it contains any segments with high heart rate values, or an empty sequence otherwise.

PostgreSQL's implementation of SQL/JSON path language has the following deviations from the SQL/JSON standard:

- `.datetime()` item method is not implemented yet mainly because immutable `jsonpath` functions and operators cannot reference session timezone, which is used in some datetime operations. Datetime support will be added to `jsonpath` in future versions of PostgreSQL.
- A path expression can be a Boolean predicate, although the SQL/JSON standard allows predicates only in filters. This is necessary for implementation of the `@@` operator. For example, the following `jsonpath` expression is valid in PostgreSQL:

```
'$.track.segments[*].HR < 70'
```

- There are minor differences in the interpretation of regular expression patterns used in `like_regex` filters, as described in Section 9.15.2.2.

9.15.2.1. Strict and Lax Modes

When you query JSON data, the path expression may not match the actual JSON data structure. An attempt to access a non-existent member of an object or element of an array results in a structural error. SQL/JSON path expressions have two modes of handling structural errors:

- `lax` (default) — the path engine implicitly adapts the queried data to the specified path. Any remaining structural errors are suppressed and converted to empty SQL/JSON sequences.
- `strict` — if a structural error occurs, an error is raised.

The lax mode facilitates matching of a JSON document structure and path expression if the JSON data does not conform to the expected schema. If an operand does not match the requirements of a particular operation, it can be automatically wrapped as an SQL/JSON array or unwrapped by converting its elements into an SQL/JSON sequence before performing this operation. Besides, comparison operators automatically unwrap their operands in the lax mode, so you can compare SQL/JSON arrays out-of-the-box. An array of size 1 is considered equal to its sole element. Automatic unwrapping is not performed only when:

- The path expression contains `type()` or `size()` methods that return the type and the number of elements in the array, respectively.
- The queried JSON data contain nested arrays. In this case, only the outermost array is unwrapped, while all the inner arrays remain unchanged. Thus, implicit unwrapping can only go one level down within each path evaluation step.

For example, when querying the GPS data listed above, you can abstract from the fact that it stores an array of segments when using the lax mode:

```
'lax $.track.segments.location'
```

In the strict mode, the specified path must exactly match the structure of the queried JSON document to return an SQL/JSON item, so using this path expression will cause an error. To get the same result as in the lax mode, you have to explicitly unwrap the `segments` array:

```
'strict $.track.segments[*].location'
```

9.15.2.2. Regular Expressions

SQL/JSON path expressions allow matching text to a regular expression with the `like_regex` filter. For example, the following SQL/JSON path query would case-insensitively match all strings in an array that start with an English vowel:

```
'$[*] ? (@ like_regex "^[aeiou]" flag "i")'
```

The optional `flag` string may include one or more of the characters `i` for case-insensitive match, `m` to allow `^` and `$` to match at newlines, `s` to allow `.` to match a newline, and `q` to quote the whole pattern (reducing the behavior to a simple substring match).

The SQL/JSON standard borrows its definition for regular expressions from the `LIKE_REGEX` operator, which in turn uses the XQuery standard. PostgreSQL does not currently support the `LIKE_REGEX` operator. Therefore, the `like_regex` filter is implemented using the POSIX regular expression engine described in Section 9.7.3. This leads to various minor discrepancies from standard SQL/JSON behavior, which are cataloged in Section 9.7.3.8. Note, however, that the flag-letter incompatibilities described there do not apply to SQL/JSON, as it translates the XQuery flag letters to match what the POSIX engine expects.

Keep in mind that the pattern argument of `like_regex` is a JSON path string literal, written according to the rules given in Section 8.14.6. This means in particular that any backslashes you want to use in the regular expression must be doubled. For example, to match strings that contain only digits:

```
'$ ? (@ like_regex "^\\d+$")'
```

9.15.2.3. SQL/JSON Path Operators and Methods

Table 9.48 shows the operators and methods available in `jsonpath`. Table 9.49 shows the available filter expression elements.

Table 9.48. `jsonpath` Operators and Methods

Operator/Method	Description	Example JSON	Example Query	Result
+ (unary)	Plus operator that iterates over the SQL/JSON sequence	<code>{"x": [2.85, -14.7, -9.4]}</code>	<code>+ \$.x.floor()</code>	2, -15, -10
- (unary)	Minus operator that iterates over the SQL/JSON sequence	<code>{"x": [2.85, -14.7, -9.4]}</code>	<code>- \$.x.floor()</code>	-2, 15, 10
+ (binary)	Addition	[2]	<code>2 + \$[0]</code>	4
- (binary)	Subtraction	[2]	<code>4 - \$[0]</code>	2
*	Multiplication	[4]	<code>2 * \$[0]</code>	8
/	Division	[8]	<code>\$[0] / 2</code>	4
%	Modulus	[32]	<code>\$[0] % 10</code>	2
<code>type()</code>	Type of the SQL/JSON item	[1, "2", {}]	<code>\$.[*].type()</code>	"number", "string", "object"
<code>size()</code>	Size of the SQL/JSON item	<code>{"m": [11, 15]}</code>	<code>\$.m.size()</code>	2
<code>double()</code>	Approximate floating-point number	<code>{"len": "1.9"}</code>	<code>\$.len.double() * 2</code>	3.8

Operator/Method	Description	Example JSON	Example Query	Result
	converted from an SQL/JSON number or a string			
ceiling()	Nearest integer greater than or equal to the SQL/JSON number	{"h": 1.3}	\$.h.ceiling()	2
floor()	Nearest integer less than or equal to the SQL/JSON number	{"h": 1.3}	\$.h.floor()	1
abs()	Absolute value of the SQL/JSON number	{"z": -0.3}	\$.z.abs()	0.3
keyvalue()	Sequence of object's key-value pairs represented as array of items containing three fields ("key", "value", and "id"). "id" is a unique identifier of the object key-value pair belongs to.	{"x": "20", "y": 32}	\$.keyvalue()	{ "key": "x", "value": "20", "id": 0}, {"key": "y", "value": 32, "id": 0}

Table 9.49. jsonpath Filter Expression Elements

Value/Predicate	Description	Example JSON	Example Query	Result
==	Equality operator	[1, 2, 1, 3]	[\$[*] ? (@ == 1)]	1, 1
!=	Non-equality operator	[1, 2, 1, 3]	[\$[*] ? (@ != 1)]	2, 3
<>	Non-equality operator (same as !=)	[1, 2, 1, 3]	[\$[*] ? (@ <> 1)]	2, 3
<	Less-than operator	[1, 2, 3]	[\$[*] ? (@ < 2)]	1
<=	Less-than-or-equal-to operator	[1, 2, 3]	[\$[*] ? (@ <= 2)]	1, 2
>	Greater-than operator	[1, 2, 3]	[\$[*] ? (@ > 2)]	3
>=	Greater-than-or-equal-to operator	[1, 2, 3]	[\$[*] ? (@ >= 2)]	2, 3
true	Value used to perform comparison with JSON true literal	[{"name": "John", "parent": false}, {"name": "Chris", "parent": true}]	[\$[*] ? (@.parent == true)]	{"name": "Chris", "parent": true}
false	Value used to perform comparison	[{"name": "John", "parent": false}, {"name": "Chris", "parent": true}]	[\$[*] ? (@.parent == false)]	{"name": "John", "parent": false}

Value/Predicate	Description	Example JSON	Example Query	Result
	with JSON false literal	{ "name": "Chris", "parent": true}]		
null	Value used to perform comparison with JSON null value	[{"name": "Mary", "job": null}, {"name": "Michael", "job": "driver"}]	\$(*) ? (@.job == null) .name	"Mary"
&&	Boolean AND	[1, 3, 7]	\$(*) ? (@ > 1 && @ < 5)	3
	Boolean OR	[1, 3, 7]	\$(*) ? (@ < 1 @ > 5)	7
!	Boolean NOT	[1, 3, 7]	\$(*) ? (!(@ < 5))	7
like_regex	Tests whether the first operand matches the regular expression given by the second operand, optionally with modifications described by a string of flag characters (see Section 9.15.2.2)	["abc", "abd", "abdc", "abdacb", "babcb"]	\$(*) ? (@ like_regex "^ab.*c" flag "i")	"abc", "abdacb"
starts with	Tests whether the second operand is an initial substring of the first operand	["John Smith", "Mary Stone", "Bob Johnson"]	\$(*) ? (@ starts with "John")	"John Smith"
exists	Tests whether a path expression matches at least one SQL/JSON item	{"x": [1, 2], "y": [2, 4]}	strict \$.* ? (exists (@ ? (@[*] > 2)))	2, 4
is unknown	Tests whether a Boolean condition is unknown	[-1, 2, 7, "infinity"]	\$(*) ? ((@ > 0) is unknown)	"infinity"

9.16. Sequence Manipulation Functions

This section describes functions for operating on *sequence objects*, also called sequence generators or just sequences. Sequence objects are special single-row tables created with CREATE SEQUENCE. Sequence objects are commonly used to generate unique identifiers for rows of a table. The sequence functions, listed in Table 9.50, provide simple, multiuser-safe methods for obtaining successive sequence values from sequence objects.

Table 9.50. Sequence Functions

Function	Return Type	Description
<code>currval(regclass)</code>	<code>bigint</code>	Return value most recently obtained with <code>nextval</code> for specified sequence
<code>lastval()</code>	<code>bigint</code>	Return value most recently obtained with <code>nextval</code> for any sequence
<code>nextval(regclass)</code>	<code>bigint</code>	Advance sequence and return new value
<code>setval(regclass, bigint)</code>	<code>bigint</code>	Set sequence's current value
<code>setval(regclass, bigint, boolean)</code>	<code>bigint</code>	Set sequence's current value and <code>is_called</code> flag

The sequence to be operated on by a sequence function is specified by a `regclass` argument, which is simply the OID of the sequence in the `pg_class` system catalog. You do not have to look up the OID by hand, however, since the `regclass` data type's input converter will do the work for you. Just write the sequence name enclosed in single quotes so that it looks like a literal constant. For compatibility with the handling of ordinary SQL names, the string will be converted to lower case unless it contains double quotes around the sequence name. Thus:

```
nextval('foo')           operates on sequence foo
nextval('FOO')           operates on sequence foo
nextval('"Foo"')         operates on sequence Foo
```

The sequence name can be schema-qualified if necessary:

```
nextval('myschema.foo')  operates on myschema.foo
nextval('"myschema".foo') same as above
nextval('foo')           searches search path for foo
```

See Section 8.19 for more information about `regclass`.

Note

Before PostgreSQL 8.1, the arguments of the sequence functions were of type `text`, not `regclass`, and the above-described conversion from a text string to an OID value would happen at run time during each call. For backward compatibility, this facility still exists, but internally it is now handled as an implicit coercion from `text` to `regclass` before the function is invoked.

When you write the argument of a sequence function as an unadorned literal string, it becomes a constant of type `regclass`. Since this is really just an OID, it will track the originally identified sequence despite later renaming, schema reassignment, etc. This “early binding” behavior is usually desirable for sequence references in column defaults and views. But sometimes you might want “late binding” where the sequence reference is resolved at run time. To get late-binding behavior, force the constant to be stored as a `text` constant instead of `regclass`:

```
nextval('foo'::text)     foo is looked up at runtime
```

Note that late binding was the only behavior supported in PostgreSQL releases before 8.1, so you might need to do this to preserve the semantics of old applications.

Of course, the argument of a sequence function can be an expression as well as a constant. If it is a text expression then the implicit coercion will result in a run-time lookup.

The available sequence functions are:

`nextval`

Advance the sequence object to its next value and return that value. This is done atomically: even if multiple sessions execute `nextval` concurrently, each will safely receive a distinct sequence value.

If a sequence object has been created with default parameters, successive `nextval` calls will return successive values beginning with 1. Other behaviors can be obtained by using special parameters in the `CREATE SEQUENCE` command; see its command reference page for more information.

Important

To avoid blocking concurrent transactions that obtain numbers from the same sequence, a `nextval` operation is never rolled back; that is, once a value has been fetched it is considered used and will not be returned again. This is true even if the surrounding transaction later aborts, or if the calling query ends up not using the value. For example an `INSERT` with an `ON CONFLICT` clause will compute the to-be-inserted tuple, including doing any required `nextval` calls, before detecting any conflict that would cause it to follow the `ON CONFLICT` rule instead. Such cases will leave unused “holes” in the sequence of assigned values. Thus, PostgreSQL sequence objects *cannot be used to obtain “gapless” sequences*.

This function requires `USAGE` or `UPDATE` privilege on the sequence.

`currval`

Return the value most recently obtained by `nextval` for this sequence in the current session. (An error is reported if `nextval` has never been called for this sequence in this session.) Because this is returning a session-local value, it gives a predictable answer whether or not other sessions have executed `nextval` since the current session did.

This function requires `USAGE` or `SELECT` privilege on the sequence.

`lastval`

Return the value most recently returned by `nextval` in the current session. This function is identical to `currval`, except that instead of taking the sequence name as an argument it refers to whichever sequence `nextval` was most recently applied to in the current session. It is an error to call `lastval` if `nextval` has not yet been called in the current session.

This function requires `USAGE` or `SELECT` privilege on the last used sequence.

`setval`

Reset the sequence object's counter value. The two-parameter form sets the sequence's `last_value` field to the specified value and sets its `is_called` field to `true`, meaning that the next `nextval` will advance the sequence before returning a value. The value reported by `currval` is also set to the specified value. In the three-parameter form, `is_called` can be set to either `true` or `false`. `true` has the same effect as the two-parameter form. If it is set to `false`, the next `nextval` will return exactly the specified value, and sequence advancement

commences with the following `nextval`. Furthermore, the value reported by `currval` is not changed in this case. For example,

```
SELECT setval('foo', 42);           Next nextval will return 43
SELECT setval('foo', 42, true);    Same as above
SELECT setval('foo', 42, false);   Next nextval will return 42
```

The result returned by `setval` is just the value of its second argument.

Important

Because sequences are non-transactional, changes made by `setval` are not undone if the transaction rolls back.

This function requires `UPDATE` privilege on the sequence.

9.17. Conditional Expressions

This section describes the SQL-compliant conditional expressions available in PostgreSQL.

Tip

If your needs go beyond the capabilities of these conditional expressions, you might want to consider writing a server-side function in a more expressive programming language.

Note

Although `COALESCE`, `GREATEST`, and `LEAST` are syntactically similar to functions, they are not ordinary functions, and thus cannot be used with explicit `VARIADIC` array arguments.

9.17.1. CASE

The SQL `CASE` expression is a generic conditional expression, similar to `if/else` statements in other programming languages:

```
CASE WHEN condition THEN result
      [WHEN ...]
      [ELSE result]
END
```

`CASE` clauses can be used wherever an expression is valid. Each *condition* is an expression that returns a boolean result. If the condition's result is true, the value of the `CASE` expression is the *result* that follows the condition, and the remainder of the `CASE` expression is not processed. If the condition's result is not true, any subsequent `WHEN` clauses are examined in the same manner. If no `WHEN` *condition* yields true, the value of the `CASE` expression is the *result* of the `ELSE` clause. If the `ELSE` clause is omitted and no condition is true, the result is null.

An example:

```
SELECT * FROM test;
```

```
a
---
1
2
3
```

```
SELECT a,
       CASE WHEN a=1 THEN 'one'
            WHEN a=2 THEN 'two'
            ELSE 'other'
       END
FROM test;
```

```
a | case
---+-----
1 | one
2 | two
3 | other
```

The data types of all the *result* expressions must be convertible to a single output type. See Section 10.5 for more details.

There is a “simple” form of CASE expression that is a variant of the general form above:

```
CASE expression
     WHEN value THEN result
     [WHEN ...]
     [ELSE result]
END
```

The first *expression* is computed, then compared to each of the *value* expressions in the WHEN clauses until one is found that is equal to it. If no match is found, the *result* of the ELSE clause (or a null value) is returned. This is similar to the *switch* statement in C.

The example above can be written using the simple CASE syntax:

```
SELECT a,
       CASE a WHEN 1 THEN 'one'
            WHEN 2 THEN 'two'
            ELSE 'other'
       END
FROM test;
```

```
a | case
---+-----
1 | one
2 | two
3 | other
```

A CASE expression does not evaluate any subexpressions that are not needed to determine the result. For example, this is a possible way of avoiding a division-by-zero failure:

```
SELECT ... WHERE CASE WHEN x <> 0 THEN y/x > 1.5 ELSE false END;
```

Note

As described in Section 4.2.14, there are various situations in which subexpressions of an expression are evaluated at different times, so that the principle that “CASE evaluates only necessary subexpressions” is not ironclad. For example a constant 1/0 subexpression will usually result in a division-by-zero failure at planning time, even if it's within a CASE arm that would never be entered at run time.

9.17.2. COALESCE

```
COALESCE(value [, ...])
```

The COALESCE function returns the first of its arguments that is not null. Null is returned only if all arguments are null. It is often used to substitute a default value for null values when data is retrieved for display, for example:

```
SELECT COALESCE(description, short_description, '(none)') ...
```

This returns `description` if it is not null, otherwise `short_description` if it is not null, otherwise `(none)`.

Like a CASE expression, COALESCE only evaluates the arguments that are needed to determine the result; that is, arguments to the right of the first non-null argument are not evaluated. This SQL-standard function provides capabilities similar to NVL and IFNULL, which are used in some other database systems.

9.17.3. NULLIF

```
NULLIF(value1, value2)
```

The NULLIF function returns a null value if `value1` equals `value2`; otherwise it returns `value1`. This can be used to perform the inverse operation of the COALESCE example given above:

```
SELECT NULLIF(value, '(none)') ...
```

In this example, if `value` is `(none)`, null is returned, otherwise the value of `value` is returned.

9.17.4. GREATEST and LEAST

```
GREATEST(value [, ...])
```

```
LEAST(value [, ...])
```

The GREATEST and LEAST functions select the largest or smallest value from a list of any number of expressions. The expressions must all be convertible to a common data type, which will be the type of the result (see Section 10.5 for details). NULL values in the list are ignored. The result will be NULL only if all the expressions evaluate to NULL.

Note that GREATEST and LEAST are not in the SQL standard, but are a common extension. Some other databases make them return NULL if any argument is NULL, rather than only when all are NULL.

9.18. Array Functions and Operators

Table 9.51 shows the operators available for array types.

Table 9.51. Array Operators

Operator	Description	Example	Result
=	equal	ARRAY[1.1, 2.1, 3.1] = ARRAY[1, 2, 3]	t
<>	not equal	ARRAY[1, 2, 3] <> ARRAY[1, 2, 4]	t
<	less than	ARRAY[1, 2, 3] < ARRAY[1, 2, 4]	t
>	greater than	ARRAY[1, 4, 3] > ARRAY[1, 2, 4]	t
<=	less than or equal	ARRAY[1, 2, 3] <= ARRAY[1, 2, 3]	t
>=	greater than or equal	ARRAY[1, 4, 3] >= ARRAY[1, 4, 3]	t
@>	contains	ARRAY[1, 4, 3] @> ARRAY[3, 1, 3]	t
<@	is contained by	ARRAY[2, 2, 7] <@ ARRAY[1, 7, 4, 2, 6]	t
&&	overlap (have elements in common)	ARRAY[1, 4, 3] && ARRAY[2, 1]	t
	array-to-array concatenation	ARRAY[1, 2, 3] ARRAY[4, 5, 6]	{1, 2, 3, 4, 5, 6}
	array-to-array concatenation	ARRAY[1, 2, 3] ARRAY[[4, 5, 6], [7, 8, 9]]	{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}}
	element-to-array concatenation	3 ARRAY[4, 5, 6]	{3, 4, 5, 6}
	array-to-element concatenation	ARRAY[4, 5, 6] 7	{4, 5, 6, 7}

The array ordering operators (<, >=, etc) compare the array contents element-by-element, using the default B-tree comparison function for the element data type, and sort based on the first difference. In multidimensional arrays the elements are visited in row-major order (last subscript varies most rapidly). If the contents of two arrays are equal but the dimensionality is different, the first difference in the dimensionality information determines the sort order. (This is a change from versions of PostgreSQL prior to 8.2: older versions would claim that two arrays with the same contents were equal, even if the number of dimensions or subscript ranges were different.)

The array containment operators (<@ and @>) consider one array to be contained in another one if each of its elements appears in the other one. Duplicates are not treated specially, thus ARRAY[1] and ARRAY[1, 1] are each considered to contain the other.

See Section 8.15 for more details about array operator behavior. See Section 11.2 for more details about which operators support indexed operations.

Table 9.52 shows the functions available for use with array types. See Section 8.15 for more information and examples of the use of these functions.

Table 9.52. Array Functions

Function	Return Type	Description	Example	Result
<code>array_append(anyarray, anyelement)</code>	anyarray	append an element to the end of an array	<code>array_append(ARRAY[1,2], 3)</code>	{1,2,3}
<code>array_cat(anyarray, anyarray)</code>	anyarray	concatenate two arrays	<code>array_cat(ARRAY[1,2,3], ARRAY[4,5])</code>	{1,2,3,4,5}
<code>array_ndims(anyarray)</code>	int	returns the number of dimensions of the array	<code>array_ndims(ARRAY[[1,2,3],[4,5,6]])</code>	2
<code>array_dims(anyarray)</code>	text	returns a text representation of array's dimensions	<code>array_dims(ARRAY[[1,2,3],[4,5,6]])</code>	[1:2][1:3]
<code>array_fill(anyelement, int[], int[])</code>	anyarray	returns an array initialized with supplied value and dimensions, optionally with lower bounds other than 1	<code>array_fill(7, ARRAY[3], ARRAY[2])</code>	[2:4]={7,7,7}
<code>array_length(anyarray, int)</code>	int	returns the length of the requested array dimension	<code>array_length(array[1,2,3], 1)</code>	3
<code>array_lower(anyarray, int)</code>	int	returns lower bound of the requested array dimension	<code>array_lower('[0:2]={1,2,3}'::int[], 1)</code>	0
<code>array_position(anyarray, anyelement [, int])</code>	int	returns the subscript of the first occurrence of the second argument in the array, starting at the element indicated by the third argument or at the first element (array must be one-dimensional)	<code>array_position(ARRAY['sun','mon','tue','wed','thu','fri','mon'])</code>	2
<code>array_positions(anyarray, anyelement)</code>	int[]	returns an array of subscripts of all occurrences of the second argument in the array given as first argument (array must be one-dimensional)	<code>array_positions(ARRAY['A','A','B','A'],'A')</code>	{1,2,4}

Function	Return Type	Description	Example	Result
<code>array_prepend(anyelement, anyarray)</code>	anyarray	append an element to the beginning of an array	<code>array_prepend(1, ARRAY[2,3])</code>	{1,2,3}
<code>array_remove(anyarray, anyelement)</code>	anyarray	remove all elements equal to the given value from the array (array must be one-dimensional)	<code>array_remove(ARRAY[1,2,3,2], 2)</code>	{1,3}
<code>array_replace(anyarray, anyelement, anyelement)</code>	anyarray	replace each array element equal to the given value with a new value	<code>array_replace(ARRAY[1,2,5,4], 5, 3)</code>	{1,2,3,4}
<code>array_to_string(anyarray, text [, text])</code>	text	concatenates array elements using supplied delimiter and optional null string	<code>array_to_string(ARRAY[1, 2, 3, NULL, 5], ',', '*')</code>	1,2,3*,5
<code>array_upper(anyarray, int)</code>	int	returns upper bound of the requested array dimension	<code>array_upper(ARRAY[1,8,3,7], 1)</code>	4
<code>cardinality(anyarray)</code>	int	returns the total number of elements in the array, or 0 if the array is empty	<code>cardinality(ARRAY[[1,2],[3,4]])</code>	4
<code>string_to_array(text [, text [, text]])</code>	text[]	splits string into array elements using supplied delimiter and optional null string	<code>string_to_array('xx~^~yy~^~z-z', '~^~', 'yy')</code>	{xx,NULL,zz}
<code>unnest(anyarray)</code>	setof anyelement	expand an array to a set of rows	<code>unnest(ARRAY[1,2])</code>	1 2 (2 rows)
<code>unnest(anyarray, anyarray [, ...])</code>	setof anyelement [, ...]	expand multiple arrays (possibly of different types) to a set of rows. This is only allowed in the FROM clause; see Section 7.2.1.4	<code>unnest(ARRAY[1,2], ARRAY['foo', 'bar'], ARRAY[NULL, baz])</code>	1 foo 2 bar NULL baz (3 rows)

In `array_position` and `array_positions`, each array element is compared to the searched value using `IS NOT DISTINCT FROM` semantics.

In `array_position`, `NULL` is returned if the value is not found.

In `array_positions`, `NULL` is returned only if the array is `NULL`; if the value is not found in the array, an empty array is returned instead.

In `string_to_array`, if the delimiter parameter is `NULL`, each character in the input string will become a separate element in the resulting array. If the delimiter is an empty string, then the entire input string is returned as a one-element array. Otherwise the input string is split at each occurrence of the delimiter string.

In `string_to_array`, if the null-string parameter is omitted or `NULL`, none of the substrings of the input will be replaced by `NULL`. In `array_to_string`, if the null-string parameter is omitted or `NULL`, any null elements in the array are simply skipped and not represented in the output string.

Note

There are two differences in the behavior of `string_to_array` from pre-9.1 versions of PostgreSQL. First, it will return an empty (zero-element) array rather than `NULL` when the input string is of zero length. Second, if the delimiter string is `NULL`, the function splits the input into individual characters, rather than returning `NULL` as before.

See also Section 9.20 about the aggregate function `array_agg` for use with arrays.

9.19. Range Functions and Operators

See Section 8.17 for an overview of range types.

Table 9.53 shows the operators available for range types.

Table 9.53. Range Operators

Operator	Description	Example	Result
=	equal	<code>int4range(1,5) = '[1,4]':::int4range</code>	t
<>	not equal	<code>numrange(1.1,2.2) <> numrange(1.1,2.3)</code>	t
<	less than	<code>int4range(1,10) < int4range(2,3)</code>	t
>	greater than	<code>int4range(1,10) > int4range(1,5)</code>	t
<=	less than or equal	<code>numrange(1.1,2.2) <= numrange(1.1,2.2)</code>	t
>=	greater than or equal	<code>numrange(1.1,2.2) >= numrange(1.1,2.0)</code>	t
@>	contains range	<code>int4range(2,4) @> int4range(2,3)</code>	t
@>	contains element	<code>'[2011-01-01,2011-03-01]':::tsrange @> '2011-01-10':::timestamp</code>	t

Operator	Description	Example	Result
<@	range is contained by	int4range(2,4) <@ in- t4range(1,7)	t
<@	element is contained by	42 <@ in- t4range(1,7)	f
&&	overlap (have points in common)	int8range(3,7) && in- t8range(4,12)	t
<<	strictly left of	int8range(1,10) << in- t8range(100,110)	t
>>	strictly right of	int8range(50,60) >> in- t8range(20,30)	t
&<	does not extend to the right of	int8range(1,20) &< in- t8range(18,20)	t
&>	does not extend to the left of	int8range(7,20) &> in- t8range(5,10)	t
- -	is adjacent to	num- range(1.1,2.2) - - num- range(2.2,3.3)	t
+	union	numrange(5,15) + numrange(10,20)	[5,20)
*	intersection	int8range(5,15) * in- t8range(10,20)	[10,15)
-	difference	int8range(5,15) - in- t8range(10,20)	[5,10)

The simple comparison operators <, >, <=, and >= compare the lower bounds first, and only if those are equal, compare the upper bounds. These comparisons are not usually very useful for ranges, but are provided to allow B-tree indexes to be constructed on ranges.

The left-of/right-of/adjacent operators always return false when an empty range is involved; that is, an empty range is not considered to be either before or after any other range.

The union and difference operators will fail if the resulting range would need to contain two disjoint sub-ranges, as such a range cannot be represented.

Table 9.54 shows the functions available for use with range types.

Table 9.54. Range Functions

Function	Return Type	Description	Example	Result
lower(anyrange)	range's element type	lower bound of range	lower(numrange(1.1,2.2))	1.1
upper(anyrange)	range's element type	upper bound of range	upper(numrange(1.1,2.2))	2.2

Function	Return Type	Description	Example	Result
<code>isempty(anyrange)</code>	boolean	is the range empty?	<code>isempty(numrange(1.1, 2.2))</code>	false
<code>lower_inc(anyrange)</code>	boolean	is the lower bound inclusive?	<code>lower_inc(numrange(1.1, 2.2))</code>	true
<code>upper_inc(anyrange)</code>	boolean	is the upper bound inclusive?	<code>upper_inc(numrange(1.1, 2.2))</code>	false
<code>lower_inf(anyrange)</code>	boolean	is the lower bound infinite?	<code>lower_inf('(',')'::date_range)</code>	true
<code>upper_inf(anyrange)</code>	boolean	is the upper bound infinite?	<code>upper_inf('(',')'::date_range)</code>	true
<code>range_merge(anyrange, anyrange)</code>	anyrange	the smallest range which includes both of the given ranges	<code>range_merge('[[1,2]]'::int4range, '[3,4]'::int4range)</code>	<code>[[1,4]]'::int4range</code>

The lower and upper functions return null if the range is empty or the requested bound is infinite. The lower_inc, upper_inc, lower_inf, and upper_inf functions all return false for an empty range.

9.20. Aggregate Functions

Aggregate functions compute a single result from a set of input values. The built-in general-purpose aggregate functions are listed in Table 9.55 and statistical aggregates in Table 9.56. The built-in within-group ordered-set aggregate functions are listed in Table 9.57 while the built-in within-group hypothetical-set ones are in Table 9.58. Grouping operations, which are closely related to aggregate functions, are listed in Table 9.59. The special syntax considerations for aggregate functions are explained in Section 4.2.7. Consult Section 2.7 for additional introductory information.

Table 9.55. General-Purpose Aggregate Functions

Function	Argument Type(s)	Return Type	Partial Mode	Description
<code>array_agg(expression)</code>	any non-array type	array of the argument type	No	input values, including nulls, concatenated into an array
<code>array_agg(expression)</code>	any array type	same as argument data type	No	input arrays concatenated into array of one higher dimension (inputs must all have same dimensionality, and cannot be empty or null)
<code>avg(expression)</code>	smallint, int, bigint, real, double precision, numeric, or interval	numeric for any integer-type argument, double precision for a floating-point ar-	Yes	the average (arithmetic mean) of all non-null input values

Function	Argument Type(s)	Return Type	Partial Mode	Description
		argument, otherwise the same as the argument data type		
<code>bit_and(expression)</code>	smallint, int, bigint, or bit	same as argument data type	Yes	the bitwise AND of all non-null input values, or null if none
<code>bit_or(expression)</code>	smallint, int, bigint, or bit	same as argument data type	Yes	the bitwise OR of all non-null input values, or null if none
<code>bool_and(expression)</code>	bool	bool	Yes	true if all input values are true, otherwise false
<code>bool_or(expression)</code>	bool	bool	Yes	true if at least one input value is true, otherwise false
<code>count(*)</code>		bigint	Yes	number of input rows
<code>count(expression)</code>	any	bigint	Yes	number of input rows for which the value of <i>expression</i> is not null
<code>every(expression)</code>	bool	bool	Yes	equivalent to <code>bool_and</code>
<code>json_agg(expression)</code>	any	json	No	aggregates values, including nulls, as a JSON array
<code>jsonb_agg(expression)</code>	any	jsonb	No	aggregates values, including nulls, as a JSON array
<code>json_object_agg(name, value)</code>	(any, any)	json	No	aggregates name/value pairs as a JSON object; values can be null, but not names
<code>jsonb_object_agg(name, value)</code>	(any, any)	jsonb	No	aggregates name/value pairs as a JSON object; values can be null, but not names
<code>max(expression)</code>	any numeric, string, date/time, network, or enum type, or arrays of these types	same as argument type	Yes	maximum value of <i>expression</i> across all non-null input values
<code>min(expression)</code>	any numeric, string, date/time, network, or enum	same as argument type	Yes	minimum value of <i>expression</i> across all non-null input values

Function	Argument Type(s)	Return Type	Partial Mode	Description
	type, or arrays of these types			
<code>string_agg(expression, delimiter)</code>	(text, text) or (bytea, bytea)	same as argument types	No	non-null input values concatenated into a string, separated by delimiter
<code>sum(expression)</code>	smallint, int, bigint, real, double precision, numeric, interval, or money	bigint for smallint or int arguments, numeric for bigint arguments, otherwise the same as the argument data type	Yes	sum of <i>expression</i> across all non-null input values
<code>xmlagg(expression)</code>	xml	xml	No	concatenation of non-null XML values (see also Section 9.14.1.7)

It should be noted that except for `count`, these functions return a null value when no rows are selected. In particular, `sum` of no rows returns null, not zero as one might expect, and `array_agg` returns null rather than an empty array when there are no input rows. The `coalesce` function can be used to substitute zero or an empty array for null when necessary.

Aggregate functions which support *Partial Mode* are eligible to participate in various optimizations, such as parallel aggregation.

Note

Boolean aggregates `bool_and` and `bool_or` correspond to standard SQL aggregates `every` and `any` or `some`. As for `any` and `some`, it seems that there is an ambiguity built into the standard syntax:

```
SELECT b1 = ANY((SELECT b2 FROM t2 ...)) FROM t1 ...;
```

Here `ANY` can be considered either as introducing a subquery, or as being an aggregate function, if the subquery returns one row with a Boolean value. Thus the standard name cannot be given to these aggregates.

Note

Users accustomed to working with other SQL database management systems might be disappointed by the performance of the `count` aggregate when it is applied to the entire table. A query like:

```
SELECT count(*) FROM sometable;
```

will require effort proportional to the size of the table: PostgreSQL will need to scan either the entire table or the entirety of an index which includes all rows in the table.

The aggregate functions `array_agg`, `json_agg`, `jsonb_agg`, `json_object_agg`, `jsonb_object_agg`, `string_agg`, and `xmlagg`, as well as similar user-defined aggregate functions, produce meaningfully different result values depending on the order of the input values. This ordering is unspecified by default, but can be controlled by writing an `ORDER BY` clause within the aggregate call, as shown in Section 4.2.7. Alternatively, supplying the input values from a sorted subquery will usually work. For example:

```
SELECT xmlagg(x) FROM (SELECT x FROM test ORDER BY y DESC) AS tab;
```

Beware that this approach can fail if the outer query level contains additional processing, such as a join, because that might cause the subquery's output to be reordered before the aggregate is computed.

Table 9.56 shows aggregate functions typically used in statistical analysis. (These are separated out merely to avoid cluttering the listing of more-commonly-used aggregates.) Where the description mentions N , it means the number of input rows for which all the input expressions are non-null. In all cases, null is returned if the computation is meaningless, for example when N is zero.

Table 9.56. Aggregate Functions for Statistics

Function	Argument Type	Return Type	Partial Mode	Description
<code>corr(Y, X)</code>	double precision	double precision	Yes	correlation coefficient
<code>covar_pop(Y, X)</code>	double precision	double precision	Yes	population covariance
<code>covar_samp(Y, X)</code>	double precision	double precision	Yes	sample covariance
<code>regr_avgx(Y, X)</code>	double precision	double precision	Yes	average of the independent variable ($\text{sum}(X)/N$)
<code>regr_avgy(Y, X)</code>	double precision	double precision	Yes	average of the dependent variable ($\text{sum}(Y)/N$)
<code>regr_count(Y, X)</code>	double precision	bigint	Yes	number of input rows in which both expressions are nonnull
<code>regr_intercept(Y, X)</code>	double precision	double precision	Yes	y-intercept of the least-squares-fit linear equation determined by the (X, Y) pairs
<code>regr_r2(Y, X)</code>	double precision	double precision	Yes	square of the correlation coefficient
<code>regr_slope(Y, X)</code>	double precision	double precision	Yes	slope of the least-squares-fit linear equation determined by the (X, Y) pairs
<code>regr_sxx(Y, X)</code>	double precision	double precision	Yes	$\text{sum}(X^2) - \text{sum}(X)^2/N$ (“sum of squares” of the independent variable)

Function	Argument Type	Return Type	Partial Mode	Description
<code>regr_sxy(Y, X)</code>	double precision	double precision	Yes	$\frac{\text{sum}(X*Y) - \text{sum}(X) * \text{sum}(Y)}{N}$ (“sum of products” of independent times dependent variable)
<code>regr_syy(Y, X)</code>	double precision	double precision	Yes	$\frac{\text{sum}(Y^2) - \text{sum}(Y)^2/N}{N}$ (“sum of squares” of the dependent variable)
<code>stddev(expression)</code>	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	Yes	historical alias for <code>stddev_samp</code>
<code>stddev_pop(expression)</code>	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	Yes	population standard deviation of the input values
<code>stddev_samp(expression)</code>	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	Yes	sample standard deviation of the input values
<code>variance(expression)</code>	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	Yes	historical alias for <code>var_samp</code>
<code>var_pop(expression)</code>	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	Yes	population variance of the input values (square of the population standard deviation)
<code>var_samp(expression)</code>	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	Yes	sample variance of the input values (square of the sample standard deviation)

Table 9.57 shows some aggregate functions that use the *ordered-set aggregate* syntax. These functions are sometimes referred to as “inverse distribution” functions.

Table 9.57. Ordered-Set Aggregate Functions

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Partial Mode	Description
<code>mode(WITHIN)</code>		any sortable type	same as sort expression	No	returns the most frequent

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Partial Mode	Description
GROUP (ORDER BY <i>sort_expression</i>)					input value (arbitrarily choosing the first one if there are multiple equally-frequent results)
percentile_cont(<i>fraction</i>) WITHIN GROUP (ORDER BY <i>sort_expression</i>)	double precision	double precision or interval	same as sort expression	No	continuous percentile: returns a value corresponding to the specified fraction in the ordering, interpolating between adjacent input items if needed
percentile_cont(<i>fractions</i>) WITHIN GROUP (ORDER BY <i>sort_expression</i>)	double precision[]	double precision or interval	array of sort expression's type	No	multiple continuous percentile: returns an array of results matching the shape of the <i>fractions</i> parameter, with each non-null element replaced by the value corresponding to that percentile
percentile_disc(<i>fraction</i>) WITHIN GROUP (ORDER BY <i>sort_expression</i>)	double precision	any sortable type	same as sort expression	No	discrete percentile: returns the first input value whose position in the ordering equals or exceeds the specified fraction
percentile_disc(<i>fractions</i>) WITHIN GROUP (ORDER BY <i>sort_expression</i>)	double precision[]	any sortable type	array of sort expression's type	No	multiple discrete percentile: returns an array of results matching the shape of the <i>fractions</i> parameter, with each non-null element replaced by the

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Partial Mode	Description
					input value corresponding to that percentile

All the aggregates listed in Table 9.57 ignore null values in their sorted input. For those that take a *fraction* parameter, the fraction value must be between 0 and 1; an error is thrown if not. However, a null fraction value simply produces a null result.

Each of the aggregates listed in Table 9.58 is associated with a window function of the same name defined in Section 9.21. In each case, the aggregate result is the value that the associated window function would have returned for the “hypothetical” row constructed from *args*, if such a row had been added to the sorted group of rows computed from the *sorted_args*.

Table 9.58. Hypothetical-Set Aggregate Functions

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Partial Mode	Description
<code>rank(args)</code> WITHIN GROUP (ORDER BY <i>sorted_args</i>)	VARIADIC "any"	VARIADIC "any"	bigint	No	rank of the hypothetical row, with gaps for duplicate rows
<code>dense_rank(args)</code> WITHIN GROUP (ORDER BY <i>sorted_args</i>)	VARIADIC "any"	VARIADIC "any"	bigint	No	rank of the hypothetical row, without gaps
<code>percent_rank(args)</code> WITHIN GROUP (ORDER BY <i>sorted_args</i>)	VARIADIC "any"	VARIADIC "any"	double precision	No	relative rank of the hypothetical row, ranging from 0 to 1
<code>cume_dist(args)</code> WITHIN GROUP (ORDER BY <i>sorted_args</i>)	VARIADIC "any"	VARIADIC "any"	double precision	No	relative rank of the hypothetical row, ranging from 1/N to 1

For each of these hypothetical-set aggregates, the list of direct arguments given in *args* must match the number and types of the aggregated arguments given in *sorted_args*. Unlike most built-in aggregates, these aggregates are not strict, that is they do not drop input rows containing nulls. Null values sort according to the rule specified in the ORDER BY clause.

Table 9.59. Grouping Operations

Function	Return Type	Description
GROUPING(<i>args...</i>)	integer	Integer bit mask indicating which arguments are not being included in the current grouping set

Grouping operations are used in conjunction with grouping sets (see Section 7.2.4) to distinguish result rows. The arguments to the GROUPING operation are not actually evaluated, but they must match exactly expressions given in the GROUP BY clause of the associated query level. Bits are assigned with the rightmost argument being the least-significant bit; each bit is 0 if the corresponding expression is included in the grouping criteria of the grouping set generating the result row, and 1 if it is not. For example:

```
=> SELECT * FROM items_sold;
make | model | sales
-----+-----+-----
Foo  | GT    | 10
Foo  | Tour  | 20
Bar  | City  | 15
Bar  | Sport | 5
(4 rows)

=> SELECT make, model, GROUPING(make,model), sum(sales) FROM
items_sold GROUP BY ROLLUP(make,model);
make | model | grouping | sum
-----+-----+-----+-----
Foo  | GT    |          0 | 10
Foo  | Tour  |          0 | 20
Bar  | City  |          0 | 15
Bar  | Sport |          0 | 5
Foo  |       |          1 | 30
Bar  |       |          1 | 20
      |       |          3 | 50
(7 rows)
```

9.21. Window Functions

Window functions provide the ability to perform calculations across sets of rows that are related to the current query row. See Section 3.5 for an introduction to this feature, and Section 4.2.8 for syntax details.

The built-in window functions are listed in Table 9.60. Note that these functions *must* be invoked using window function syntax, i.e., an OVER clause is required.

In addition to these functions, any built-in or user-defined general-purpose or statistical aggregate (i.e., not ordered-set or hypothetical-set aggregates) can be used as a window function; see Section 9.20 for a list of the built-in aggregates. Aggregate functions act as window functions only when an OVER clause follows the call; otherwise they act as non-window aggregates and return a single row for the entire set.

Table 9.60. General-Purpose Window Functions

Function	Return Type	Description
row_number()	bigint	number of the current row within its partition, counting from 1

Function	Return Type	Description
<code>rank()</code>	<code>bigint</code>	rank of the current row with gaps; same as <code>row_number</code> of its first peer
<code>dense_rank()</code>	<code>bigint</code>	rank of the current row without gaps; this function counts peer groups
<code>percent_rank()</code>	<code>double precision</code>	relative rank of the current row: $(rank - 1) / (total\ partition\ rows - 1)$
<code>cume_dist()</code>	<code>double precision</code>	cumulative distribution: (number of partition rows preceding or peer with current row) / total partition rows
<code>ntile(num_buckets integer)</code>	<code>integer</code>	integer ranging from 1 to the argument value, dividing the partition as equally as possible
<code>lag(value anyelement [, offset integer [, default anyelement]])</code>	same type as <i>value</i>	returns <i>value</i> evaluated at the row that is <i>offset</i> rows before the current row within the partition; if there is no such row, instead return <i>default</i> (which must be of the same type as <i>value</i>). Both <i>offset</i> and <i>default</i> are evaluated with respect to the current row. If omitted, <i>offset</i> defaults to 1 and <i>default</i> to null
<code>lead(value anyelement [, offset integer [, default anyelement]])</code>	same type as <i>value</i>	returns <i>value</i> evaluated at the row that is <i>offset</i> rows after the current row within the partition; if there is no such row, instead return <i>default</i> (which must be of the same type as <i>value</i>). Both <i>offset</i> and <i>default</i> are evaluated with respect to the current row. If omitted, <i>offset</i> defaults to 1 and <i>default</i> to null
<code>first_value(value any)</code>	same type as <i>value</i>	returns <i>value</i> evaluated at the row that is the first row of the window frame
<code>last_value(value any)</code>	same type as <i>value</i>	returns <i>value</i> evaluated at the row that is the last row of the window frame
<code>nth_value(value any, nth integer)</code>	same type as <i>value</i>	returns <i>value</i> evaluated at the row that is the <i>nth</i> row of the window frame (counting from 1); null if no such row

All of the functions listed in Table 9.60 depend on the sort ordering specified by the `ORDER BY` clause of the associated window definition. Rows that are not distinct when considering only the `ORDER BY` columns are said to be *peers*. The four ranking functions (including `cume_dist`) are defined so that they give the same answer for all peer rows.

Note that `first_value`, `last_value`, and `nth_value` consider only the rows within the “window frame”, which by default contains the rows from the start of the partition through the last peer of the current row. This is likely to give unhelpful results for `last_value` and sometimes also `nth_value`. You can redefine the frame by adding a suitable frame specification (`RANGE`, `ROWS` or `GROUPS`) to the `OVER` clause. See Section 4.2.8 for more information about frame specifications.

When an aggregate function is used as a window function, it aggregates over the rows within the current row's window frame. An aggregate used with `ORDER BY` and the default window frame definition produces a “running sum” type of behavior, which may or may not be what's wanted. To obtain aggregation over the whole partition, omit `ORDER BY` or use `ROWS BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING`. Other frame specifications can be used to obtain other effects.

Note

The SQL standard defines a `RESPECT NULLS` or `IGNORE NULLS` option for `lead`, `lag`, `first_value`, `last_value`, and `nth_value`. This is not implemented in PostgreSQL: the behavior is always the same as the standard's default, namely `RESPECT NULLS`. Likewise, the standard's `FROM FIRST` or `FROM LAST` option for `nth_value` is not implemented: only the default `FROM FIRST` behavior is supported. (You can achieve the result of `FROM LAST` by reversing the `ORDER BY` ordering.)

`cume_dist` computes the fraction of partition rows that are less than or equal to the current row and its peers, while `percent_rank` computes the fraction of partition rows that are less than the current row, assuming the current row does not exist in the partition.

9.22. Subquery Expressions

This section describes the SQL-compliant subquery expressions available in PostgreSQL. All of the expression forms documented in this section return Boolean (true/false) results.

9.22.1. EXISTS

`EXISTS (subquery)`

The argument of `EXISTS` is an arbitrary `SELECT` statement, or *subquery*. The subquery is evaluated to determine whether it returns any rows. If it returns at least one row, the result of `EXISTS` is “true”; if the subquery returns no rows, the result of `EXISTS` is “false”.

The subquery can refer to variables from the surrounding query, which will act as constants during any one evaluation of the subquery.

The subquery will generally only be executed long enough to determine whether at least one row is returned, not all the way to completion. It is unwise to write a subquery that has side effects (such as calling sequence functions); whether the side effects occur might be unpredictable.

Since the result depends only on whether any rows are returned, and not on the contents of those rows, the output list of the subquery is normally unimportant. A common coding convention is to write all `EXISTS` tests in the form `EXISTS(SELECT 1 WHERE ...)`. There are exceptions to this rule however, such as subqueries that use `INTERSECT`.

This simple example is like an inner join on `col2`, but it produces at most one output row for each `tab1` row, even if there are several matching `tab2` rows:

```
SELECT col1
```

```
FROM tab1
WHERE EXISTS (SELECT 1 FROM tab2 WHERE col2 = tab1.col2);
```

9.22.2. IN

expression IN (*subquery*)

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result. The result of IN is “true” if any equal subquery row is found. The result is “false” if no equal row is found (including the case where the subquery returns no rows).

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand row yields null, the result of the IN construct will be null, not false. This is in accordance with SQL’s normal rules for Boolean combinations of null values.

As with EXISTS, it’s unwise to assume that the subquery will be evaluated completely.

row_constructor IN (*subquery*)

The left-hand side of this form of IN is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result. The result of IN is “true” if any equal subquery row is found. The result is “false” if no equal row is found (including the case where the subquery returns no rows).

As usual, null values in the rows are combined per the normal rules of SQL Boolean expressions. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of that row comparison is unknown (null). If all the per-row results are either unequal or null, with at least one null, then the result of IN is null.

9.22.3. NOT IN

expression NOT IN (*subquery*)

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result. The result of NOT IN is “true” if only unequal subquery rows are found (including the case where the subquery returns no rows). The result is “false” if any equal row is found.

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand row yields null, the result of the NOT IN construct will be null, not true. This is in accordance with SQL’s normal rules for Boolean combinations of null values.

As with EXISTS, it’s unwise to assume that the subquery will be evaluated completely.

row_constructor NOT IN (*subquery*)

The left-hand side of this form of NOT IN is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result. The result of NOT IN is “true” if only unequal subquery rows are found (including the case where the subquery returns no rows). The result is “false” if any equal row is found.

As usual, null values in the rows are combined per the normal rules of SQL Boolean expressions. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of that row comparison is unknown (null). If all the per-row results are either unequal or null, with at least one null, then the result of `NOT IN` is null.

9.22.4. ANY/SOME

```
expression operator ANY (subquery)
expression operator SOME (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result using the given *operator*, which must yield a Boolean result. The result of `ANY` is “true” if any true result is obtained. The result is “false” if no true result is found (including the case where the subquery returns no rows).

`SOME` is a synonym for `ANY`. `IN` is equivalent to `= ANY`.

Note that if there are no successes and at least one right-hand row yields null for the operator's result, the result of the `ANY` construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

As with `EXISTS`, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor operator ANY (subquery)
row_constructor operator SOME (subquery)
```

The left-hand side of this form of `ANY` is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result, using the given *operator*. The result of `ANY` is “true” if the comparison returns true for any subquery row. The result is “false” if the comparison returns false for every subquery row (including the case where the subquery returns no rows). The result is `NULL` if no comparison with a subquery row returns true, and at least one comparison returns `NULL`.

See Section 9.23.5 for details about the meaning of a row constructor comparison.

9.22.5. ALL

```
expression operator ALL (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result using the given *operator*, which must yield a Boolean result. The result of `ALL` is “true” if all rows yield true (including the case where the subquery returns no rows). The result is “false” if any false result is found. The result is `NULL` if no comparison with a subquery row returns false, and at least one comparison returns `NULL`.

`NOT IN` is equivalent to `<> ALL`.

As with `EXISTS`, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor operator ALL (subquery)
```

The left-hand side of this form of `ALL` is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each

row of the subquery result, using the given *operator*. The result of ALL is “true” if the comparison returns true for all subquery rows (including the case where the subquery returns no rows). The result is “false” if the comparison returns false for any subquery row. The result is NULL if no comparison with a subquery row returns false, and at least one comparison returns NULL.

See Section 9.23.5 for details about the meaning of a row constructor comparison.

9.22.6. Single-Row Comparison

row_constructor operator (subquery)

The left-hand side is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. Furthermore, the subquery cannot return more than one row. (If it returns zero rows, the result is taken to be null.) The left-hand side is evaluated and compared row-wise to the single subquery result row.

See Section 9.23.5 for details about the meaning of a row constructor comparison.

9.23. Row and Array Comparisons

This section describes several specialized constructs for making multiple comparisons between groups of values. These forms are syntactically related to the subquery forms of the previous section, but do not involve subqueries. The forms involving array subexpressions are PostgreSQL extensions; the rest are SQL-compliant. All of the expression forms documented in this section return Boolean (true/false) results.

9.23.1. IN

expression IN (value [, ...])

The right-hand side is a parenthesized list of scalar expressions. The result is “true” if the left-hand expression's result is equal to any of the right-hand expressions. This is a shorthand notation for

```
expression = value1
OR
expression = value2
OR
...
```

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand expression yields null, the result of the IN construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

9.23.2. NOT IN

expression NOT IN (value [, ...])

The right-hand side is a parenthesized list of scalar expressions. The result is “true” if the left-hand expression's result is unequal to all of the right-hand expressions. This is a shorthand notation for

```
expression <> value1
AND
```

```
expression <> value2
AND
...
```

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand expression yields null, the result of the NOT IN construct will be null, not true as one might naively expect. This is in accordance with SQL's normal rules for Boolean combinations of null values.

Tip

x NOT IN y is equivalent to NOT (x IN y) in all cases. However, null values are much more likely to trip up the novice when working with NOT IN than when working with IN. It is best to express your condition positively if possible.

9.23.3. ANY/SOME (array)

```
expression operator ANY (array expression)
expression operator SOME (array expression)
```

The right-hand side is a parenthesized expression, which must yield an array value. The left-hand expression is evaluated and compared to each element of the array using the given *operator*, which must yield a Boolean result. The result of ANY is “true” if any true result is obtained. The result is “false” if no true result is found (including the case where the array has zero elements).

If the array expression yields a null array, the result of ANY will be null. If the left-hand expression yields null, the result of ANY is ordinarily null (though a non-strict comparison operator could possibly yield a different result). Also, if the right-hand array contains any null elements and no true comparison result is obtained, the result of ANY will be null, not false (again, assuming a strict comparison operator). This is in accordance with SQL's normal rules for Boolean combinations of null values.

SOME is a synonym for ANY.

9.23.4. ALL (array)

```
expression operator ALL (array expression)
```

The right-hand side is a parenthesized expression, which must yield an array value. The left-hand expression is evaluated and compared to each element of the array using the given *operator*, which must yield a Boolean result. The result of ALL is “true” if all comparisons yield true (including the case where the array has zero elements). The result is “false” if any false result is found.

If the array expression yields a null array, the result of ALL will be null. If the left-hand expression yields null, the result of ALL is ordinarily null (though a non-strict comparison operator could possibly yield a different result). Also, if the right-hand array contains any null elements and no false comparison result is obtained, the result of ALL will be null, not true (again, assuming a strict comparison operator). This is in accordance with SQL's normal rules for Boolean combinations of null values.

9.23.5. Row Constructor Comparison

```
row_constructor operator row_constructor
```

Each side is a row constructor, as described in Section 4.2.13. The two row values must have the same number of fields. Each side is evaluated and they are compared row-wise. Row constructor

comparisons are allowed when the *operator* is =, <>, <, <=, > or >=. Every row element must be of a type which has a default B-tree operator class or the attempted comparison may generate an error.

Note

Errors related to the number or types of elements might not occur if the comparison is resolved using earlier columns.

The = and <> cases work slightly differently from the others. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of the row comparison is unknown (null).

For the <, <=, > and >= cases, the row elements are compared left-to-right, stopping as soon as an unequal or null pair of elements is found. If either of this pair of elements is null, the result of the row comparison is unknown (null); otherwise comparison of this pair of elements determines the result. For example, ROW(1, 2, NULL) < ROW(1, 3, 0) yields true, not null, because the third pair of elements are not considered.

Note

Prior to PostgreSQL 8.2, the <, <=, > and >= cases were not handled per SQL specification. A comparison like ROW(a, b) < ROW(c, d) was implemented as a < c AND b < d whereas the correct behavior is equivalent to a < c OR (a = c AND b < d).

row_constructor IS DISTINCT FROM *row_constructor*

This construct is similar to a <> row comparison, but it does not yield null for null inputs. Instead, any null value is considered unequal to (distinct from) any non-null value, and any two nulls are considered equal (not distinct). Thus the result will either be true or false, never null.

row_constructor IS NOT DISTINCT FROM *row_constructor*

This construct is similar to a = row comparison, but it does not yield null for null inputs. Instead, any null value is considered unequal to (distinct from) any non-null value, and any two nulls are considered equal (not distinct). Thus the result will always be either true or false, never null.

9.23.6. Composite Type Comparison

record operator record

The SQL specification requires row-wise comparison to return NULL if the result depends on comparing two NULL values or a NULL and a non-NULL. PostgreSQL does this only when comparing the results of two row constructors (as in Section 9.23.5) or comparing a row constructor to the output of a subquery (as in Section 9.22). In other contexts where two composite-type values are compared, two NULL field values are considered equal, and a NULL is considered larger than a non-NULL. This is necessary in order to have consistent sorting and indexing behavior for composite types.

Each side is evaluated and they are compared row-wise. Composite type comparisons are allowed when the *operator* is =, <>, <, <=, > or >=, or has semantics similar to one of these. (To be specific, an operator can be a row comparison operator if it is a member of a B-tree operator class, or is the negator of the = member of a B-tree operator class.) The default behavior of the above operators is the same as for IS [NOT] DISTINCT FROM for row constructors (see Section 9.23.5).

To support matching of rows which include elements without a default B-tree operator class, the following operators are defined for composite type comparison: `*=`, `*<>`, `*<`, `*<=`, `*>`, and `*>=`. These operators compare the internal binary representation of the two rows. Two rows might have a different binary representation even though comparisons of the two rows with the equality operator is true. The ordering of rows under these comparison operators is deterministic but not otherwise meaningful. These operators are used internally for materialized views and might be useful for other specialized purposes such as replication but are not intended to be generally useful for writing queries.

9.24. Set Returning Functions

This section describes functions that possibly return more than one row. The most widely used functions in this class are series generating functions, as detailed in Table 9.61 and Table 9.62. Other, more specialized set-returning functions are described elsewhere in this manual. See Section 7.2.1.4 for ways to combine multiple set-returning functions.

Table 9.61. Series Generating Functions

Function	Argument Type	Return Type	Description
<code>generate_series(start, stop)</code>	int, bigint or numeric	setof int, setof bigint, or setof numeric (same as argument type)	Generate a series of values, from <i>start</i> to <i>stop</i> with a step size of one
<code>generate_series(start, stop, step)</code>	int, bigint or numeric	setof int, setof bigint or setof numeric (same as argument type)	Generate a series of values, from <i>start</i> to <i>stop</i> with a step size of <i>step</i>
<code>generate_series(start, stop, step interval)</code>	timestamp or timestamp with time zone	setof timestamp or setof timestamp with time zone (same as argument type)	Generate a series of values, from <i>start</i> to <i>stop</i> with a step size of <i>step</i>

When *step* is positive, zero rows are returned if *start* is greater than *stop*. Conversely, when *step* is negative, zero rows are returned if *start* is less than *stop*. Zero rows are also returned for NULL inputs. It is an error for *step* to be zero. Some examples follow:

```
SELECT * FROM generate_series(2,4);
generate_series
-----
                2
                3
                4
(3 rows)
```

```
SELECT * FROM generate_series(5,1,-2);
generate_series
-----
                5
                3
                1
(3 rows)
```

```
SELECT * FROM generate_series(4,3);
generate_series
-----
```

```
(0 rows)

SELECT generate_series(1.1, 4, 1.3);
 generate_series
-----
          1.1
          2.4
          3.7
(3 rows)

-- this example relies on the date-plus-integer operator
SELECT current_date + s.a AS dates FROM generate_series(0,14,7) AS
s(a);
  dates
-----
2004-02-05
2004-02-12
2004-02-19
(3 rows)

SELECT * FROM generate_series('2008-03-01 00:00'::timestamp,
                              '2008-03-04 12:00', '10 hours');
 generate_series
-----
2008-03-01 00:00:00
2008-03-01 10:00:00
2008-03-01 20:00:00
2008-03-02 06:00:00
2008-03-02 16:00:00
2008-03-03 02:00:00
2008-03-03 12:00:00
2008-03-03 22:00:00
2008-03-04 08:00:00
(9 rows)
```

Table 9.62. Subscript Generating Functions

Function	Return Type	Description
<code>generate_subscripts(array anyarray, dim int)</code>	setof int	Generate a series comprising the given array's subscripts.
<code>generate_subscripts(array anyarray, dim int, reverse boolean)</code>	setof int	Generate a series comprising the given array's subscripts. When <i>reverse</i> is true, the series is returned in reverse order.

`generate_subscripts` is a convenience function that generates the set of valid subscripts for the specified dimension of the given array. Zero rows are returned for arrays that do not have the requested dimension, or for NULL arrays (but valid subscripts are returned for NULL array elements). Some examples follow:

```
-- basic usage
SELECT generate_subscripts('{NULL,1,NULL,2}'::int[], 1) AS s;
s
---
```

```

1
2
3
4
(4 rows)

```

```

-- presenting an array, the subscript and the subscripted
-- value requires a subquery
SELECT * FROM arrays;

```

```

      a
-----
{-1,-2}
{100,200,300}
(2 rows)

```

```

SELECT a AS array, s AS subscript, a[s] AS value
FROM (SELECT generate_subscripts(a, 1) AS s, a FROM arrays) foo;

```

```

      array      | subscript | value
-----+-----+-----
{-1,-2}         |          1 |    -1
{-1,-2}         |          2 |    -2
{100,200,300}   |          1 |   100
{100,200,300}   |          2 |   200
{100,200,300}   |          3 |   300
(5 rows)

```

```

-- unnest a 2D array
CREATE OR REPLACE FUNCTION unnest2(anyarray)
RETURNS SETOF anyelement AS $$
select $1[i][j]
      from generate_subscripts($1,1) g1(i),
           generate_subscripts($1,2) g2(j);
$$ LANGUAGE sql IMMUTABLE;
CREATE FUNCTION
SELECT * FROM unnest2(ARRAY[[1,2],[3,4]]);
unnest2

```

```

-----
      1
      2
      3
      4
(4 rows)

```

When a function in the FROM clause is suffixed by WITH ORDINALITY, a bigint column is appended to the output which starts from 1 and increments by 1 for each row of the function's output. This is most useful in the case of set returning functions such as unnest().

```

-- set returning function WITH ORDINALITY
SELECT * FROM pg_ls_dir('.') WITH ORDINALITY AS t(ls,n);

```

```

      ls      | n
-----+-----
pg_serial    | 1
pg_twophase  | 2
postmaster.opts | 3
pg_notify    | 4
postgresql.conf | 5
pg_tblspc    | 6

```

```

logfile          | 7
base            | 8
postmaster.pid  | 9
pg_ident.conf   | 10
global         | 11
pg_xact        | 12
pg_snapshots   | 13
pg_multixact   | 14
PG_VERSION     | 15
pg_wal         | 16
pg_hba.conf    | 17
pg_stat_tmp    | 18
pg_subtrans    | 19
(19 rows)

```

9.25. System Information Functions and Operators

Table 9.63 shows several functions that extract session and system information.

In addition to the functions listed in this section, there are a number of functions related to the statistics system that also provide system information. See Section 27.2.2 for more information.

Table 9.63. Session Information Functions

Name	Return Type	Description
<code>current_catalog</code>	name	name of current database (called “catalog” in the SQL standard)
<code>current_database()</code>	name	name of current database
<code>current_query()</code>	text	text of the currently executing query, as submitted by the client (might contain more than one statement)
<code>current_role</code>	name	equivalent to <code>current_user</code>
<code>current_schema[()]</code>	name	name of current schema
<code>current_schemas(boolean)</code>	name[]	names of schemas in search path, optionally including implicit schemas
<code>current_user</code>	name	user name of current execution context
<code>inet_client_addr()</code>	inet	address of the remote connection
<code>inet_client_port()</code>	int	port of the remote connection
<code>inet_server_addr()</code>	inet	address of the local connection
<code>inet_server_port()</code>	int	port of the local connection
<code>pg_backend_pid()</code>	int	Process ID of the server process attached to the current session
<code>pg_blocking_pids(int)</code>	int[]	Process ID(s) that are blocking specified server process ID from acquiring a lock
<code>pg_conf_load_time()</code>	timestamp with time zone	configuration load time

Name	Return Type	Description
<code>pg_current_logfile([text])</code>	text	Primary log file name, or log in the requested format, currently in use by the logging collector
<code>pg_my_temp_schema()</code>	oid	OID of session's temporary schema, or 0 if none
<code>pg_is_other_temp_schema(oid)</code>	boolean	is schema another session's temporary schema?
<code>pg_jit_available()</code>	boolean	is JIT compilation available in this session (see Chapter 31)? Returns false if jit is set to false.
<code>pg_listening_channels()</code>	setof text	channel names that the session is currently listening on
<code>pg_notification_queue_usage()</code>	double	fraction of the asynchronous notification queue currently occupied (0-1)
<code>pg_postmaster_start_time()</code>	timestamp with time zone	server start time
<code>pg_safe_snapshot_blocking_pids(int)</code>	int[]	Process ID(s) that are blocking specified server process ID from acquiring a safe snapshot
<code>pg_trigger_depth()</code>	int	current nesting level of PostgreSQL triggers (0 if not called, directly or indirectly, from inside a trigger)
<code>session_user</code>	name	session user name
<code>user</code>	name	equivalent to <code>current_user</code>
<code>version()</code>	text	PostgreSQL version information. See also <code>server_version_num</code> for a machine-readable version.

Note

`current_catalog`, `current_role`, `current_schema`, `current_user`, `session_user`, and `user` have special syntactic status in SQL: they must be called without trailing parentheses. (In PostgreSQL, parentheses can optionally be used with `current_schema`, but not with the others.)

The `session_user` is normally the user who initiated the current database connection; but superusers can change this setting with `SET SESSION AUTHORIZATION`. The `current_user` is the user identifier that is applicable for permission checking. Normally it is equal to the session user, but it can be changed with `SET ROLE`. It also changes during the execution of functions with the attribute `SECURITY DEFINER`. In Unix parlance, the session user is the “real user” and the current user is the “effective user”. `current_role` and `user` are synonyms for `current_user`. (The SQL standard draws a distinction between `current_role` and `current_user`, but PostgreSQL does not, since it unifies users and roles into a single kind of entity.)

`current_schema` returns the name of the schema that is first in the search path (or a null value if the search path is empty). This is the schema that will be used for any tables or other named objects that are created without specifying a target schema. `current_schemas(boolean)` returns an array

of the names of all schemas presently in the search path. The Boolean option determines whether or not implicitly included system schemas such as `pg_catalog` are included in the returned search path.

Note

The search path can be altered at run time. The command is:

```
SET search_path TO schema [ , schema , ... ]
```

`inet_client_addr` returns the IP address of the current client, and `inet_client_port` returns the port number. `inet_server_addr` returns the IP address on which the server accepted the current connection, and `inet_server_port` returns the port number. All these functions return NULL if the current connection is via a Unix-domain socket.

`pg_blocking_pids` returns an array of the process IDs of the sessions that are blocking the server process with the specified process ID, or an empty array if there is no such server process or it is not blocked. One server process blocks another if it either holds a lock that conflicts with the blocked process's lock request (hard block), or is waiting for a lock that would conflict with the blocked process's lock request and is ahead of it in the wait queue (soft block). When using parallel queries the result always lists client-visible process IDs (that is, `pg_backend_pid` results) even if the actual lock is held or awaited by a child worker process. As a result of that, there may be duplicated PIDs in the result. Also note that when a prepared transaction holds a conflicting lock, it will be represented by a zero process ID in the result of this function. Frequent calls to this function could have some impact on database performance, because it needs exclusive access to the lock manager's shared state for a short time.

`pg_conf_load_time` returns the timestamp with time zone when the server configuration files were last loaded. (If the current session was alive at the time, this will be the time when the session itself re-read the configuration files, so the reading will vary a little in different sessions. Otherwise it is the time when the postmaster process re-read the configuration files.)

`pg_current_logfile` returns, as text, the path of the log file(s) currently in use by the logging collector. The path includes the `log_directory` directory and the log file name. Log collection must be enabled or the return value is NULL. When multiple log files exist, each in a different format, `pg_current_logfile` called without arguments returns the path of the file having the first format found in the ordered list: `stderr`, `csvlog`. NULL is returned when no log file has any of these formats. To request a specific file format supply, as text, either `csvlog` or `stderr` as the value of the optional parameter. The return value is NULL when the log format requested is not a configured `log_destination`. The `pg_current_logfile` reflects the contents of the `current_logfiles` file.

`pg_my_temp_schema` returns the OID of the current session's temporary schema, or zero if it has none (because it has not created any temporary tables). `pg_is_other_temp_schema` returns true if the given OID is the OID of another session's temporary schema. (This can be useful, for example, to exclude other sessions' temporary tables from a catalog display.)

`pg_listening_channels` returns a set of names of asynchronous notification channels that the current session is listening to. `pg_notification_queue_usage` returns the fraction of the total available space for notifications currently occupied by notifications that are waiting to be processed, as a double in the range 0-1. See LISTEN and NOTIFY for more information.

`pg_postmaster_start_time` returns the timestamp with time zone when the server started.

`pg_safe_snapshot_blocking_pids` returns an array of the process IDs of the sessions that are blocking the server process with the specified process ID from acquiring a safe snapshot, or an empty array if there is no such server process or it is not blocked. A session running a `SERIALIZABLE` transaction blocks a `SERIALIZABLE READ ONLY DEFERRABLE` transaction from acquiring a snapshot until the latter determines that it is safe to avoid taking any predicate locks. See Section 13.2.3 for more information about serializable and deferrable transactions. Frequent calls to this function could have some impact on database performance, because it needs access to the predicate lock manager's shared state for a short time.

`version` returns a string describing the PostgreSQL server's version. You can also get this information from `server_version` or for a machine-readable version, `server_version_num`. Software developers should use `server_version_num` (available since 8.2) or `PQserverVersion` instead of parsing the text version.

Table 9.64 lists functions that allow the user to query object access privileges programmatically. See Section 5.7 for more information about privileges.

Table 9.64. Access Privilege Inquiry Functions

Name	Return Type	Description
<code>has_any_column_privilege(user, table, privilege)</code>	boolean	does user have privilege for any column of table
<code>has_any_column_privilege(table, privilege)</code>	boolean	does current user have privilege for any column of table
<code>has_column_privilege(user, table, column, privilege)</code>	boolean	does user have privilege for column
<code>has_column_privilege(table, column, privilege)</code>	boolean	does current user have privilege for column
<code>has_database_privilege(user, database, privilege)</code>	boolean	does user have privilege for database
<code>has_database_privilege(database, privilege)</code>	boolean	does current user have privilege for database
<code>has_foreign_data_wrapper_privilege(user, fdw, privilege)</code>	boolean	does user have privilege for foreign-data wrapper
<code>has_foreign_data_wrapper_privilege(fdw, privilege)</code>	boolean	does current user have privilege for foreign-data wrapper
<code>has_function_privilege(user, function, privilege)</code>	boolean	does user have privilege for function
<code>has_function_privilege(function, privilege)</code>	boolean	does current user have privilege for function

Name	Return Type	Description
<code>has_language_privilege(user, language, privilege)</code>	boolean	does user have privilege for language
<code>has_language_privilege(language, privilege)</code>	boolean	does current user have privilege for language
<code>has_schema_privilege(user, schema, privilege)</code>	boolean	does user have privilege for schema
<code>has_schema_privilege(schema, privilege)</code>	boolean	does current user have privilege for schema
<code>has_sequence_privilege(user, sequence, privilege)</code>	boolean	does user have privilege for sequence
<code>has_sequence_privilege(sequence, privilege)</code>	boolean	does current user have privilege for sequence
<code>has_server_privilege(user, server, privilege)</code>	boolean	does user have privilege for foreign server
<code>has_server_privilege(server, privilege)</code>	boolean	does current user have privilege for foreign server
<code>has_table_privilege(user, table, privilege)</code>	boolean	does user have privilege for table
<code>has_table_privilege(table, privilege)</code>	boolean	does current user have privilege for table
<code>has_tablespace_privilege(user, tablespace, privilege)</code>	boolean	does user have privilege for tablespace
<code>has_tablespace_privilege(tablespace, privilege)</code>	boolean	does current user have privilege for tablespace
<code>has_type_privilege(user, type, privilege)</code>	boolean	does user have privilege for type
<code>has_type_privilege(type, privilege)</code>	boolean	does current user have privilege for type
<code>pg_has_role(user, role, privilege)</code>	boolean	does user have privilege for role
<code>pg_has_role(role, privilege)</code>	boolean	does current user have privilege for role
<code>row_security_active(table)</code>	boolean	does current user have row level security active for table

`has_table_privilege` checks whether a user can access a table in a particular way. The user can be specified by name, by OID (`pg_authid.oid`), `public` to indicate the PUBLIC pseudo-role, or

if the argument is omitted `current_user` is assumed. The table can be specified by name or by OID. (Thus, there are actually six variants of `has_table_privilege`, which can be distinguished by the number and types of their arguments.) When specifying by name, the name can be schema-qualified if necessary. The desired access privilege type is specified by a text string, which must evaluate to one of the values `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, `REFERENCES`, or `TRIGGER`. Optionally, `WITH GRANT OPTION` can be added to a privilege type to test whether the privilege is held with grant option. Also, multiple privilege types can be listed separated by commas, in which case the result will be `true` if any of the listed privileges is held. (Case of the privilege string is not significant, and extra whitespace is allowed between but not within privilege names.) Some examples:

```
SELECT has_table_privilege('myschema.mytable', 'select');
SELECT has_table_privilege('joe', 'mytable', 'INSERT, SELECT WITH
GRANT OPTION');
```

`has_sequence_privilege` checks whether a user can access a sequence in a particular way. The possibilities for its arguments are analogous to `has_table_privilege`. The desired access privilege type must evaluate to one of `USAGE`, `SELECT`, or `UPDATE`.

`has_any_column_privilege` checks whether a user can access any column of a table in a particular way. Its argument possibilities are analogous to `has_table_privilege`, except that the desired access privilege type must evaluate to some combination of `SELECT`, `INSERT`, `UPDATE`, or `REFERENCES`. Note that having any of these privileges at the table level implicitly grants it for each column of the table, so `has_any_column_privilege` will always return `true` if `has_table_privilege` does for the same arguments. But `has_any_column_privilege` also succeeds if there is a column-level grant of the privilege for at least one column.

`has_column_privilege` checks whether a user can access a column in a particular way. Its argument possibilities are analogous to `has_table_privilege`, with the addition that the column can be specified either by name or attribute number. The desired access privilege type must evaluate to some combination of `SELECT`, `INSERT`, `UPDATE`, or `REFERENCES`. Note that having any of these privileges at the table level implicitly grants it for each column of the table.

`has_database_privilege` checks whether a user can access a database in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to some combination of `CREATE`, `CONNECT`, `TEMPORARY`, or `TEMP` (which is equivalent to `TEMPORARY`).

`has_function_privilege` checks whether a user can access a function in a particular way. Its argument possibilities are analogous to `has_table_privilege`. When specifying a function by a text string rather than by OID, the allowed input is the same as for the `regprocedure` data type (see Section 8.19). The desired access privilege type must evaluate to `EXECUTE`. An example is:

```
SELECT has_function_privilege('joeuser', 'myfunc(int, text)',
'execute');
```

`has_foreign_data_wrapper_privilege` checks whether a user can access a foreign-data wrapper in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `USAGE`.

`has_language_privilege` checks whether a user can access a procedural language in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `USAGE`.

`has_schema_privilege` checks whether a user can access a schema in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to some combination of `CREATE` or `USAGE`.

`has_server_privilege` checks whether a user can access a foreign server in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `USAGE`.

`has_tablespace_privilege` checks whether a user can access a tablespace in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `CREATE`.

`has_type_privilege` checks whether a user can access a type in a particular way. Its argument possibilities are analogous to `has_table_privilege`. When specifying a type by a text string rather than by `OID`, the allowed input is the same as for the `regtype` data type (see Section 8.19). The desired access privilege type must evaluate to `USAGE`.

`pg_has_role` checks whether a user can access a role in a particular way. Its argument possibilities are analogous to `has_table_privilege`, except that `public` is not allowed as a user name. The desired access privilege type must evaluate to some combination of `MEMBER` or `USAGE`. `MEMBER` denotes direct or indirect membership in the role (that is, the right to do `SET ROLE`), while `USAGE` denotes whether the privileges of the role are immediately available without doing `SET ROLE`.

`row_security_active` checks whether row level security is active for the specified table in the context of the `current_user` and environment. The table can be specified by name or by `OID`.

Table 9.66 shows the operators available for the `aclitem` type, which is the catalog representation of access privileges. See Section 5.7 for information about how to read access privilege values.

Table 9.65. `aclitem` Operators

Operator	Description	Example	Result
<code>=</code>	equal	<code>'calvin=r*w/hobbes'::aclitem = 'calvin=r*w*/hobbes'::aclitem</code>	<code>f</code>
<code>@></code>	contains element	<code>'{calvin=r*w/hobbes,hobbes=r*w*/postgres}'::aclitem[] @> 'calvin=r*w/hobbes'::aclitem</code>	<code>t</code>
<code>~</code>	contains element	<code>'{calvin=r*w/hobbes,hobbes=r*w*/postgres}'::aclitem[] ~ 'calvin=r*w/hobbes'::aclitem</code>	<code>t</code>

Table 9.66 shows some additional functions to manage the `aclitem` type.

Table 9.66. `aclitem` Functions

Name	Return Type	Description
<code>acldefault(type, ownerId)</code>	<code>aclitem[]</code>	get the default access privileges for an object belonging to <code>ownerId</code>
<code>aclexplode(aclitem[])</code>	<code>setof record</code>	get <code>aclitem</code> array as tuples
<code>makeaclitem(grantee, grantor, privilege, grantable)</code>	<code>aclitem</code>	build an <code>aclitem</code> from input

`acldefault` returns the built-in default access privileges for an object of type *type* belonging to role *ownerId*. These represent the access privileges that will be assumed when an object's ACL entry is null. (The default access privileges are described in Section 5.7.) The *type* parameter is a CHAR: write 'c' for COLUMN, 'r' for TABLE and table-like objects, 's' for SEQUENCE, 'd' for DATABASE, 'f' for FUNCTION or PROCEDURE, 'l' for LANGUAGE, 'L' for LARGE OBJECT, 'n' for SCHEMA, 't' for TABLESPACE, 'F' for FOREIGN DATA WRAPPER, 'S' for FOREIGN SERVER, or 'T' for TYPE or DOMAIN.

`aclxplode` returns an `aclitem` array as a set of rows. Output columns are grantor `oid`, grantee `oid` (0 for PUBLIC), granted privilege as text (SELECT, ...) and whether the privilege is grantable as boolean. `makeaclitem` performs the inverse operation.

Table 9.67 shows functions that determine whether a certain object is *visible* in the current schema search path. For example, a table is said to be visible if its containing schema is in the search path and no table of the same name appears earlier in the search path. This is equivalent to the statement that the table can be referenced by name without explicit schema qualification. To list the names of all visible tables:

```
SELECT relname FROM pg_class WHERE pg_table_is_visible(oid);
```

Table 9.67. Schema Visibility Inquiry Functions

Name	Return Type	Description
<code>pg_collation_is_visible(collation_oid)</code>	boolean	is collation visible in search path
<code>pg_conversion_is_visible(conversion_oid)</code>	boolean	is conversion visible in search path
<code>pg_function_is_visible(function_oid)</code>	boolean	is function visible in search path
<code>pg_opclass_is_visible(opclass_oid)</code>	boolean	is operator class visible in search path
<code>pg_operator_is_visible(operator_oid)</code>	boolean	is operator visible in search path
<code>pg_opfamily_is_visible(opclass_oid)</code>	boolean	is operator family visible in search path
<code>pg_statistics_object_is_visible(stat_oid)</code>	boolean	is statistics object visible in search path
<code>pg_table_is_visible(table_oid)</code>	boolean	is table visible in search path
<code>pg_ts_config_is_visible(config_oid)</code>	boolean	is text search configuration visible in search path
<code>pg_ts_dict_is_visible(dict_oid)</code>	boolean	is text search dictionary visible in search path
<code>pg_ts_parser_is_visible(parser_oid)</code>	boolean	is text search parser visible in search path
<code>pg_ts_template_is_visible(template_oid)</code>	boolean	is text search template visible in search path
<code>pg_type_is_visible(type_oid)</code>	boolean	is type (or domain) visible in search path

Each function performs the visibility check for one type of database object. Note that `pg_table_is_visible` can also be used with views, materialized views, indexes, sequences and foreign tables; `pg_function_is_visible` can also be used with procedures and aggregates; `pg_type_is_visible` can also be used with domains. For functions and operators, an object in the search path is visible if there is no object of the same name *and argument data type(s)* earlier in the path. For operator classes, both name and associated index access method are considered.

All these functions require object OIDs to identify the object to be checked. If you want to test an object by name, it is convenient to use the OID alias types (`regclass`, `regtype`, `regprocedure`, `regoperator`, `regconfig`, or `regdictionary`), for example:

```
SELECT pg_type_is_visible('myschema.widget'::regtype);
```

Note that it would not make much sense to test a non-schema-qualified type name in this way — if the name can be recognized at all, it must be visible.

Table 9.68 lists functions that extract information from the system catalogs.

Table 9.68. System Catalog Information Functions

Name	Return Type	Description
<code>format_type(type_oid, typemod)</code>	text	get SQL name of a data type
<code>pg_get_constraintdef(constraint_oid)</code>	text	get definition of a constraint
<code>pg_get_constraintdef(constraint_oid, pretty_bool)</code>	text	get definition of a constraint
<code>pg_get_expr(pg_node_tree, relation_oid)</code>	text	decompile internal form of an expression, assuming that any Vars in it refer to the relation indicated by the second parameter
<code>pg_get_expr(pg_node_tree, relation_oid, pretty_bool)</code>	text	decompile internal form of an expression, assuming that any Vars in it refer to the relation indicated by the second parameter
<code>pg_get_functiondef(func_oid)</code>	text	get definition of a function or procedure
<code>pg_get_function_arguments(func_oid)</code>	text	get argument list of function's or procedure's definition (with default values)
<code>pg_get_function_identity_arguments(func_oid)</code>	text	get argument list to identify a function or procedure (without default values)
<code>pg_get_function_result(func_oid)</code>	text	get RETURNS clause for function (returns null for a procedure)
<code>pg_get_indexdef(index_oid)</code>	text	get CREATE INDEX command for index
<code>pg_get_indexdef(index_oid, column_no, pretty_bool)</code>	text	get CREATE INDEX command for index, or definition of just one index column when <code>column_no</code> is not zero

Name	Return Type	Description
<code>pg_get_keywords()</code>	setof record	get list of SQL keywords and their categories
<code>pg_get_ruledef(rule_oid)</code>	text	get CREATE RULE command for rule
<code>pg_get_ruledef(rule_oid, pretty_bool)</code>	text	get CREATE RULE command for rule
<code>pg_get_serial_sequence(table_name, column_name)</code>	text	get name of the sequence that a serial or identity column uses
<code>pg_get_statisticsobjdef(statobj_oid)</code>	text	get CREATE STATISTICS command for extended statistics object
<code>pg_get_triggerdef(trigger_oid)</code>	text	get CREATE [CONSTRAINT] TRIGGER command for trigger
<code>pg_get_triggerdef(trigger_oid, pretty_bool)</code>	text	get CREATE [CONSTRAINT] TRIGGER command for trigger
<code>pg_get_userbyid(role_oid)</code>	name	get role name with given OID
<code>pg_get_viewdef(view_name)</code>	text	get underlying SELECT command for view or materialized view (<i>deprecated</i>)
<code>pg_get_viewdef(view_name, pretty_bool)</code>	text	get underlying SELECT command for view or materialized view (<i>deprecated</i>)
<code>pg_get_viewdef(view_oid)</code>	text	get underlying SELECT command for view or materialized view
<code>pg_get_viewdef(view_oid, pretty_bool)</code>	text	get underlying SELECT command for view or materialized view
<code>pg_get_viewdef(view_oid, wrap_column_int)</code>	text	get underlying SELECT command for view or materialized view; lines with fields are wrapped to specified number of columns, pretty-printing is implied
<code>pg_index_column_has_property(index_oid, column_no, prop_name)</code>	boolean	test whether an index column has a specified property
<code>pg_index_has_property(index_oid, prop_name)</code>	boolean	test whether an index has a specified property
<code>pg_indexam_has_property(am_oid, prop_name)</code>	boolean	test whether an index access method has a specified property

Name	Return Type	Description
<code>pg_options_to_table(<i>reloptions</i>)</code>	setof record	get the set of storage option name/value pairs
<code>pg_tablespace_databases(<i>tablespace_oid</i>)</code>	setof oid	get the set of database OIDs that have objects in the tablespace
<code>pg_tablespace_location(<i>tablespace_oid</i>)</code>	text	get the path in the file system that this tablespace is located in
<code>pg_typeof(<i>any</i>)</code>	regtype	get the data type of any value
<code>collation for (<i>any</i>)</code>	text	get the collation of the argument
<code>to_regclass(<i>rel_name</i>)</code>	regclass	get the OID of the named relation
<code>to_regproc(<i>func_name</i>)</code>	regproc	get the OID of the named function
<code>to_regprocedure(<i>func_name</i>)</code>	regprocedure	get the OID of the named function
<code>to_regoper(<i>operator_name</i>)</code>	regoper	get the OID of the named operator
<code>to_regoperator(<i>operator_name</i>)</code>	regoperator	get the OID of the named operator
<code>to_regtype(<i>type_name</i>)</code>	regtype	get the OID of the named type
<code>to_regnamespace(<i>schema_name</i>)</code>	regnamespace	get the OID of the named schema
<code>to_regrole(<i>role_name</i>)</code>	regrole	get the OID of the named role

`format_type` returns the SQL name of a data type that is identified by its type OID and possibly a type modifier. Pass NULL for the type modifier if no specific modifier is known.

`pg_get_keywords` returns a set of records describing the SQL keywords recognized by the server. The `word` column contains the keyword. The `catcode` column contains a category code: U for unreserved, C for column name, T for type or function name, or R for reserved. The `catdesc` column contains a possibly-localized string describing the category.

`pg_get_constraintdef`, `pg_get_indexdef`, `pg_get_ruledef`, `pg_get_statisticsobjdef`, and `pg_get_triggerdef`, respectively reconstruct the creating command for a constraint, index, rule, extended statistics object, or trigger. (Note that this is a decompiled reconstruction, not the original text of the command.) `pg_get_expr` decompiles the internal form of an individual expression, such as the default value for a column. It can be useful when examining the contents of system catalogs. If the expression might contain Vars, specify the OID of the relation they refer to as the second parameter; if no Vars are expected, zero is sufficient. `pg_get_viewdef` reconstructs the SELECT query that defines a view. Most of these functions come in two variants, one of which can optionally “pretty-print” the result. The pretty-printed format is more readable, but the default format is more likely to be interpreted the same way by future versions of PostgreSQL; avoid using pretty-printed output for dump purposes. Passing `false` for the pretty-print parameter yields the same result as the variant that does not have the parameter at all.

`pg_get_functiondef` returns a complete CREATE OR REPLACE FUNCTION statement for a function. `pg_get_function_arguments` returns the argument list of a function, in the form it would need to appear in within CREATE FUNCTION. `pg_get_function_result` similarly returns the appropriate RETURNS clause for the function. `pg_get_function_identity_arguments` returns the argument list necessary to identify a function, in the form it would need to appear in within ALTER FUNCTION, for instance. This form omits default values.

`pg_get_serial_sequence` returns the name of the sequence associated with a column, or NULL if no sequence is associated with the column. If the column is an identity column, the associated se-

quence is the sequence internally created for the identity column. For columns created using one of the serial types (`serial`, `smallserial`, `bigserial`), it is the sequence created for that serial column definition. In the latter case, this association can be modified or removed with `ALTER SEQUENCE OWNED BY`. (The function probably should have been called `pg_get_owned_sequence`; its current name reflects the fact that it has typically been used with `serial` or `bigserial` columns.) The first input parameter is a table name with optional schema, and the second parameter is a column name. Because the first parameter is potentially a schema and table, it is not treated as a double-quoted identifier, meaning it is lower cased by default, while the second parameter, being just a column name, is treated as double-quoted and has its case preserved. The function returns a value suitably formatted for passing to sequence functions (see Section 9.16). A typical use is in reading the current value of a sequence for an identity or serial column, for example:

```
SELECT currval(pg_get_serial_sequence('sometable', 'id'));
```

`pg_get_userbyid` extracts a role's name given its OID.

`pg_index_column_has_property`, `pg_index_has_property`, and `pg_index-am_has_property` return whether the specified index column, index, or index access method possesses the named property. `NULL` is returned if the property name is not known or does not apply to the particular object, or if the OID or column number does not identify a valid object. Refer to Table 9.69 for column properties, Table 9.70 for index properties, and Table 9.71 for access method properties. (Note that extension access methods can define additional property names for their indexes.)

Table 9.69. Index Column Properties

Name	Description
<code>asc</code>	Does the column sort in ascending order on a forward scan?
<code>desc</code>	Does the column sort in descending order on a forward scan?
<code>nulls_first</code>	Does the column sort with nulls first on a forward scan?
<code>nulls_last</code>	Does the column sort with nulls last on a forward scan?
<code>orderable</code>	Does the column possess any defined sort ordering?
<code>distance_orderable</code>	Can the column be scanned in order by a “distance” operator, for example <code>ORDER BY col <-> constant</code> ?
<code>returnable</code>	Can the column value be returned by an index-only scan?
<code>search_array</code>	Does the column natively support <code>col = ANY(array)</code> searches?
<code>search_nulls</code>	Does the column support <code>IS NULL</code> and <code>IS NOT NULL</code> searches?

Table 9.70. Index Properties

Name	Description
<code>clusterable</code>	Can the index be used in a <code>CLUSTER</code> command?
<code>index_scan</code>	Does the index support plain (non-bitmap) scans?
<code>bitmap_scan</code>	Does the index support bitmap scans?

Name	Description
backward_scan	Can the scan direction be changed in mid-scan (to support FETCH BACKWARD on a cursor without needing materialization)?

Table 9.71. Index Access Method Properties

Name	Description
can_order	Does the access method support ASC, DESC and related keywords in CREATE INDEX?
can_unique	Does the access method support unique indexes?
can_multi_col	Does the access method support indexes with multiple columns?
can_exclude	Does the access method support exclusion constraints?
can_include	Does the access method support the INCLUDE clause of CREATE INDEX?

pg_options_to_table returns the set of storage option name/value pairs (*option_name/option_value*) when passed pg_class.reloptions or pg_attribute.attoptions.

pg_tablespace_databases allows a tablespace to be examined. It returns the set of OIDs of databases that have objects stored in the tablespace. If this function returns any rows, the tablespace is not empty and cannot be dropped. To display the specific objects populating the tablespace, you will need to connect to the databases identified by pg_tablespace_databases and query their pg_class catalogs.

pg_typeof returns the OID of the data type of the value that is passed to it. This can be helpful for troubleshooting or dynamically constructing SQL queries. The function is declared as returning regtype, which is an OID alias type (see Section 8.19); this means that it is the same as an OID for comparison purposes but displays as a type name. For example:

```
SELECT pg_typeof(33);

 pg_typeof
-----
 integer
(1 row)

SELECT typlen FROM pg_type WHERE oid = pg_typeof(33);
 typlen
-----
      4
(1 row)
```

The expression collation_for returns the collation of the value that is passed to it. Example:

```
SELECT collation_for (description) FROM pg_description LIMIT 1;
 pg_collation_for
-----
 "default"
(1 row)

SELECT collation_for ('foo' COLLATE "de_DE");
 pg_collation_for
```

```
-----
"de_DE"
(1 row)
```

The value might be quoted and schema-qualified. If no collation is derived for the argument expression, then a null value is returned. If the argument is not of a collatable data type, then an error is raised.

The `to_regclass`, `to_regproc`, `to_regprocedure`, `to_regoper`, `to_regoperator`, `to_regtype`, `to_regnamespace`, and `to_regrole` functions translate relation, function, operator, type, schema, and role names (given as text) to objects of type `regclass`, `regproc`, `regprocedure`, `regoper`, `regoperator`, `regtype`, `regnamespace`, and `regrole` respectively. These functions differ from a cast from text in that they don't accept a numeric OID, and that they return null rather than throwing an error if the name is not found (or, for `to_regproc` and `to_regoper`, if the given name matches multiple objects).

Table 9.72 lists functions related to database object identification and addressing.

Table 9.72. Object Information and Addressing Functions

Name	Return Type	Description
<code>pg_describe_object(classid oid, objid oid, objsubid integer)</code>	text	get description of a database object
<code>pg_identify_object(classid oid, objid oid, objsubid integer)</code>	<i>type</i> text, <i>schema</i> text, <i>name</i> text, <i>identity</i> text	get identity of a database object
<code>pg_identify_object_as_address(classid oid, objid oid, objsubid integer)</code>	<i>type</i> text, <i>object_names</i> text[], <i>object_args</i> text[]	get external representation of a database object's address
<code>pg_get_object_address(type text, object_names text[], object_args text[])</code>	<i>classid</i> oid, <i>objid</i> oid, <i>objsubid</i> integer	get address of a database object from its external representation

`pg_describe_object` returns a textual description of a database object specified by catalog OID, object OID, and sub-object ID (such as a column number within a table; the sub-object ID is zero when referring to a whole object). This description is intended to be human-readable, and might be translated, depending on server configuration. This is useful to determine the identity of an object as stored in the `pg_depend` catalog.

`pg_identify_object` returns a row containing enough information to uniquely identify the database object specified by catalog OID, object OID and sub-object ID. This information is intended to be machine-readable, and is never translated. *type* identifies the type of database object; *schema* is the schema name that the object belongs in, or NULL for object types that do not belong to schemas; *name* is the name of the object, quoted if necessary, if the name (along with schema name, if pertinent) is sufficient to uniquely identify the object, otherwise NULL; *identity* is the complete object identity, with the precise format depending on object type, and each name within the format being schema-qualified and quoted as necessary.

`pg_identify_object_as_address` returns a row containing enough information to uniquely identify the database object specified by catalog OID, object OID and sub-object ID. The returned information is independent of the current server, that is, it could be used to identify an identically named object in another server. *type* identifies the type of database object; *object_names* and *object_args* are text arrays that together form a reference to the object. These three values can be passed to `pg_get_object_address` to obtain the internal address of the object. This function is the inverse of `pg_get_object_address`.

`pg_get_object_address` returns a row containing enough information to uniquely identify the database object specified by its type and object name and argument arrays. The returned values are the ones that would be used in system catalogs such as `pg_depend` and can be passed to other system functions such as `pg_identify_object` or `pg_describe_object`. `classid` is the OID of the system catalog containing the object; `objid` is the OID of the object itself, and `objsubid` is the sub-object ID, or zero if none. This function is the inverse of `pg_identify_object_as_address`.

The functions shown in Table 9.73 extract comments previously stored with the `COMMENT` command. A null value is returned if no comment could be found for the specified parameters.

Table 9.73. Comment Information Functions

Name	Return Type	Description
<code>col_description(table_oid, column_number)</code>	text	get comment for a table column
<code>obj_description(object_oid, catalog_name)</code>	text	get comment for a database object
<code>obj_description(object_oid)</code>	text	get comment for a database object (<i>deprecated</i>)
<code>shobj_description(object_oid, catalog_name)</code>	text	get comment for a shared database object

`col_description` returns the comment for a table column, which is specified by the OID of its table and its column number. (`obj_description` cannot be used for table columns since columns do not have OIDs of their own.)

The two-parameter form of `obj_description` returns the comment for a database object specified by its OID and the name of the containing system catalog. For example, `obj_description(123456, 'pg_class')` would retrieve the comment for the table with OID 123456. The one-parameter form of `obj_description` requires only the object OID. It is deprecated since there is no guarantee that OIDs are unique across different system catalogs; therefore, the wrong comment might be returned.

`shobj_description` is used just like `obj_description` except it is used for retrieving comments on shared objects. Some system catalogs are global to all databases within each cluster, and the descriptions for objects in them are stored globally as well.

The functions shown in Table 9.74 provide server transaction information in an exportable form. The main use of these functions is to determine which transactions were committed between two snapshots.

Table 9.74. Transaction IDs and Snapshots

Name	Return Type	Description
<code>txid_current()</code>	bigint	get current transaction ID, assigning a new one if the current transaction does not have one
<code>txid_current_if_assigned()</code>	bigint	same as <code>txid_current()</code> but returns null instead of assigning a new transaction ID if none is already assigned

Name	Return Type	Description
<code>txid_current_snapshot()</code>	<code>txid_snapshot</code>	get current snapshot
<code>txid_snapshot_xip(txid_snapshot)</code>	setof <code>bigint</code>	get in-progress transaction IDs in snapshot
<code>txid_snapshot_xmax(txid_snapshot)</code>	<code>bigint</code>	get xmax of snapshot
<code>txid_snapshot_xmin(txid_snapshot)</code>	<code>bigint</code>	get xmin of snapshot
<code>txid_visible_in_snapshot(bigint, txid_snapshot)</code>	boolean	is transaction ID visible in snapshot? (do not use with subtransaction ids)
<code>txid_status(bigint)</code>	text	report the status of the given transaction: committed, aborted, in progress, or null if the transaction ID is too old

The internal transaction ID type (`xid`) is 32 bits wide and wraps around every 4 billion transactions. However, these functions export a 64-bit format that is extended with an “epoch” counter so it will not wrap around during the life of an installation. The data type used by these functions, `txid_snapshot`, stores information about transaction ID visibility at a particular moment in time. Its components are described in Table 9.75.

Table 9.75. Snapshot Components

Name	Description
<code>xmin</code>	Earliest transaction ID (<code>txid</code>) that is still active. All earlier transactions will either be committed and visible, or rolled back and dead.
<code>xmax</code>	First as-yet-unassigned <code>txid</code> . All <code>txids</code> greater than or equal to this are not yet started as of the time of the snapshot, and thus invisible.
<code>xip_list</code>	Active <code>txids</code> at the time of the snapshot. The list includes only those active <code>txids</code> between <code>xmin</code> and <code>xmax</code> ; there might be active <code>txids</code> higher than <code>xmax</code> . A <code>txid</code> that is <code>xmin <= txid < xmax</code> and not in this list was already completed at the time of the snapshot, and thus either visible or dead according to its commit status. The list does not include <code>txids</code> of subtransactions.

`txid_snapshot`'s textual representation is `xmin:xmax:xip_list`. For example `10:20:10,14,15` means `xmin=10`, `xmax=20`, `xip_list=10, 14, 15`.

`txid_status(bigint)` reports the commit status of a recent transaction. Applications may use it to determine whether a transaction committed or aborted when the application and database server become disconnected while a `COMMIT` is in progress. The status of a transaction will be reported as either `in progress`, `committed`, or `aborted`, provided that the transaction is recent enough that the system retains the commit status of that transaction. If is old enough that no references to that transaction survive in the system and the commit status information has been discarded, this function will return `NULL`. Note that prepared transactions are reported as `in progress`; applications must check `pg_prepared_xacts` if they need to determine whether the `txid` is a prepared transaction.

The functions shown in Table 9.76 provide information about transactions that have been already committed. These functions mainly provide information about when the transactions were committed. They only provide useful data when `track_commit_timestamp` configuration option is enabled and only for transactions that were committed after it was enabled.

Table 9.76. Committed Transaction Information

Name	Return Type	Description
<code>pg_xact_commit_timestamp(xid)</code>	timestamp with time zone	get commit timestamp of a transaction
<code>pg_last_committed_xact()</code>	<i>xid</i> <i>xid</i> , <i>timestamp</i> timestamp with time zone	get transaction ID and commit timestamp of latest committed transaction

The functions shown in Table 9.77 print information initialized during `initdb`, such as the catalog version. They also show information about write-ahead logging and checkpoint processing. This information is cluster-wide, and not specific to any one database. They provide most of the same information, from the same source, as `pg_controldata`, although in a form better suited to SQL functions.

Table 9.77. Control Data Functions

Name	Return Type	Description
<code>pg_control_checkpoint()</code>	record	Returns information about current checkpoint state.
<code>pg_control_system()</code>	record	Returns information about current control file state.
<code>pg_control_init()</code>	record	Returns information about cluster initialization state.
<code>pg_control_recovery()</code>	record	Returns information about recovery state.

`pg_control_checkpoint` returns a record, shown in Table 9.78

Table 9.78. pg_control_checkpoint Columns

Column Name	Data Type
<code>checkpoint_lsn</code>	<code>pg_lsn</code>
<code>redo_lsn</code>	<code>pg_lsn</code>
<code>redo_wal_file</code>	text
<code>timeline_id</code>	integer
<code>prev_timeline_id</code>	integer
<code>full_page_writes</code>	boolean
<code>next_xid</code>	text
<code>next_oid</code>	oid
<code>next_multixact_id</code>	xid
<code>next_multi_offset</code>	xid
<code>oldest_xid</code>	xid
<code>oldest_xid_dbid</code>	oid
<code>oldest_active_xid</code>	xid
<code>oldest_multi_xid</code>	xid

Column Name	Data Type
oldest_multi_dbid	oid
oldest_commit_ts_xid	xid
newest_commit_ts_xid	xid
checkpoint_time	timestamp with time zone

`pg_control_system` returns a record, shown in Table 9.79

Table 9.79. `pg_control_system` Columns

Column Name	Data Type
<code>pg_control_version</code>	integer
<code>catalog_version_no</code>	integer
<code>system_identifier</code>	bigint
<code>pg_control_last_modified</code>	timestamp with time zone

`pg_control_init` returns a record, shown in Table 9.80

Table 9.80. `pg_control_init` Columns

Column Name	Data Type
<code>max_data_alignment</code>	integer
<code>database_block_size</code>	integer
<code>blocks_per_segment</code>	integer
<code>wal_block_size</code>	integer
<code>bytes_per_wal_segment</code>	integer
<code>max_identifier_length</code>	integer
<code>max_index_columns</code>	integer
<code>max_toast_chunk_size</code>	integer
<code>large_object_chunk_size</code>	integer
<code>float4_pass_by_value</code>	boolean
<code>float8_pass_by_value</code>	boolean
<code>data_page_checksum_version</code>	integer

`pg_control_recovery` returns a record, shown in Table 9.81

Table 9.81. `pg_control_recovery` Columns

Column Name	Data Type
<code>min_recovery_end_lsn</code>	pg_lsn
<code>min_recovery_end_timeline</code>	integer
<code>backup_start_lsn</code>	pg_lsn
<code>backup_end_lsn</code>	pg_lsn
<code>end_of_backup_record_required</code>	boolean

9.26. System Administration Functions

The functions described in this section are used to control and monitor a PostgreSQL installation.

9.26.1. Configuration Settings Functions

Table 9.82 shows the functions available to query and alter run-time configuration parameters.

Table 9.82. Configuration Settings Functions

Name	Return Type	Description
<code>current_setting(<i>setting_name</i> [, <i>missing_ok</i>])</code>	text	get current value of setting
<code>set_config(<i>setting_name</i>, <i>new_value</i>, <i>is_local</i>)</code>	text	set parameter and return new value

The function `current_setting` yields the current value of the setting `setting_name`. It corresponds to the SQL command `SHOW`. An example:

```
SELECT current_setting('datestyle');

 current_setting
-----
 ISO, MDY
(1 row)
```

If there is no setting named `setting_name`, `current_setting` throws an error unless `missing_ok` is supplied and is true.

`set_config` sets the parameter `setting_name` to `new_value`. If `is_local` is true, the new value will only apply to the current transaction. If you want the new value to apply for the current session, use `false` instead. The function corresponds to the SQL command `SET`. An example:

```
SELECT set_config('log_statement_stats', 'off', false);

 set_config
-----
 off
(1 row)
```

9.26.2. Server Signaling Functions

The functions shown in Table 9.83 send control signals to other server processes. Use of these functions is restricted to superusers by default but access may be granted to others using `GRANT`, with noted exceptions.

Table 9.83. Server Signaling Functions

Name	Return Type	Description
<code>pg_cancel_backend(<i>pid</i> int)</code>	boolean	Cancel a backend's current query. This is also allowed if the calling role is a member of the role whose backend is being canceled or the calling role has been granted <code>pg_sig-</code>

Name	Return Type	Description
		nal_backend, however only superusers can cancel superuser backends.
pg_reload_conf()	boolean	Cause server processes to reload their configuration files
pg_rotate_logfile()	boolean	Rotate server's log file
pg_terminate_backend(pid int)	boolean	Terminate a backend. This is also allowed if the calling role is a member of the role whose backend is being terminated or the calling role has been granted pg_signal_backend, however only superusers can terminate superuser backends.

Each of these functions returns true if successful and false otherwise.

pg_cancel_backend and pg_terminate_backend send signals (SIGINT or SIGTERM respectively) to backend processes identified by process ID. The process ID of an active backend can be found from the pid column of the pg_stat_activity view, or by listing the postgres processes on the server (using ps on Unix or the Task Manager on Windows). The role of an active backend can be found from the username column of the pg_stat_activity view.

pg_reload_conf sends a SIGHUP signal to the server, causing configuration files to be reloaded by all server processes.

pg_rotate_logfile signals the log-file manager to switch to a new output file immediately. This works only when the built-in log collector is running, since otherwise there is no log-file manager subprocess.

9.26.3. Backup Control Functions

The functions shown in Table 9.84 assist in making on-line backups. These functions cannot be executed during recovery (except non-exclusive pg_start_backup, non-exclusive pg_stop_backup, pg_is_in_backup, pg_backup_start_time and pg_wal_lsn_diff).

Table 9.84. Backup Control Functions

Name	Return Type	Description
pg_create_restore_point(name text)	pg_lsn	Create a named point for performing restore (restricted to superusers by default, but other users can be granted EXECUTE to run the function)
pg_current_wal_flush_lsn()	pg_lsn	Get current write-ahead log flush location
pg_current_wal_insert_lsn()	pg_lsn	Get current write-ahead log insert location
pg_current_wal_lsn()	pg_lsn	Get current write-ahead log write location
pg_start_backup(label text [, fast boolean] [, exclusive boolean])	pg_lsn	Prepare for performing on-line backup (restricted to superusers by default, but other users can

Name	Return Type	Description
		be granted EXECUTE to run the function)
<code>pg_stop_backup()</code>	<code>pg_lsn</code>	Finish performing exclusive on-line backup (restricted to superusers by default, but other users can be granted EXECUTE to run the function)
<code>pg_stop_backup(exclusive boolean [, wait_for_archive boolean])</code>	<code>setof record</code>	Finish performing exclusive or non-exclusive on-line backup (restricted to superusers by default, but other users can be granted EXECUTE to run the function)
<code>pg_is_in_backup()</code>	<code>bool</code>	True if an on-line exclusive backup is still in progress.
<code>pg_backup_start_time()</code>	<code>timestamp with time zone</code>	Get start time of an on-line exclusive backup in progress.
<code>pg_switch_wal()</code>	<code>pg_lsn</code>	Force switch to a new write-ahead log file (restricted to superusers by default, but other users can be granted EXECUTE to run the function)
<code>pg_walfile_name(lsn pg_lsn)</code>	<code>text</code>	Convert write-ahead log location to file name
<code>pg_walfile_name_offset(lsn pg_lsn)</code>	<code>text, integer</code>	Convert write-ahead log location to file name and decimal byte offset within file
<code>pg_wal_lsn_diff(lsn pg_lsn, lsn pg_lsn)</code>	<code>numeric</code>	Calculate the difference between two write-ahead log locations

`pg_start_backup` accepts an arbitrary user-defined label for the backup. (Typically this would be the name under which the backup dump file will be stored.) When used in exclusive mode, the function writes a backup label file (`backup_label`) and, if there are any links in the `pg_tblspc/` directory, a tablespace map file (`tablespace_map`) into the database cluster's data directory, performs a checkpoint, and then returns the backup's starting write-ahead log location as text. The user can ignore this result value, but it is provided in case it is useful. When used in non-exclusive mode, the contents of these files are instead returned by the `pg_stop_backup` function, and should be written to the backup by the caller.

```
postgres=# select pg_start_backup('label_goes_here');
pg_start_backup
-----
 0/D4445B8
(1 row)
```

There is an optional second parameter of type `boolean`. If `true`, it specifies executing `pg_start_backup` as quickly as possible. This forces an immediate checkpoint which will cause a spike in I/O operations, slowing any concurrently executing queries.

In an exclusive backup, `pg_stop_backup` removes the label file and, if it exists, the `tablespace_map` file created by `pg_start_backup`. In a non-exclusive backup, the contents of the `backup_label` and `tablespace_map` are returned in the result of the function, and should be written to files in the backup (and not in the data directory). There is an optional second parameter of

type `boolean`. If false, the `pg_stop_backup` will return immediately after the backup is completed without waiting for WAL to be archived. This behavior is only useful for backup software which independently monitors WAL archiving. Otherwise, WAL required to make the backup consistent might be missing and make the backup useless. When this parameter is set to true, `pg_stop_backup` will wait for WAL to be archived when archiving is enabled; on the standby, this means that it will wait only when `archive_mode = always`. If write activity on the primary is low, it may be useful to run `pg_switch_wal` on the primary in order to trigger an immediate segment switch.

When executed on a primary, the function also creates a backup history file in the write-ahead log archive area. The history file includes the label given to `pg_start_backup`, the starting and ending write-ahead log locations for the backup, and the starting and ending times of the backup. The return value is the backup's ending write-ahead log location (which again can be ignored). After recording the ending location, the current write-ahead log insertion point is automatically advanced to the next write-ahead log file, so that the ending write-ahead log file can be archived immediately to complete the backup.

`pg_switch_wal` moves to the next write-ahead log file, allowing the current file to be archived (assuming you are using continuous archiving). The return value is the ending write-ahead log location + 1 within the just-completed write-ahead log file. If there has been no write-ahead log activity since the last write-ahead log switch, `pg_switch_wal` does nothing and returns the start location of the write-ahead log file currently in use.

`pg_create_restore_point` creates a named write-ahead log record that can be used as recovery target, and returns the corresponding write-ahead log location. The given name can then be used with `recovery_target_name` to specify the point up to which recovery will proceed. Avoid creating multiple restore points with the same name, since recovery will stop at the first one whose name matches the recovery target.

`pg_current_wal_lsn` displays the current write-ahead log write location in the same format used by the above functions. Similarly, `pg_current_wal_insert_lsn` displays the current write-ahead log insertion location and `pg_current_wal_flush_lsn` displays the current write-ahead log flush location. The insertion location is the “logical” end of the write-ahead log at any instant, while the write location is the end of what has actually been written out from the server's internal buffers and flush location is the location guaranteed to be written to durable storage. The write location is the end of what can be examined from outside the server, and is usually what you want if you are interested in archiving partially-complete write-ahead log files. The insertion and flush locations are made available primarily for server debugging purposes. These are both read-only operations and do not require superuser permissions.

You can use `pg_walfile_name_offset` to extract the corresponding write-ahead log file name and byte offset from the results of any of the above functions. For example:

```
postgres=# SELECT * FROM pg_walfile_name_offset(pg_stop_backup());
      file_name      | file_offset
-----+-----
 00000001000000000000000D |      4039624
(1 row)
```

Similarly, `pg_walfile_name` extracts just the write-ahead log file name. When the given write-ahead log location is exactly at a write-ahead log file boundary, both these functions return the name of the preceding write-ahead log file. This is usually the desired behavior for managing write-ahead log archiving behavior, since the preceding file is the last one that currently needs to be archived.

`pg_wal_lsn_diff` calculates the difference in bytes between two write-ahead log locations. It can be used with `pg_stat_replication` or some functions shown in Table 9.84 to get the replication lag.

For details about proper usage of these functions, see Section 25.3.

9.26.4. Recovery Control Functions

The functions shown in Table 9.85 provide information about the current status of the standby. These functions may be executed both during recovery and in normal running.

Table 9.85. Recovery Information Functions

Name	Return Type	Description
<code>pg_is_in_recovery()</code>	bool	True if recovery is still in progress.
<code>pg_last_wal_receive_lsn()</code>	pg_lsn	Get last write-ahead log location received and synced to disk by streaming replication. While streaming replication is in progress this will increase monotonically. If recovery has completed this will remain static at the value of the last WAL record received and synced to disk during recovery. If streaming replication is disabled, or if it has not yet started, the function returns NULL.
<code>pg_last_wal_replay_lsn()</code>	pg_lsn	Get last write-ahead log location replayed during recovery. If recovery is still in progress this will increase monotonically. If recovery has completed then this value will remain static at the value of the last WAL record applied during that recovery. When the server has been started normally without recovery the function returns NULL.
<code>pg_last_xact_replay_timestamp()</code>	timestamp with time zone	Get time stamp of last transaction replayed during recovery. This is the time at which the commit or abort WAL record for that transaction was generated on the primary. If no transactions have been replayed during recovery, this function returns NULL. Otherwise, if recovery is still in progress this will increase monotonically. If recovery has completed then this value will remain static at the value of the last transaction applied during that recovery. When the server has been started normally without recovery the function returns NULL.

The functions shown in Table 9.86 control the progress of recovery. These functions may be executed only during recovery.

Table 9.86. Recovery Control Functions

Name	Return Type	Description
<code>pg_is_wal_replay_paused()</code>	bool	True if recovery is paused.
<code>pg_promote(wait boolean DEFAULT true, wait_seconds integer DEFAULT 60)</code>	boolean	Promotes a physical standby server. With <i>wait</i> set to <code>true</code> (the default), the function waits until promotion is completed or <i>wait_seconds</i> seconds have passed, and returns <code>true</code> if promotion is successful and <code>false</code> otherwise. If <i>wait</i> is set to <code>false</code> , the function returns <code>true</code> immediately after sending SIGUSR1 to the postmaster to trigger the promotion. This function is restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_wal_replay_pause()</code>	void	Pauses recovery immediately (restricted to superusers by default, but other users can be granted EXECUTE to run the function).
<code>pg_wal_replay_resume()</code>	void	Restarts recovery if it was paused (restricted to superusers by default, but other users can be granted EXECUTE to run the function).

While recovery is paused no further database changes are applied. If in hot standby, all new queries will see the same consistent snapshot of the database, and no further query conflicts will be generated until recovery is resumed.

If streaming replication is disabled, the paused state may continue indefinitely without problem. While streaming replication is in progress WAL records will continue to be received, which will eventually fill available disk space, depending upon the duration of the pause, the rate of WAL generation and available disk space.

9.26.5. Snapshot Synchronization Functions

PostgreSQL allows database sessions to synchronize their snapshots. A *snapshot* determines which data is visible to the transaction that is using the snapshot. Synchronized snapshots are necessary when two or more sessions need to see identical content in the database. If two sessions just start their transactions independently, there is always a possibility that some third transaction commits between the executions of the two `START TRANSACTION` commands, so that one session sees the effects of that transaction and the other does not.

To solve this problem, PostgreSQL allows a transaction to *export* the snapshot it is using. As long as the exporting transaction remains open, other transactions can *import* its snapshot, and thereby be guaranteed that they see exactly the same view of the database that the first transaction sees. But note that any database changes made by any one of these transactions remain invisible to the other transactions, as is usual for changes made by uncommitted transactions. So the transactions are synchronized with respect to pre-existing data, but act normally for changes they make themselves.

Snapshots are exported with the `pg_export_snapshot` function, shown in Table 9.87, and imported with the `SET TRANSACTION` command.

Table 9.87. Snapshot Synchronization Functions

Name	Return Type	Description
<code>pg_export_snapshot()</code>	text	Save the current snapshot and return its identifier

The function `pg_export_snapshot` saves the current snapshot and returns a text string identifying the snapshot. This string must be passed (outside the database) to clients that want to import the snapshot. The snapshot is available for import only until the end of the transaction that exported it. A transaction can export more than one snapshot, if needed. Note that doing so is only useful in `READ COMMITTED` transactions, since in `REPEATABLE READ` and higher isolation levels, transactions use the same snapshot throughout their lifetime. Once a transaction has exported any snapshots, it cannot be prepared with `PREPARE TRANSACTION`.

See `SET TRANSACTION` for details of how to use an exported snapshot.

9.26.6. Replication Functions

The functions shown in Table 9.88 are for controlling and interacting with replication features. See Section 26.2.5, Section 26.2.6, and Chapter 49 for information about the underlying features. Use of functions for replication origin is restricted to superusers. Use of functions for replication slot is restricted to superusers and users having `REPLICATION` privilege.

Many of these functions have equivalent commands in the replication protocol; see Section 52.4.

The functions described in Section 9.26.3, Section 9.26.4, and Section 9.26.5 are also relevant for replication.

Table 9.88. Replication SQL Functions

Function	Return Type	Description
<code>pg_create_physical_replication_slot(slot_name name [, immediately_reserve boolean, temporary boolean])</code>	<code>(slot_name name, lsn pg_lsn)</code>	Creates a new physical replication slot named <code>slot_name</code> . The optional second parameter, when <code>true</code> , specifies that the LSN for this replication slot be reserved immediately; otherwise the LSN is reserved on first connection from a streaming replication client. Streaming changes from a physical slot is only possible with the streaming-replication protocol — see Section 52.4. The optional third parameter, <code>temporary</code> , when set to <code>true</code> , specifies that the slot should not be permanently stored to disk and is only meant for use by current session. Temporary slots are also released upon any error. This function corresponds to the replication protocol command <code>CREATE_REPLICATION_SLOT ... PHYSICAL</code> .

Function	Return Type	Description
<code>pg_drop_replication_slot(slot_name name)</code>	void	Drops the physical or logical replication slot named <code>slot_name</code> . Same as replication protocol command <code>DROP_REPLICATION_SLOT</code> . For logical slots, this must be called when connected to the same database the slot was created on.
<code>pg_create_logical_replication_slot(slot_name name, plugin name [, temporary boolean])</code>	<code>(slot_name name, lsn pg_lsn)</code>	Creates a new logical (decoding) replication slot named <code>slot_name</code> using the output plugin <code>plugin</code> . The optional third parameter, <code>temporary</code> , when set to true, specifies that the slot should not be permanently stored to disk and is only meant for use by current session. Temporary slots are also released upon any error. A call to this function has the same effect as the replication protocol command <code>CREATE_REPLICATION_SLOT ... LOGICAL</code> .
<code>pg_copy_physical_replication_slot(src_slot_name name, dst_slot_name name [, temporary boolean])</code>	<code>(slot_name name, lsn pg_lsn)</code>	Copies an existing physical replication slot named <code>src_slot_name</code> to a physical replication slot named <code>dst_slot_name</code> . The copied physical slot starts to reserve WAL from the same LSN as the source slot. <code>temporary</code> is optional. If <code>temporary</code> is omitted, the same value as the source slot is used.
<code>pg_copy_logical_replication_slot(src_slot_name name, dst_slot_name name [, temporary boolean [, plugin name]])</code>	<code>(slot_name name, lsn pg_lsn)</code>	Copies an existing logical replication slot name <code>src_slot_name</code> to a logical replication slot named <code>dst_slot_name</code> while changing the output plugin and persistence. The copied logical slot starts from the same LSN as the source logical slot. Both <code>temporary</code> and <code>plugin</code> are optional. If <code>temporary</code> or <code>plugin</code> are omitted, the same values as the source logical slot are used.
<code>pg_logical_slot_get_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])</code>	<code>(lsn pg_lsn, xid xid, data text)</code>	Returns changes in the slot <code>slot_name</code> , starting from the point at which since changes have been consumed last. If <code>upto_lsn</code> and <code>upto_nchanges</code> are NULL, logical

Function	Return Type	Description
		decoding will continue until end of WAL. If <i>upto_lsn</i> is non-NULL, decoding will include only those transactions which commit prior to the specified LSN. If <i>upto_nchanges</i> is non-NULL, decoding will stop when the number of rows produced by decoding exceeds the specified value. Note, however, that the actual number of rows returned may be larger, since this limit is only checked after adding the rows produced when decoding each new transaction commit.
<code>pg_logical_slot_peek_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])</code>	<code>(lsn pg_lsn, xid xid, data text)</code>	Behaves just like the <code>pg_logical_slot_get_changes()</code> function, except that changes are not consumed; that is, they will be returned again on future calls.
<code>pg_logical_slot_get_binary_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])</code>	<code>(lsn pg_lsn, xid xid, data bytea)</code>	Behaves just like the <code>pg_logical_slot_get_changes()</code> function, except that changes are returned as <code>bytea</code> .
<code>pg_logical_slot_peek_binary_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])</code>	<code>(lsn pg_lsn, xid xid, data bytea)</code>	Behaves just like the <code>pg_logical_slot_get_changes()</code> function, except that changes are returned as <code>bytea</code> and that changes are not consumed; that is, they will be returned again on future calls.
<code>pg_replication_slot_advance(slot_name name, upto_lsn pg_lsn)</code>	<code>(slot_name name, end_lsn pg_lsn) bool</code>	Advances the current confirmed position of a replication slot named <i>slot_name</i> . The slot will not be moved backwards, and it will not be moved beyond the current insert location. Returns name of the slot and real position to which it was advanced to.
<code>pg_replication_origin_create(node_name text)</code>	<code>oid</code>	Create a replication origin with the given external name, and return the internal id assigned to it.
<code>pg_replication_origin_drop(node_name text)</code>	<code>void</code>	Delete a previously created replication origin, including any associated replay progress.

Function	Return Type	Description
<code>pg_replication_origin_oid(<i>node_name</i> text)</code>	oid	Lookup a replication origin by name and return the internal id. If no corresponding replication origin is found an error is thrown.
<code>pg_replication_origin_session_setup(<i>node_name</i> text)</code>	void	Mark the current session as replaying from the given origin, allowing replay progress to be tracked. Use <code>pg_replication_origin_session_reset</code> to revert. Can only be used if no previous origin is configured.
<code>pg_replication_origin_session_reset()</code>	void	Cancel the effects of <code>pg_replication_origin_session_setup()</code> .
<code>pg_replication_origin_session_is_setup()</code>	bool	Has a replication origin been configured in the current session?
<code>pg_replication_origin_session_progress(<i>flush</i> bool)</code>	pg_lsn	Return the replay location for the replication origin configured in the current session. The parameter <i>flush</i> determines whether the corresponding local transaction will be guaranteed to have been flushed to disk or not.
<code>pg_replication_origin_xact_setup(<i>origin_lsn</i> pg_lsn, <i>origin_timestamp</i> timestampz)</code>	void	Mark the current transaction as replaying a transaction that has committed at the given LSN and timestamp. Can only be called when a replication origin has previously been configured using <code>pg_replication_origin_session_setup()</code> .
<code>pg_replication_origin_xact_reset()</code>	void	Cancel the effects of <code>pg_replication_origin_xact_setup()</code> .
<code>pg_replication_origin_advance(<i>node_name</i> text, <i>lsn</i> pg_lsn)</code>	void	Set replication progress for the given node to the given location. This primarily is useful for setting up the initial location or a new location after configuration changes and similar. Be aware that careless use of this function can lead to inconsistently replicated data.
<code>pg_replication_origin_progress(<i>node_name</i> text, <i>flush</i> bool)</code>	pg_lsn	Return the replay location for the given replication origin. The parameter <i>flush</i> determines whether the corresponding local transaction will be guaranteed to have been flushed to disk or not.
<code>pg_logical_emit_message(<i>transactional</i></code>	pg_lsn	Emit text logical decoding message. This can be used to

Function	Return Type	Description
<code>bool, prefix text, content text)</code>		pass generic messages to logical decoding plugins through WAL. The parameter <i>transactional</i> specifies if the message should be part of current transaction or if it should be written immediately and decoded as soon as the logical decoding reads the record. The <i>prefix</i> is textual prefix used by the logical decoding plugins to easily recognize interesting messages for them. The <i>content</i> is the text of the message.
<code>pg_logical_emit_message(transactional bool, prefix text, content bytea)</code>	<code>pg_lsn</code>	Emit binary logical decoding message. This can be used to pass generic messages to logical decoding plugins through WAL. The parameter <i>transactional</i> specifies if the message should be part of current transaction or if it should be written immediately and decoded as soon as the logical decoding reads the record. The <i>prefix</i> is textual prefix used by the logical decoding plugins to easily recognize interesting messages for them. The <i>content</i> is the binary content of the message.

9.26.7. Database Object Management Functions

The functions shown in Table 9.89 calculate the disk space usage of database objects.

Table 9.89. Database Object Size Functions

Name	Return Type	Description
<code>pg_column_size(any)</code>	<code>int</code>	Number of bytes used to store a particular value (possibly compressed)
<code>pg_database_size(oid)</code>	<code>bigint</code>	Disk space used by the database with the specified OID
<code>pg_database_size(name)</code>	<code>bigint</code>	Disk space used by the database with the specified name
<code>pg_indexes_size(regclass)</code>	<code>bigint</code>	Total disk space used by indexes attached to the specified table
<code>pg_relation_size(relation regclass, fork text)</code>	<code>bigint</code>	Disk space used by the specified fork ('main', 'fsm', 'vm', or 'init') of the specified table or index

Name	Return Type	Description
<code>pg_relation_size(re- lation regclass)</code>	<code>bigint</code>	Shorthand for <code>pg_rela- tion_size(..., 'main')</code>
<code>pg_size_bytes(text)</code>	<code>bigint</code>	Converts a size in human-read- able format with size units into bytes
<code>pg_size_pretty(big- int)</code>	<code>text</code>	Converts a size in bytes ex- pressed as a 64-bit integer into a human-readable format with size units
<code>pg_size_pretty(numer- ic)</code>	<code>text</code>	Converts a size in bytes ex- pressed as a numeric value into a human-readable format with size units
<code>pg_table_size(reg- class)</code>	<code>bigint</code>	Disk space used by the specified table, excluding indexes (but in- cluding TOAST, free space map, and visibility map)
<code>pg_table- space_size(oid)</code>	<code>bigint</code>	Disk space used by the table- space with the specified OID
<code>pg_table- space_size(name)</code>	<code>bigint</code>	Disk space used by the table- space with the specified name
<code>pg_total_rela- tion_size(regclass)</code>	<code>bigint</code>	Total disk space used by the specified table, including all in- dexes and TOAST data

`pg_column_size` shows the space used to store any individual data value.

`pg_total_relation_size` accepts the OID or name of a table or toast table, and returns the total on-disk space used for that table, including all associated indexes. This function is equivalent to `pg_table_size + pg_indexes_size`.

`pg_table_size` accepts the OID or name of a table and returns the disk space needed for that table, exclusive of indexes. (TOAST space, free space map, and visibility map are included.)

`pg_indexes_size` accepts the OID or name of a table and returns the total disk space used by all the indexes attached to that table.

`pg_database_size` and `pg_tablespace_size` accept the OID or name of a database or tablespace, and return the total disk space used therein. To use `pg_database_size`, you must have `CONNECT` permission on the specified database (which is granted by default), or be a member of the `pg_read_all_stats` role. To use `pg_tablespace_size`, you must have `CREATE` permission on the specified tablespace, or be a member of the `pg_read_all_stats` role unless it is the default tablespace for the current database.

`pg_relation_size` accepts the OID or name of a table, index or toast table, and returns the on-disk size in bytes of one fork of that relation. (Note that for most purposes it is more convenient to use the higher-level functions `pg_total_relation_size` or `pg_table_size`, which sum the sizes of all forks.) With one argument, it returns the size of the main data fork of the relation. The second argument can be provided to specify which fork to examine:

- 'main' returns the size of the main data fork of the relation.
- 'fsm' returns the size of the Free Space Map (see Section 68.3) associated with the relation.
- 'vm' returns the size of the Visibility Map (see Section 68.4) associated with the relation.

- 'init' returns the size of the initialization fork, if any, associated with the relation.

`pg_size_pretty` can be used to format the result of one of the other functions in a human-readable way, using bytes, kB, MB, GB or TB as appropriate.

`pg_size_bytes` can be used to get the size in bytes from a string in human-readable format. The input may have units of bytes, kB, MB, GB or TB, and is parsed case-insensitively. If no units are specified, bytes are assumed.

Note

The units kB, MB, GB and TB used by the functions `pg_size_pretty` and `pg_size_bytes` are defined using powers of 2 rather than powers of 10, so 1kB is 1024 bytes, 1MB is $1024^2 = 1048576$ bytes, and so on.

The functions above that operate on tables or indexes accept a `regclass` argument, which is simply the OID of the table or index in the `pg_class` system catalog. You do not have to look up the OID by hand, however, since the `regclass` data type's input converter will do the work for you. Just write the table name enclosed in single quotes so that it looks like a literal constant. For compatibility with the handling of ordinary SQL names, the string will be converted to lower case unless it contains double quotes around the table name.

If an OID that does not represent an existing object is passed as argument to one of the above functions, NULL is returned.

The functions shown in Table 9.90 assist in identifying the specific disk files associated with database objects.

Table 9.90. Database Object Location Functions

Name	Return Type	Description
<code>pg_relation_file-</code> <code>ode(relation reg-</code> <code>class)</code>	oid	Filenode number of the specified relation
<code>pg_rela-</code> <code>tion_filepath(re-</code> <code>lation regclass)</code>	text	File path name of the specified relation
<code>pg_filenode_rela-</code> <code>tion(tablespace oid,</code> <code>filenode oid)</code>	regclass	Find the relation associated with a given tablespace and filenode

`pg_relation_filenode` accepts the OID or name of a table, index, sequence, or toast table, and returns the “filenode” number currently assigned to it. The filenode is the base component of the file name(s) used for the relation (see Section 68.1 for more information). For most tables the result is the same as `pg_class.relfilenode`, but for certain system catalogs `relfilenode` is zero and this function must be used to get the correct value. The function returns NULL if passed a relation that does not have storage, such as a view.

`pg_relation_filepath` is similar to `pg_relation_filenode`, but it returns the entire file path name (relative to the database cluster's data directory PGDATA) of the relation.

`pg_filenode_relation` is the reverse of `pg_relation_filenode`. Given a “tablespace” OID and a “filenode”, it returns the associated relation's OID. For a table in the database's default tablespace, the tablespace can be specified as 0.

Table 9.91 lists functions used to manage collations.

Table 9.91. Collation Management Functions

Name	Return Type	Description
<code>pg_collation_actual_version(oid)</code>	text	Return actual version of collation from operating system
<code>pg_import_system_collations(schema regnamespace)</code>	integer	Import operating system collations

`pg_collation_actual_version` returns the actual version of the collation object as it is currently installed in the operating system. If this is different from the value in `pg_collation.collversion`, then objects depending on the collation might need to be rebuilt. See also ALTER COLLATION.

`pg_import_system_collations` adds collations to the system catalog `pg_collation` based on all the locales it finds in the operating system. This is what `initdb` uses; see Section 23.2.2 for more details. If additional locales are installed into the operating system later on, this function can be run again to add collations for the new locales. Locales that match existing entries in `pg_collation` will be skipped. (But collation objects based on locales that are no longer present in the operating system are not removed by this function.) The `schema` parameter would typically be `pg_catalog`, but that is not a requirement; the collations could be installed into some other schema as well. The function returns the number of new collation objects it created.

Table 9.92. Partitioning Information Functions

Name	Return Type	Description
<code>pg_partition_tree(regclass)</code>	setof record	List information about tables or indexes in a partition tree for a given partitioned table or partitioned index, with one row for each partition. Information provided includes the name of the partition, the name of its immediate parent, a boolean value telling if the partition is a leaf, and an integer telling its level in the hierarchy. The value of level begins at 0 for the input table or index in its role as the root of the partition tree, 1 for its partitions, 2 for their partitions, and so on.
<code>pg_partition_ancestors(regclass)</code>	setof regclass	List the ancestor relations of the given partition, including the partition itself.
<code>pg_partition_root(regclass)</code>	regclass	Return the top-most parent of a partition tree to which the given relation belongs.

To check the total size of the data contained in measurement table described in Section 5.11.2.1, one could use the following query:

```
=# SELECT pg_size_pretty(sum(pg_relation_size(releid))) AS
total_size
```

```

        FROM pg_partition_tree('measurement');
total_size
-----
24 kB
(1 row)

```

9.26.8. Index Maintenance Functions

Table 9.93 shows the functions available for index maintenance tasks. These functions cannot be executed during recovery. Use of these functions is restricted to superusers and the owner of the given index.

Table 9.93. Index Maintenance Functions

Name	Return Type	Description
<code>brin_summarize_new_values(index regclass)</code>	integer	summarize page ranges not already summarized
<code>brin_summarize_range(index regclass, blockNumber bigint)</code>	integer	summarize the page range covering the given block, if not already summarized
<code>brin_desummarize_range(index regclass, blockNumber bigint)</code>	integer	de-summarize the page range covering the given block, if summarized
<code>gin_clean_pending_list(index regclass)</code>	bigint	move GIN pending list entries into main index structure

`brin_summarize_new_values` accepts the OID or name of a BRIN index and inspects the index to find page ranges in the base table that are not currently summarized by the index; for any such range it creates a new summary index tuple by scanning the table pages. It returns the number of new page range summaries that were inserted into the index. `brin_summarize_range` does the same, except it only summarizes the range that covers the given block number.

`gin_clean_pending_list` accepts the OID or name of a GIN index and cleans up the pending list of the specified index by moving entries in it to the main GIN data structure in bulk. It returns the number of pages removed from the pending list. Note that if the argument is a GIN index built with the `fastupdate` option disabled, no cleanup happens and the return value is 0, because the index doesn't have a pending list. Please see Section 66.4.1 and Section 66.5 for details of the pending list and `fastupdate` option.

9.26.9. Generic File Access Functions

The functions shown in Table 9.94 provide native access to files on the machine hosting the server. Only files within the database cluster directory and the `log_directory` can be accessed unless the user is granted the role `pg_read_server_files`. Use a relative path for files in the cluster directory, and a path matching the `log_directory` configuration setting for log files.

Note that granting users the `EXECUTE` privilege on `pg_read_file()`, or related functions, allows them the ability to read any file on the server which the database can read and that those reads bypass all in-database privilege checks. This means that, among other things, a user with this access is able to read the contents of the `pg_authid` table where authentication information is contained, as well as read any file in the database. Therefore, granting access to these functions should be carefully considered.

Table 9.94. Generic File Access Functions

Name	Return Type	Description
<code>pg_ls_dir(dirname text [, missing_ok boolean, include_dot_dirs boolean])</code>	setof text	List the contents of a directory. Restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_ls_logdir()</code>	setof record	List the name, size, and last modification time of files in the log directory. Access is granted to members of the <code>pg_monitor</code> role and may be granted to other non-superuser roles.
<code>pg_ls_waldir()</code>	setof record	List the name, size, and last modification time of files in the WAL directory. Access is granted to members of the <code>pg_monitor</code> role and may be granted to other non-superuser roles.
<code>pg_ls_archive_statusdir()</code>	setof record	List the name, size, and last modification time of files in the WAL archive status directory. Access is granted to members of the <code>pg_monitor</code> role and may be granted to other non-superuser roles.
<code>pg_ls_tmpdir([tablespace oid])</code>	setof record	List the name, size, and last modification time of files in the temporary directory for <code>tablespace</code> . If <code>tablespace</code> is not provided, the <code>pg_default</code> tablespace is used. Access is granted to members of the <code>pg_monitor</code> role and may be granted to other non-superuser roles.
<code>pg_read_file(filename text [, offset bigint, length bigint [, missing_ok boolean]])</code>	text	Return the contents of a text file. Restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_read_binary_file(filename text [, offset bigint, length bigint [, missing_ok boolean]])</code>	bytea	Return the contents of a file. Restricted to superusers by default, but other users can be granted EXECUTE to run the function.
<code>pg_stat_file(filename text [, missing_ok boolean])</code>	record	Return information about a file. Restricted to superusers by default, but other users can be granted EXECUTE to run the function.

Some of these functions take an optional `missing_ok` parameter, which specifies the behavior when the file or directory does not exist. If `true`, the function returns NULL (except `pg_ls_dir`, which returns an empty result set). If `false`, an error is raised. The default is `false`.

`pg_ls_dir` returns the names of all files (and directories and other special files) in the specified directory. The `include_dot_dirs` indicates whether “.” and “..” are included in the result set. The default is to exclude them (`false`), but including them can be useful when `missing_ok` is `true`, to distinguish an empty directory from a non-existent directory.

`pg_ls_logdir` returns the name, size, and last modified time (`mtime`) of each file in the log directory. By default, only superusers and members of the `pg_monitor` role can use this function. Access may be granted to others using `GRANT`.

`pg_ls_waldir` returns the name, size, and last modified time (`mtime`) of each file in the write ahead log (WAL) directory. By default only superusers and members of the `pg_monitor` role can use this function. Access may be granted to others using `GRANT`.

`pg_ls_archive_statusdir` returns the name, size, and last modified time (`mtime`) of each file in the WAL archive status directory `pg_wal/archive_status`. By default only superusers and members of the `pg_monitor` role can use this function. Access may be granted to others using `GRANT`.

`pg_ls_tmpdir` returns the name, size, and last modified time (`mtime`) of each file in the temporary file directory for the specified `tablespace`. If `tablespace` is not provided, the `pg_default` tablespace is used. By default only superusers and members of the `pg_monitor` role can use this function. Access may be granted to others using `GRANT`.

`pg_read_file` returns part of a text file, starting at the given `offset`, returning at most `length` bytes (less if the end of file is reached first). If `offset` is negative, it is relative to the end of the file. If `offset` and `length` are omitted, the entire file is returned. The bytes read from the file are interpreted as a string in the server encoding; an error is thrown if they are not valid in that encoding.

`pg_read_binary_file` is similar to `pg_read_file`, except that the result is a `bytea` value; accordingly, no encoding checks are performed. In combination with the `convert_from` function, this function can be used to read a file in a specified encoding:

```
SELECT convert_from(pg_read_binary_file('file_in_utf8.txt'),
    'UTF8');
```

`pg_stat_file` returns a record containing the file size, last accessed time stamp, last modified time stamp, last file status change time stamp (Unix platforms only), file creation time stamp (Windows only), and a `boolean` indicating if it is a directory. Typical usages include:

```
SELECT * FROM pg_stat_file('filename');
SELECT (pg_stat_file('filename')).modification;
```

9.26.10. Advisory Lock Functions

The functions shown in Table 9.95 manage advisory locks. For details about proper use of these functions, see Section 13.3.5.

Table 9.95. Advisory Lock Functions

Name	Return Type	Description
<code>pg_advisory_lock(key bigint)</code>	<code>void</code>	Obtain exclusive session level advisory lock

Name	Return Type	Description
<code>pg_advisory_lock(key1 int, key2 int)</code>	void	Obtain exclusive session level advisory lock
<code>pg_advisory_lock_shared(key bigint)</code>	void	Obtain shared session level advisory lock
<code>pg_advisory_lock_shared(key1 int, key2 int)</code>	void	Obtain shared session level advisory lock
<code>pg_advisory_unlock(key bigint)</code>	boolean	Release an exclusive session level advisory lock
<code>pg_advisory_unlock(key1 int, key2 int)</code>	boolean	Release an exclusive session level advisory lock
<code>pg_advisory_unlock_all()</code>	void	Release all session level advisory locks held by the current session
<code>pg_advisory_unlock_shared(key bigint)</code>	boolean	Release a shared session level advisory lock
<code>pg_advisory_unlock_shared(key1 int, key2 int)</code>	boolean	Release a shared session level advisory lock
<code>pg_advisory_xact_lock(key bigint)</code>	void	Obtain exclusive transaction level advisory lock
<code>pg_advisory_xact_lock(key1 int, key2 int)</code>	void	Obtain exclusive transaction level advisory lock
<code>pg_advisory_xact_lock_shared(key bigint)</code>	void	Obtain shared transaction level advisory lock
<code>pg_advisory_xact_lock_shared(key1 int, key2 int)</code>	void	Obtain shared transaction level advisory lock
<code>pg_try_advisory_lock(key bigint)</code>	boolean	Obtain exclusive session level advisory lock if available
<code>pg_try_advisory_lock(key1 int, key2 int)</code>	boolean	Obtain exclusive session level advisory lock if available
<code>pg_try_advisory_lock_shared(key bigint)</code>	boolean	Obtain shared session level advisory lock if available
<code>pg_try_advisory_lock_shared(key1 int, key2 int)</code>	boolean	Obtain shared session level advisory lock if available
<code>pg_try_advisory_xact_lock(key bigint)</code>	boolean	Obtain exclusive transaction level advisory lock if available
<code>pg_try_advisory_xact_lock(key1 int, key2 int)</code>	boolean	Obtain exclusive transaction level advisory lock if available

Name	Return Type	Description
<code>pg_try_advisory_xact_lock_shared(key bigint)</code>	boolean	Obtain shared transaction level advisory lock if available
<code>pg_try_advisory_xact_lock_shared(key1 int, key2 int)</code>	boolean	Obtain shared transaction level advisory lock if available

`pg_advisory_lock` locks an application-defined resource, which can be identified either by a single 64-bit key value or two 32-bit key values (note that these two key spaces do not overlap). If another session already holds a lock on the same resource identifier, this function will wait until the resource becomes available. The lock is exclusive. Multiple lock requests stack, so that if the same resource is locked three times it must then be unlocked three times to be released for other sessions' use.

`pg_advisory_lock_shared` works the same as `pg_advisory_lock`, except the lock can be shared with other sessions requesting shared locks. Only would-be exclusive lockers are locked out.

`pg_try_advisory_lock` is similar to `pg_advisory_lock`, except the function will not wait for the lock to become available. It will either obtain the lock immediately and return `true`, or return `false` if the lock cannot be acquired immediately.

`pg_try_advisory_lock_shared` works the same as `pg_try_advisory_lock`, except it attempts to acquire a shared rather than an exclusive lock.

`pg_advisory_unlock` will release a previously-acquired exclusive session level advisory lock. It returns `true` if the lock is successfully released. If the lock was not held, it will return `false`, and in addition, an SQL warning will be reported by the server.

`pg_advisory_unlock_shared` works the same as `pg_advisory_unlock`, except it releases a shared session level advisory lock.

`pg_advisory_unlock_all` will release all session level advisory locks held by the current session. (This function is implicitly invoked at session end, even if the client disconnects ungracefully.)

`pg_advisory_xact_lock` works the same as `pg_advisory_lock`, except the lock is automatically released at the end of the current transaction and cannot be released explicitly.

`pg_advisory_xact_lock_shared` works the same as `pg_advisory_lock_shared`, except the lock is automatically released at the end of the current transaction and cannot be released explicitly.

`pg_try_advisory_xact_lock` works the same as `pg_try_advisory_lock`, except the lock, if acquired, is automatically released at the end of the current transaction and cannot be released explicitly.

`pg_try_advisory_xact_lock_shared` works the same as `pg_try_advisory_lock_shared`, except the lock, if acquired, is automatically released at the end of the current transaction and cannot be released explicitly.

9.27. Trigger Functions

Currently PostgreSQL provides one built in trigger function, `suppress_redundant_updates_trigger`, which will prevent any update that does not actually change the data in the row from taking place, in contrast to the normal behavior which always performs the update regardless of whether or not the data has changed. (This normal behavior makes updates run faster, since no checking is required, and is also useful in certain cases.)

Ideally, you should normally avoid running updates that don't actually change the data in the record. Redundant updates can cost considerable unnecessary time, especially if there are lots of indexes to alter, and space in dead rows that will eventually have to be vacuumed. However, detecting such situations in client code is not always easy, or even possible, and writing expressions to detect them can be error-prone. An alternative is to use `suppress_redundant_updates_trigger`, which will skip updates that don't change the data. You should use this with care, however. The trigger takes a small but non-trivial time for each record, so if most of the records affected by an update are actually changed, use of this trigger will actually make the update run slower.

The `suppress_redundant_updates_trigger` function can be added to a table like this:

```
CREATE TRIGGER z_min_update
BEFORE UPDATE ON tablename
FOR EACH ROW EXECUTE FUNCTION suppress_redundant_updates_trigger();
```

In most cases, you would want to fire this trigger last for each row. Bearing in mind that triggers fire in name order, you would then choose a trigger name that comes after the name of any other trigger you might have on the table.

For more information about creating triggers, see `CREATE TRIGGER`.

9.28. Event Trigger Functions

PostgreSQL provides these helper functions to retrieve information from event triggers.

For more information about event triggers, see Chapter 39.

9.28.1. Capturing Changes at Command End

`pg_event_trigger_ddl_commands` returns a list of DDL commands executed by each user action, when invoked in a function attached to a `ddl_command_end` event trigger. If called in any other context, an error is raised. `pg_event_trigger_ddl_commands` returns one row for each base command executed; some commands that are a single SQL sentence may return more than one row. This function returns the following columns:

Name	Type	Description
<code>classid</code>	<code>oid</code>	OID of catalog the object belongs in
<code>objid</code>	<code>oid</code>	OID of the object itself
<code>objsubid</code>	<code>integer</code>	Sub-object ID (e.g. attribute number for a column)
<code>command_tag</code>	<code>text</code>	Command tag
<code>object_type</code>	<code>text</code>	Type of the object
<code>schema_name</code>	<code>text</code>	Name of the schema the object belongs in, if any; otherwise NULL. No quoting is applied.
<code>object_identity</code>	<code>text</code>	Text rendering of the object identity, schema-qualified. Each

Name	Type	Description
		identifier included in the identity is quoted if necessary.
<code>in_extension</code>	<code>bool</code>	True if the command is part of an extension script
<code>command</code>	<code>pg_ddl_command</code>	A complete representation of the command, in internal format. This cannot be output directly, but it can be passed to other functions to obtain different pieces of information about the command.

9.28.2. Processing Objects Dropped by a DDL Command

`pg_event_trigger_dropped_objects` returns a list of all objects dropped by the command in whose `sql_drop` event it is called. If called in any other context, `pg_event_trigger_dropped_objects` raises an error. `pg_event_trigger_dropped_objects` returns the following columns:

Name	Type	Description
<code>classid</code>	<code>oid</code>	OID of catalog the object belonged in
<code>objid</code>	<code>oid</code>	OID of the object itself
<code>objsubid</code>	<code>integer</code>	Sub-object ID (e.g. attribute number for a column)
<code>original</code>	<code>bool</code>	True if this was one of the root object(s) of the deletion
<code>normal</code>	<code>bool</code>	True if there was a normal dependency relationship in the dependency graph leading to this object
<code>is_temporary</code>	<code>bool</code>	True if this was a temporary object
<code>object_type</code>	<code>text</code>	Type of the object
<code>schema_name</code>	<code>text</code>	Name of the schema the object belonged in, if any; otherwise NULL. No quoting is applied.
<code>object_name</code>	<code>text</code>	Name of the object, if the combination of schema and name can be used as a unique identifier for the object; otherwise NULL. No quoting is applied, and name is never schema-qualified.
<code>object_identity</code>	<code>text</code>	Text rendering of the object identity, schema-qualified. Each identifier included in the identity is quoted if necessary.
<code>address_names</code>	<code>text[]</code>	An array that, together with <code>object_type</code> and <code>address_args</code> , can be used

Name	Type	Description
		by the <code>pg_get_object_address()</code> function to recreate the object address in a remote server containing an identically named object of the same kind
<code>address_args</code>	<code>text[]</code>	Complement for <code>address_names</code>

The `pg_event_trigger_dropped_objects` function can be used in an event trigger like this:

```
CREATE FUNCTION test_event_trigger_for_drops()
    RETURNS event_trigger LANGUAGE plpgsql AS $$
DECLARE
    obj record;
BEGIN
    FOR obj IN SELECT * FROM pg_event_trigger_dropped_objects()
    LOOP
        RAISE NOTICE '% dropped object: % %.% %',
            tg_tag,
            obj.object_type,
            obj.schema_name,
            obj.object_name,
            obj.object_identity;
    END LOOP;
END
$$;
CREATE EVENT TRIGGER test_event_trigger_for_drops
    ON sql_drop
    EXECUTE FUNCTION test_event_trigger_for_drops();
```

9.28.3. Handling a Table Rewrite Event

The functions shown in Table 9.96 provide information about a table for which a `table_rewrite` event has just been called. If called in any other context, an error is raised.

Table 9.96. Table Rewrite Information

Name	Return Type	Description
<code>pg_event_trigger_table_rewrite_oid()</code>	<code>Oid</code>	The OID of the table about to be rewritten.
<code>pg_event_trigger_table_rewrite_reason()</code>	<code>int</code>	The reason code(s) explaining the reason for rewriting. The exact meaning of the codes is release dependent.

The `pg_event_trigger_table_rewrite_oid` function can be used in an event trigger like this:

```
CREATE FUNCTION test_event_trigger_table_rewrite_oid()
    RETURNS event_trigger
    LANGUAGE plpgsql AS
$$
BEGIN
    RAISE NOTICE 'rewriting table % for reason %',
```

```

        pg_event_trigger_table_rewrite_oid()::regclass,
        pg_event_trigger_table_rewrite_reason());
END;
$$;

CREATE EVENT TRIGGER test_table_rewrite_oid
    ON table_rewrite
    EXECUTE FUNCTION test_event_trigger_table_rewrite_oid();

```

9.29. Statistics Information Functions

PostgreSQL provides a function to inspect complex statistics defined using the CREATE STATISTICS command.

9.29.1. Inspecting MCV Lists

`pg_mcv_list_items` returns a list of all items stored in a multi-column MCV list, and returns the following columns:

Name	Type	Description
<code>index</code>	<code>int</code>	index of the item in the MCV list
<code>values</code>	<code>text[]</code>	values stored in the MCV item
<code>nulls</code>	<code>boolean[]</code>	flags identifying NULL values
<code>frequency</code>	<code>double precision</code>	frequency of this MCV item
<code>base_frequency</code>	<code>double precision</code>	base frequency of this MCV item

The `pg_mcv_list_items` function can be used like this:

```

SELECT m.* FROM pg_statistic_ext join pg_statistic_ext_data on (oid
= stxoid),
        pg_mcv_list_items(stxdmcv) m WHERE stxname =
'stts';

```

Values of the `pg_mcv_list` can be obtained only from the `pg_statistic_ext_data.stxdmcv` column.

Chapter 10. Type Conversion

SQL statements can, intentionally or not, require the mixing of different data types in the same expression. PostgreSQL has extensive facilities for evaluating mixed-type expressions.

In many cases a user does not need to understand the details of the type conversion mechanism. However, implicit conversions done by PostgreSQL can affect the results of a query. When necessary, these results can be tailored by using *explicit* type conversion.

This chapter introduces the PostgreSQL type conversion mechanisms and conventions. Refer to the relevant sections in Chapter 8 and Chapter 9 for more information on specific data types and allowed functions and operators.

10.1. Overview

SQL is a strongly typed language. That is, every data item has an associated data type which determines its behavior and allowed usage. PostgreSQL has an extensible type system that is more general and flexible than other SQL implementations. Hence, most type conversion behavior in PostgreSQL is governed by general rules rather than by *ad hoc* heuristics. This allows the use of mixed-type expressions even with user-defined types.

The PostgreSQL scanner/parser divides lexical elements into five fundamental categories: integers, non-integer numbers, strings, identifiers, and key words. Constants of most non-numeric types are first classified as strings. The SQL language definition allows specifying type names with strings, and this mechanism can be used in PostgreSQL to start the parser down the correct path. For example, the query:

```
SELECT text 'Origin' AS "label", point '(0,0)' AS "value";
```

label	value
Origin	(0,0)

(1 row)

has two literal constants, of type `text` and `point`. If a type is not specified for a string literal, then the placeholder type `unknown` is assigned initially, to be resolved in later stages as described below.

There are four fundamental SQL constructs requiring distinct type conversion rules in the PostgreSQL parser:

Function calls

Much of the PostgreSQL type system is built around a rich set of functions. Functions can have one or more arguments. Since PostgreSQL permits function overloading, the function name alone does not uniquely identify the function to be called; the parser must select the right function based on the data types of the supplied arguments.

Operators

PostgreSQL allows expressions with prefix and postfix unary (one-argument) operators, as well as binary (two-argument) operators. Like functions, operators can be overloaded, so the same problem of selecting the right operator exists.

Value Storage

SQL `INSERT` and `UPDATE` statements place the results of expressions into a table. The expressions in the statement must be matched up with, and perhaps converted to, the types of the target columns.

UNION, CASE, and related constructs

Since all query results from a unionized `SELECT` statement must appear in a single set of columns, the types of the results of each `SELECT` clause must be matched up and converted to a uniform set. Similarly, the result expressions of a `CASE` construct must be converted to a common type so that the `CASE` expression as a whole has a known output type. The same holds for `ARRAY` constructs, and for the `GREATEST` and `LEAST` functions.

The system catalogs store information about which conversions, or *casts*, exist between which data types, and how to perform those conversions. Additional casts can be added by the user with the `CREATE CAST` command. (This is usually done in conjunction with defining new data types. The set of casts between built-in types has been carefully crafted and is best not altered.)

An additional heuristic provided by the parser allows improved determination of the proper casting behavior among groups of types that have implicit casts. Data types are divided into several basic *type categories*, including `boolean`, `numeric`, `string`, `bitstring`, `datetime`, `timespan`, `geometric`, `network`, and user-defined. (For a list see Table 51.64; but note it is also possible to create custom type categories.) Within each category there can be one or more *preferred types*, which are preferred when there is a choice of possible types. With careful selection of preferred types and available implicit casts, it is possible to ensure that ambiguous expressions (those with multiple candidate parsing solutions) can be resolved in a useful way.

All type conversion rules are designed with several principles in mind:

- Implicit conversions should never have surprising or unpredictable outcomes.
- There should be no extra overhead in the parser or executor if a query does not need implicit type conversion. That is, if a query is well-formed and the types already match, then the query should execute without spending extra time in the parser and without introducing unnecessary implicit conversion calls in the query.
- Additionally, if a query usually requires an implicit conversion for a function, and if then the user defines a new function with the correct argument types, the parser should use this new function and no longer do implicit conversion to use the old function.

10.2. Operators

The specific operator that is referenced by an operator expression is determined using the following procedure. Note that this procedure is indirectly affected by the precedence of the operators involved, since that will determine which sub-expressions are taken to be the inputs of which operators. See Section 4.1.6 for more information.

Operator Type Resolution

1. Select the operators to be considered from the `pg_operator` system catalog. If a non-schema-qualified operator name was used (the usual case), the operators considered are those with the matching name and argument count that are visible in the current search path (see Section 5.9.3). If a qualified operator name was given, only operators in the specified schema are considered.
 - (Optional) If the search path finds multiple operators with identical argument types, only the one appearing earliest in the path is considered. Operators with different argument types are considered on an equal footing regardless of search path position.
2. Check for an operator accepting exactly the input argument types. If one exists (there can be only one exact match in the set of operators considered), use it. Lack of an exact match creates a security hazard when calling, via qualified name¹ (not typical), any operator found in a schema

¹ The hazard does not arise with a non-schema-qualified name, because a search path containing schemas that permit untrusted users to create objects is not a secure schema usage pattern.

that permits untrusted users to create objects. In such situations, cast arguments to force an exact match.

- a. (Optional) If one argument of a binary operator invocation is of the unknown type, then assume it is the same type as the other argument for this check. Invocations involving two unknown inputs, or a unary operator with an unknown input, will never find a match at this step.
 - b. (Optional) If one argument of a binary operator invocation is of the unknown type and the other is of a domain type, next check to see if there is an operator accepting exactly the domain's base type on both sides; if so, use it.
3. Look for the best match.
- a. Discard candidate operators for which the input types do not match and cannot be converted (using an implicit conversion) to match. unknown literals are assumed to be convertible to anything for this purpose. If only one candidate remains, use it; else continue to the next step.
 - b. If any input argument is of a domain type, treat it as being of the domain's base type for all subsequent steps. This ensures that domains act like their base types for purposes of ambiguous-operator resolution.
 - c. Run through all candidates and keep those with the most exact matches on input types. Keep all candidates if none have exact matches. If only one candidate remains, use it; else continue to the next step.
 - d. Run through all candidates and keep those that accept preferred types (of the input data type's type category) at the most positions where type conversion will be required. Keep all candidates if none accept preferred types. If only one candidate remains, use it; else continue to the next step.
 - e. If any input arguments are unknown, check the type categories accepted at those argument positions by the remaining candidates. At each position, select the `string` category if any candidate accepts that category. (This bias towards string is appropriate since an unknown-type literal looks like a string.) Otherwise, if all the remaining candidates accept the same type category, select that category; otherwise fail because the correct choice cannot be deduced without more clues. Now discard candidates that do not accept the selected type category. Furthermore, if any candidate accepts a preferred type in that category, discard candidates that accept non-preferred types for that argument. Keep all candidates if none survive these tests. If only one candidate remains, use it; else continue to the next step.
 - f. If there are both unknown and known-type arguments, and all the known-type arguments have the same type, assume that the unknown arguments are also of that type, and check which candidates can accept that type at the unknown-argument positions. If exactly one candidate passes this test, use it. Otherwise, fail.

Some examples follow.

Example 10.1. Factorial Operator Type Resolution

There is only one factorial operator (postfix `!`) defined in the standard catalog, and it takes an argument of type `bigint`. The scanner assigns an initial type of `integer` to the argument in this query expression:

```
SELECT 40 ! AS "40 factorial";

          40 factorial
-----
81591528324789773434561126959611589427200000000
```

```
(1 row)
```

So the parser does a type conversion on the operand and the query is equivalent to:

```
SELECT CAST(40 AS bigint) ! AS "40 factorial";
```

Example 10.2. String Concatenation Operator Type Resolution

A string-like syntax is used for working with string types and for working with complex extension types. Strings with unspecified type are matched with likely operator candidates.

An example with one unspecified argument:

```
SELECT text 'abc' || 'def' AS "text and unknown";
```

```
text and unknown
-----
abcdef
(1 row)
```

In this case the parser looks to see if there is an operator taking `text` for both arguments. Since there is, it assumes that the second argument should be interpreted as type `text`.

Here is a concatenation of two values of unspecified types:

```
SELECT 'abc' || 'def' AS "unspecified";
```

```
unspecified
-----
abcdef
(1 row)
```

In this case there is no initial hint for which type to use, since no types are specified in the query. So, the parser looks for all candidate operators and finds that there are candidates accepting both string-category and bit-string-category inputs. Since string category is preferred when available, that category is selected, and then the preferred type for strings, `text`, is used as the specific type to resolve the unknown-type literals as.

Example 10.3. Absolute-Value and Negation Operator Type Resolution

The PostgreSQL operator catalog has several entries for the prefix operator `@`, all of which implement absolute-value operations for various numeric data types. One of these entries is for type `float8`, which is the preferred type in the numeric category. Therefore, PostgreSQL will use that entry when faced with an unknown input:

```
SELECT @ '-4.5' AS "abs";
abs
-----
4.5
(1 row)
```

Here the system has implicitly resolved the unknown-type literal as type `float8` before applying the chosen operator. We can verify that `float8` and not some other type was used:

```
SELECT @ '-4.5e500' AS "abs";

ERROR:  "-4.5e500" is out of range for type double precision
```

On the other hand, the prefix operator `~` (bitwise negation) is defined only for integer data types, not for `float8`. So, if we try a similar case with `~`, we get:

```
SELECT ~ '20' AS "negation";
```

```
ERROR: operator is not unique: ~ "unknown"
HINT: Could not choose a best candidate operator. You might need
to add
explicit type casts.
```

This happens because the system cannot decide which of the several possible `~` operators should be preferred. We can help it out with an explicit cast:

```
SELECT ~ CAST('20' AS int8) AS "negation";
```

```
negation
-----
      -21
(1 row)
```

Example 10.4. Array Inclusion Operator Type Resolution

Here is another example of resolving an operator with one known and one unknown input:

```
SELECT array[1,2] <@ '{1,2,3}' as "is subset";
```

```
is subset
-----
t
(1 row)
```

The PostgreSQL operator catalog has several entries for the infix operator `<@`, but the only two that could possibly accept an integer array on the left-hand side are array inclusion (`anyarray <@ anyarray`) and range inclusion (`anyelement <@ anyrange`). Since none of these polymorphic pseudo-types (see Section 8.21) are considered preferred, the parser cannot resolve the ambiguity on that basis. However, Step 3.f tells it to assume that the unknown-type literal is of the same type as the other input, that is, integer array. Now only one of the two operators can match, so array inclusion is selected. (Had range inclusion been selected, we would have gotten an error, because the string does not have the right format to be a range literal.)

Example 10.5. Custom Operator on a Domain Type

Users sometimes try to declare operators applying just to a domain type. This is possible but is not nearly as useful as it might seem, because the operator resolution rules are designed to select operators applying to the domain's base type. As an example consider

```
CREATE DOMAIN mytext AS text CHECK(...);
CREATE FUNCTION mytext_eq_text (mytext, text) RETURNS boolean
AS ...;
CREATE OPERATOR = (procedure=mytext_eq_text, leftarg=mytext,
rightarg=text);
CREATE TABLE mytable (val mytext);

SELECT * FROM mytable WHERE val = 'foo';
```

This query will not use the custom operator. The parser will first see if there is a `mytext = mytext` operator (Step 2.a), which there is not; then it will consider the domain's base type `text`, and see if

there is a `text = text` operator (Step 2.b), which there is; so it resolves the unknown-type literal as `text` and uses the `text = text` operator. The only way to get the custom operator to be used is to explicitly cast the literal:

```
SELECT * FROM mytable WHERE val = text 'foo';
```

so that the `mytext = text` operator is found immediately according to the exact-match rule. If the best-match rules are reached, they actively discriminate against operators on domain types. If they did not, such an operator would create too many ambiguous-operator failures, because the casting rules always consider a domain as castable to or from its base type, and so the domain operator would be considered usable in all the same cases as a similarly-named operator on the base type.

10.3. Functions

The specific function that is referenced by a function call is determined using the following procedure.

Function Type Resolution

1. Select the functions to be considered from the `pg_proc` system catalog. If a non-schema-qualified function name was used, the functions considered are those with the matching name and argument count that are visible in the current search path (see Section 5.9.3). If a qualified function name was given, only functions in the specified schema are considered.
 - a. (Optional) If the search path finds multiple functions of identical argument types, only the one appearing earliest in the path is considered. Functions of different argument types are considered on an equal footing regardless of search path position.
 - b. (Optional) If a function is declared with a `VARIADIC` array parameter, and the call does not use the `VARIADIC` keyword, then the function is treated as if the array parameter were replaced by one or more occurrences of its element type, as needed to match the call. After such expansion the function might have effective argument types identical to some non-variadic function. In that case the function appearing earlier in the search path is used, or if the two functions are in the same schema, the non-variadic one is preferred.

This creates a security hazard when calling, via qualified name², a variadic function found in a schema that permits untrusted users to create objects. A malicious user can take control and execute arbitrary SQL functions as though you executed them. Substitute a call bearing the `VARIADIC` keyword, which bypasses this hazard. Calls populating `VARIADIC "any"` parameters often have no equivalent formulation containing the `VARIADIC` keyword. To issue those calls safely, the function's schema must permit only trusted users to create objects.

- c. (Optional) Functions that have default values for parameters are considered to match any call that omits zero or more of the defaultable parameter positions. If more than one such function matches a call, the one appearing earliest in the search path is used. If there are two or more such functions in the same schema with identical parameter types in the non-defaulted positions (which is possible if they have different sets of defaultable parameters), the system will not be able to determine which to prefer, and so an “ambiguous function call” error will result if no better match to the call can be found.

This creates an availability hazard when calling, via qualified name², any function found in a schema that permits untrusted users to create objects. A malicious user can create a function with the name of an existing function, replicating that function's parameters and appending novel parameters having default values. This precludes new calls to the original

² The hazard does not arise with a non-schema-qualified name, because a search path containing schemas that permit untrusted users to create objects is not a secure schema usage pattern.

function. To forestall this hazard, place functions in schemas that permit only trusted users to create objects.

2. Check for a function accepting exactly the input argument types. If one exists (there can be only one exact match in the set of functions considered), use it. Lack of an exact match creates a security hazard when calling, via qualified name², a function found in a schema that permits untrusted users to create objects. In such situations, cast arguments to force an exact match. (Cases involving `unknown` will never find a match at this step.)
3. If no exact match is found, see if the function call appears to be a special type conversion request. This happens if the function call has just one argument and the function name is the same as the (internal) name of some data type. Furthermore, the function argument must be either an `unknown`-type literal, or a type that is binary-coercible to the named data type, or a type that could be converted to the named data type by applying that type's I/O functions (that is, the conversion is either to or from one of the standard string types). When these conditions are met, the function call is treated as a form of `CAST` specification.³
4. Look for the best match.
 - a. Discard candidate functions for which the input types do not match and cannot be converted (using an implicit conversion) to match. `unknown` literals are assumed to be convertible to anything for this purpose. If only one candidate remains, use it; else continue to the next step.
 - b. If any input argument is of a domain type, treat it as being of the domain's base type for all subsequent steps. This ensures that domains act like their base types for purposes of ambiguous-function resolution.
 - c. Run through all candidates and keep those with the most exact matches on input types. Keep all candidates if none have exact matches. If only one candidate remains, use it; else continue to the next step.
 - d. Run through all candidates and keep those that accept preferred types (of the input data type's type category) at the most positions where type conversion will be required. Keep all candidates if none accept preferred types. If only one candidate remains, use it; else continue to the next step.
 - e. If any input arguments are `unknown`, check the type categories accepted at those argument positions by the remaining candidates. At each position, select the `string` category if any candidate accepts that category. (This bias towards string is appropriate since an `unknown`-type literal looks like a string.) Otherwise, if all the remaining candidates accept the same type category, select that category; otherwise fail because the correct choice cannot be deduced without more clues. Now discard candidates that do not accept the selected type category. Furthermore, if any candidate accepts a preferred type in that category, discard candidates that accept non-preferred types for that argument. Keep all candidates if none survive these tests. If only one candidate remains, use it; else continue to the next step.
 - f. If there are both `unknown` and known-type arguments, and all the known-type arguments have the same type, assume that the `unknown` arguments are also of that type, and check which candidates can accept that type at the `unknown`-argument positions. If exactly one candidate passes this test, use it. Otherwise, fail.

Note that the “best match” rules are identical for operator and function type resolution. Some examples follow.

³ The reason for this step is to support function-style cast specifications in cases where there is not an actual cast function. If there is a cast function, it is conventionally named after its output type, and so there is no need to have a special case. See `CREATE CAST` for additional commentary.

Example 10.6. Rounding Function Argument Type Resolution

There is only one `round` function that takes two arguments; it takes a first argument of type `numeric` and a second argument of type `integer`. So the following query automatically converts the first argument of type `integer` to `numeric`:

```
SELECT round(4, 4);
```

```
round
-----
4.0000
(1 row)
```

That query is actually transformed by the parser to:

```
SELECT round(CAST (4 AS numeric), 4);
```

Since `numeric` constants with decimal points are initially assigned the type `numeric`, the following query will require no type conversion and therefore might be slightly more efficient:

```
SELECT round(4.0, 4);
```

Example 10.7. Variadic Function Resolution

```
CREATE FUNCTION public.variadic_example(VARIADIC numeric[]) RETURNS
int
LANGUAGE sql AS 'SELECT 1';
CREATE FUNCTION
```

This function accepts, but does not require, the `VARIADIC` keyword. It tolerates both `integer` and `numeric` arguments:

```
SELECT public.variadic_example(0),
       public.variadic_example(0.0),
       public.variadic_example(VARIADIC array[0.0]);
variadic_example | variadic_example | variadic_example
-----+-----+-----
1 | 1 | 1
(1 row)
```

However, the first and second calls will prefer more-specific functions, if available:

```
CREATE FUNCTION public.variadic_example(numeric) RETURNS int
LANGUAGE sql AS 'SELECT 2';
CREATE FUNCTION

CREATE FUNCTION public.variadic_example(int) RETURNS int
LANGUAGE sql AS 'SELECT 3';
CREATE FUNCTION

SELECT public.variadic_example(0),
       public.variadic_example(0.0),
       public.variadic_example(VARIADIC array[0.0]);
variadic_example | variadic_example | variadic_example
```

```

-----+-----+-----
          3 |           2 |           1
(1 row)

```

Given the default configuration and only the first function existing, the first and second calls are insecure. Any user could intercept them by creating the second or third function. By matching the argument type exactly and using the `VARIADIC` keyword, the third call is secure.

Example 10.8. Substring Function Type Resolution

There are several `substr` functions, one of which takes types `text` and `integer`. If called with a string constant of unspecified type, the system chooses the candidate function that accepts an argument of the preferred category `string` (namely of type `text`).

```

SELECT substr('1234', 3);

 substr
-----
      34
(1 row)

```

If the string is declared to be of type `varchar`, as might be the case if it comes from a table, then the parser will try to convert it to become `text`:

```

SELECT substr(varchar '1234', 3);

 substr
-----
      34
(1 row)

```

This is transformed by the parser to effectively become:

```

SELECT substr(CAST (varchar '1234' AS text), 3);

```

Note

The parser learns from the `pg_cast` catalog that `text` and `varchar` are binary-compatible, meaning that one can be passed to a function that accepts the other without doing any physical conversion. Therefore, no type conversion call is really inserted in this case.

And, if the function is called with an argument of type `integer`, the parser will try to convert that to `text`:

```

SELECT substr(1234, 3);
ERROR:  function substr(integer, integer) does not exist
HINT:  No function matches the given name and argument types. You
       might need
       to add explicit type casts.

```

This does not work because `integer` does not have an implicit cast to `text`. An explicit cast will work, however:

```
SELECT substr(CAST (1234 AS text), 3);

 substr
-----
      34
(1 row)
```

10.4. Value Storage

Values to be inserted into a table are converted to the destination column's data type according to the following steps.

Value Storage Type Conversion

1. Check for an exact match with the target.
2. Otherwise, try to convert the expression to the target type. This is possible if an *assignment cast* between the two types is registered in the `pg_cast` catalog (see `CREATE CAST`). Alternatively, if the expression is an unknown-type literal, the contents of the literal string will be fed to the input conversion routine for the target type.
3. Check to see if there is a sizing cast for the target type. A sizing cast is a cast from that type to itself. If one is found in the `pg_cast` catalog, apply it to the expression before storing into the destination column. The implementation function for such a cast always takes an extra parameter of type `integer`, which receives the destination column's `atttypmod` value (typically its declared length, although the interpretation of `atttypmod` varies for different data types), and it may take a third `boolean` parameter that says whether the cast is explicit or implicit. The cast function is responsible for applying any length-dependent semantics such as size checking or truncation.

Example 10.9. character Storage Type Conversion

For a target column declared as `character(20)` the following statement shows that the stored value is sized correctly:

```
CREATE TABLE vv (v character(20));
INSERT INTO vv SELECT 'abc' || 'def';
SELECT v, octet_length(v) FROM vv;
```

v		octet_length
-----	+	-----
abcdef		20
(1 row)		

What has really happened here is that the two unknown literals are resolved to `text` by default, allowing the `||` operator to be resolved as `text` concatenation. Then the `text` result of the operator is converted to `bpchar` (“blank-padded char”, the internal name of the `character` data type) to match the target column type. (Since the conversion from `text` to `bpchar` is binary-coercible, this conversion does not insert any real function call.) Finally, the sizing function `bpchar(bpchar, integer, boolean)` is found in the system catalog and applied to the operator's result and the stored column length. This type-specific function performs the required length check and addition of padding spaces.

10.5. UNION, CASE, and Related Constructs

SQL `UNION` constructs must match up possibly dissimilar types to become a single result set. The resolution algorithm is applied separately to each output column of a union query. The `INTERSECT`

and `EXCEPT` constructs resolve dissimilar types in the same way as `UNION`. The `CASE`, `ARRAY`, `VALUES`, `GREATEST` and `LEAST` constructs use the identical algorithm to match up their component expressions and select a result data type.

Type Resolution for `UNION`, `CASE`, and Related Constructs

1. If all inputs are of the same type, and it is not unknown, resolve as that type.
2. If any input is of a domain type, treat it as being of the domain's base type for all subsequent steps.⁴
3. If all inputs are of type `unknown`, resolve as type `text` (the preferred type of the string category). Otherwise, unknown inputs are ignored for the purposes of the remaining rules.
4. If the non-unknown inputs are not all of the same type category, fail.
5. Choose the first non-unknown input type which is a preferred type in that category, if there is one.
6. Otherwise, choose the last non-unknown input type that allows all the preceding non-unknown inputs to be implicitly converted to it. (There always is such a type, since at least the first type in the list must satisfy this condition.)
7. Convert all inputs to the selected type. Fail if there is not a conversion from a given input to the selected type.

Some examples follow.

Example 10.10. Type Resolution with Underspecified Types in a Union

```
SELECT text 'a' AS "text" UNION SELECT 'b';

 text
-----
 a
 b
(2 rows)
```

Here, the unknown-type literal `'b'` will be resolved to type `text`.

Example 10.11. Type Resolution in a Simple Union

```
SELECT 1.2 AS "numeric" UNION SELECT 1;

 numeric
-----
      1
     1.2
(2 rows)
```

The literal `1.2` is of type `numeric`, and the integer value `1` can be cast implicitly to `numeric`, so that type is used.

Example 10.12. Type Resolution in a Transposed Union

⁴ Somewhat like the treatment of domain inputs for operators and functions, this behavior allows a domain type to be preserved through a `UNION` or similar construct, so long as the user is careful to ensure that all inputs are implicitly or explicitly of that exact type. Otherwise the domain's base type will be preferred.

```
SELECT 1 AS "real" UNION SELECT CAST('2.2' AS REAL);

 real
-----
    1
    2.2
(2 rows)
```

Here, since type `real` cannot be implicitly cast to `integer`, but `integer` can be implicitly cast to `real`, the union result type is resolved as `real`.

Example 10.13. Type Resolution in a Nested Union

```
SELECT NULL UNION SELECT NULL UNION SELECT 1;
```

```
ERROR: UNION types text and integer cannot be matched
```

This failure occurs because PostgreSQL treats multiple `UNION`s as a nest of pairwise operations; that is, this input is the same as

```
(SELECT NULL UNION SELECT NULL) UNION SELECT 1;
```

The inner `UNION` is resolved as emitting type `text`, according to the rules given above. Then the outer `UNION` has inputs of types `text` and `integer`, leading to the observed error. The problem can be fixed by ensuring that the leftmost `UNION` has at least one input of the desired result type.

`INTERSECT` and `EXCEPT` operations are likewise resolved pairwise. However, the other constructs described in this section consider all of their inputs in one resolution step.

10.6. SELECT Output Columns

The rules given in the preceding sections will result in assignment of non-unknown data types to all expressions in a SQL query, except for unspecified-type literals that appear as simple output columns of a `SELECT` command. For example, in

```
SELECT 'Hello World';
```

there is nothing to identify what type the string literal should be taken as. In this situation PostgreSQL will fall back to resolving the literal's type as `text`.

When the `SELECT` is one arm of a `UNION` (or `INTERSECT` or `EXCEPT`) construct, or when it appears within `INSERT ... SELECT`, this rule is not applied since rules given in preceding sections take precedence. The type of an unspecified-type literal can be taken from the other `UNION` arm in the first case, or from the destination column in the second case.

`RETURNING` lists are treated the same as `SELECT` output lists for this purpose.

Note

Prior to PostgreSQL 10, this rule did not exist, and unspecified-type literals in a `SELECT` output list were left as type `unknown`. That had assorted bad consequences, so it's been changed.

Chapter 11. Indexes

Indexes are a common way to enhance database performance. An index allows the database server to find and retrieve specific rows much faster than it could do without an index. But indexes also add overhead to the database system as a whole, so they should be used sensibly.

11.1. Introduction

Suppose we have a table similar to this:

```
CREATE TABLE test1 (  
    id integer,  
    content varchar  
);
```

and the application issues many queries of the form:

```
SELECT content FROM test1 WHERE id = constant;
```

With no advance preparation, the system would have to scan the entire `test1` table, row by row, to find all matching entries. If there are many rows in `test1` and only a few rows (perhaps zero or one) that would be returned by such a query, this is clearly an inefficient method. But if the system has been instructed to maintain an index on the `id` column, it can use a more efficient method for locating matching rows. For instance, it might only have to walk a few levels deep into a search tree.

A similar approach is used in most non-fiction books: terms and concepts that are frequently looked up by readers are collected in an alphabetic index at the end of the book. The interested reader can scan the index relatively quickly and flip to the appropriate page(s), rather than having to read the entire book to find the material of interest. Just as it is the task of the author to anticipate the items that readers are likely to look up, it is the task of the database programmer to foresee which indexes will be useful.

The following command can be used to create an index on the `id` column, as discussed:

```
CREATE INDEX test1_id_index ON test1 (id);
```

The name `test1_id_index` can be chosen freely, but you should pick something that enables you to remember later what the index was for.

To remove an index, use the `DROP INDEX` command. Indexes can be added to and removed from tables at any time.

Once an index is created, no further intervention is required: the system will update the index when the table is modified, and it will use the index in queries when it thinks doing so would be more efficient than a sequential table scan. But you might have to run the `ANALYZE` command regularly to update statistics to allow the query planner to make educated decisions. See Chapter 14 for information about how to find out whether an index is used and when and why the planner might choose *not* to use an index.

Indexes can also benefit `UPDATE` and `DELETE` commands with search conditions. Indexes can moreover be used in join searches. Thus, an index defined on a column that is part of a join condition can also significantly speed up queries with joins.

Creating an index on a large table can take a long time. By default, PostgreSQL allows reads (`SELECT` statements) to occur on the table in parallel with index creation, but writes (`INSERT`, `UPDATE`, `DELETE`) are blocked until the index build is finished. In production environments this is often unac-

ceptable. It is possible to allow writes to occur in parallel with index creation, but there are several caveats to be aware of — for more information see *Building Indexes Concurrently*.

After an index is created, the system has to keep it synchronized with the table. This adds overhead to data manipulation operations. Therefore indexes that are seldom or never used in queries should be removed.

11.2. Index Types

PostgreSQL provides several index types: B-tree, Hash, GiST, SP-GiST, GIN and BRIN. Each index type uses a different algorithm that is best suited to different types of queries. By default, the `CREATE INDEX` command creates B-tree indexes, which fit the most common situations.

B-trees can handle equality and range queries on data that can be sorted into some ordering. In particular, the PostgreSQL query planner will consider using a B-tree index whenever an indexed column is involved in a comparison using one of these operators:

```
<
<=
=
>=
>
```

Constructs equivalent to combinations of these operators, such as `BETWEEN` and `IN`, can also be implemented with a B-tree index search. Also, an `IS NULL` or `IS NOT NULL` condition on an index column can be used with a B-tree index.

The optimizer can also use a B-tree index for queries involving the pattern matching operators `LIKE` and `~` if the pattern is a constant and is anchored to the beginning of the string — for example, `col LIKE 'foo%'` or `col ~ '^foo'`, but not `col LIKE '%bar'`. However, if your database does not use the C locale you will need to create the index with a special operator class to support indexing of pattern-matching queries; see Section 11.10 below. It is also possible to use B-tree indexes for `ILIKE` and `~*`, but only if the pattern starts with non-alphabetic characters, i.e., characters that are not affected by upper/lower case conversion.

B-tree indexes can also be used to retrieve data in sorted order. This is not always faster than a simple scan and sort, but it is often helpful.

Hash indexes can only handle simple equality comparisons. The query planner will consider using a hash index whenever an indexed column is involved in a comparison using the `=` operator. The following command is used to create a hash index:

```
CREATE INDEX name ON table USING HASH (column);
```

GiST indexes are not a single kind of index, but rather an infrastructure within which many different indexing strategies can be implemented. Accordingly, the particular operators with which a GiST index can be used vary depending on the indexing strategy (the *operator class*). As an example, the standard distribution of PostgreSQL includes GiST operator classes for several two-dimensional geometric data types, which support indexed queries using these operators:

```
<<
&<
&>
>>
<< |
&< |
| &>
| >>
@>
```

<@
 ~=
 &&

(See Section 9.11 for the meaning of these operators.) The GiST operator classes included in the standard distribution are documented in Table 64.1. Many other GiST operator classes are available in the `contrib` collection or as separate projects. For more information see Chapter 64.

GiST indexes are also capable of optimizing “nearest-neighbor” searches, such as

```
SELECT * FROM places ORDER BY location <-> point '(101,456)' LIMIT
  10;
```

which finds the ten places closest to a given target point. The ability to do this is again dependent on the particular operator class being used. In Table 64.1, operators that can be used in this way are listed in the column “Ordering Operators”.

SP-GiST indexes, like GiST indexes, offer an infrastructure that supports various kinds of searches. SP-GiST permits implementation of a wide range of different non-balanced disk-based data structures, such as quadtrees, k-d trees, and radix trees (tries). As an example, the standard distribution of PostgreSQL includes SP-GiST operator classes for two-dimensional points, which support indexed queries using these operators:

<<
 >>
 ~=
 <@
 <^
 >^

(See Section 9.11 for the meaning of these operators.) The SP-GiST operator classes included in the standard distribution are documented in Table 65.1. For more information see Chapter 65.

Like GiST, SP-GiST supports “nearest-neighbor” searches. For SP-GiST operator classes that support distance ordering, the corresponding operator is specified in the “Ordering Operators” column in Table 65.1.

GIN indexes are “inverted indexes” which are appropriate for data values that contain multiple component values, such as arrays. An inverted index contains a separate entry for each component value, and can efficiently handle queries that test for the presence of specific component values.

Like GiST and SP-GiST, GIN can support many different user-defined indexing strategies, and the particular operators with which a GIN index can be used vary depending on the indexing strategy. As an example, the standard distribution of PostgreSQL includes a GIN operator class for arrays, which supports indexed queries using these operators:

<@
 @>
 =
 &&

(See Section 9.18 for the meaning of these operators.) The GIN operator classes included in the standard distribution are documented in Table 66.1. Many other GIN operator classes are available in the `contrib` collection or as separate projects. For more information see Chapter 66.

BRIN indexes (a shorthand for Block Range INdexes) store summaries about the values stored in consecutive physical block ranges of a table. Like GiST, SP-GiST and GIN, BRIN can support many different indexing strategies, and the particular operators with which a BRIN index can be used vary depending on the indexing strategy. For data types that have a linear sort order, the indexed data

corresponds to the minimum and maximum values of the values in the column for each block range. This supports indexed queries using these operators:

```
<
<=
=
>=
>
```

The BRIN operator classes included in the standard distribution are documented in Table 67.1. For more information see Chapter 67.

11.3. Multicolumn Indexes

An index can be defined on more than one column of a table. For example, if you have a table of this form:

```
CREATE TABLE test2 (
    major int,
    minor int,
    name varchar
);
```

(say, you keep your /dev directory in a database...) and you frequently issue queries like:

```
SELECT name FROM test2 WHERE major = constant AND minor = constant;
```

then it might be appropriate to define an index on the columns `major` and `minor` together, e.g.:

```
CREATE INDEX test2_mm_idx ON test2 (major, minor);
```

Currently, only the B-tree, GiST, GIN, and BRIN index types support multicolumn indexes. Up to 32 columns can be specified. (This limit can be altered when building PostgreSQL; see the file `pg_config_manual.h`.)

A multicolumn B-tree index can be used with query conditions that involve any subset of the index's columns, but the index is most efficient when there are constraints on the leading (leftmost) columns. The exact rule is that equality constraints on leading columns, plus any inequality constraints on the first column that does not have an equality constraint, will be used to limit the portion of the index that is scanned. Constraints on columns to the right of these columns are checked in the index, so they save visits to the table proper, but they do not reduce the portion of the index that has to be scanned. For example, given an index on `(a, b, c)` and a query condition `WHERE a = 5 AND b >= 42 AND c < 77`, the index would have to be scanned from the first entry with `a = 5` and `b = 42` up through the last entry with `a = 5`. Index entries with `c >= 77` would be skipped, but they'd still have to be scanned through. This index could in principle be used for queries that have constraints on `b` and/or `c` with no constraint on `a` — but the entire index would have to be scanned, so in most cases the planner would prefer a sequential table scan over using the index.

A multicolumn GiST index can be used with query conditions that involve any subset of the index's columns. Conditions on additional columns restrict the entries returned by the index, but the condition on the first column is the most important one for determining how much of the index needs to be scanned. A GiST index will be relatively ineffective if its first column has only a few distinct values, even if there are many distinct values in additional columns.

A multicolumn GIN index can be used with query conditions that involve any subset of the index's columns. Unlike B-tree or GiST, index search effectiveness is the same regardless of which index column(s) the query conditions use.

A multicolumn BRIN index can be used with query conditions that involve any subset of the index's columns. Like GIN and unlike B-tree or GiST, index search effectiveness is the same regardless of which index column(s) the query conditions use. The only reason to have multiple BRIN indexes instead of one multicolumn BRIN index on a single table is to have a different `pages_per_range` storage parameter.

Of course, each column must be used with operators appropriate to the index type; clauses that involve other operators will not be considered.

Multicolumn indexes should be used sparingly. In most situations, an index on a single column is sufficient and saves space and time. Indexes with more than three columns are unlikely to be helpful unless the usage of the table is extremely stylized. See also Section 11.5 and Section 11.9 for some discussion of the merits of different index configurations.

11.4. Indexes and ORDER BY

In addition to simply finding the rows to be returned by a query, an index may be able to deliver them in a specific sorted order. This allows a query's `ORDER BY` specification to be honored without a separate sorting step. Of the index types currently supported by PostgreSQL, only B-tree can produce sorted output — the other index types return matching rows in an unspecified, implementation-dependent order.

The planner will consider satisfying an `ORDER BY` specification either by scanning an available index that matches the specification, or by scanning the table in physical order and doing an explicit sort. For a query that requires scanning a large fraction of the table, an explicit sort is likely to be faster than using an index because it requires less disk I/O due to following a sequential access pattern. Indexes are more useful when only a few rows need be fetched. An important special case is `ORDER BY` in combination with `LIMIT n`: an explicit sort will have to process all the data to identify the first n rows, but if there is an index matching the `ORDER BY`, the first n rows can be retrieved directly, without scanning the remainder at all.

By default, B-tree indexes store their entries in ascending order with nulls last (table TID is treated as a tiebreaker column among otherwise equal entries). This means that a forward scan of an index on column x produces output satisfying `ORDER BY x` (or more verbosely, `ORDER BY x ASC NULLS LAST`). The index can also be scanned backward, producing output satisfying `ORDER BY x DESC` (or more verbosely, `ORDER BY x DESC NULLS FIRST`, since `NULLS FIRST` is the default for `ORDER BY DESC`).

You can adjust the ordering of a B-tree index by including the options `ASC`, `DESC`, `NULLS FIRST`, and/or `NULLS LAST` when creating the index; for example:

```
CREATE INDEX test2_info_nulls_low ON test2 (info NULLS FIRST);
CREATE INDEX test3_desc_index ON test3 (id DESC NULLS LAST);
```

An index stored in ascending order with nulls first can satisfy either `ORDER BY x ASC NULLS FIRST` or `ORDER BY x DESC NULLS LAST` depending on which direction it is scanned in.

You might wonder why bother providing all four options, when two options together with the possibility of backward scan would cover all the variants of `ORDER BY`. In single-column indexes the options are indeed redundant, but in multicolumn indexes they can be useful. Consider a two-column index on (x, y) : this can satisfy `ORDER BY x, y` if we scan forward, or `ORDER BY x DESC, y DESC` if we scan backward. But it might be that the application frequently needs to use `ORDER BY x ASC, y DESC`. There is no way to get that ordering from a plain index, but it is possible if the index is defined as $(x \text{ ASC}, y \text{ DESC})$ or $(x \text{ DESC}, y \text{ ASC})$.

Obviously, indexes with non-default sort orderings are a fairly specialized feature, but sometimes they can produce tremendous speedups for certain queries. Whether it's worth maintaining such an index depends on how often you use queries that require a special sort ordering.

11.5. Combining Multiple Indexes

A single index scan can only use query clauses that use the index's columns with operators of its operator class and are joined with `AND`. For example, given an index on `(a, b)` a query condition like `WHERE a = 5 AND b = 6` could use the index, but a query like `WHERE a = 5 OR b = 6` could not directly use the index.

Fortunately, PostgreSQL has the ability to combine multiple indexes (including multiple uses of the same index) to handle cases that cannot be implemented by single index scans. The system can form `AND` and `OR` conditions across several index scans. For example, a query like `WHERE x = 42 OR x = 47 OR x = 53 OR x = 99` could be broken down into four separate scans of an index on `x`, each scan using one of the query clauses. The results of these scans are then `OR`ed together to produce the result. Another example is that if we have separate indexes on `x` and `y`, one possible implementation of a query like `WHERE x = 5 AND y = 6` is to use each index with the appropriate query clause and then `AND` together the index results to identify the result rows.

To combine multiple indexes, the system scans each needed index and prepares a *bitmap* in memory giving the locations of table rows that are reported as matching that index's conditions. The bitmaps are then `AND`ed and `OR`ed together as needed by the query. Finally, the actual table rows are visited and returned. The table rows are visited in physical order, because that is how the bitmap is laid out; this means that any ordering of the original indexes is lost, and so a separate sort step will be needed if the query has an `ORDER BY` clause. For this reason, and because each additional index scan adds extra time, the planner will sometimes choose to use a simple index scan even though additional indexes are available that could have been used as well.

In all but the simplest applications, there are various combinations of indexes that might be useful, and the database developer must make trade-offs to decide which indexes to provide. Sometimes multicolumn indexes are best, but sometimes it's better to create separate indexes and rely on the index-combination feature. For example, if your workload includes a mix of queries that sometimes involve only column `x`, sometimes only column `y`, and sometimes both columns, you might choose to create two separate indexes on `x` and `y`, relying on index combination to process the queries that use both columns. You could also create a multicolumn index on `(x, y)`. This index would typically be more efficient than index combination for queries involving both columns, but as discussed in Section 11.3, it would be almost useless for queries involving only `y`, so it should not be the only index. A combination of the multicolumn index and a separate index on `y` would serve reasonably well. For queries involving only `x`, the multicolumn index could be used, though it would be larger and hence slower than an index on `x` alone. The last alternative is to create all three indexes, but this is probably only reasonable if the table is searched much more often than it is updated and all three types of query are common. If one of the types of query is much less common than the others, you'd probably settle for creating just the two indexes that best match the common types.

11.6. Unique Indexes

Indexes can also be used to enforce uniqueness of a column's value, or the uniqueness of the combined values of more than one column.

```
CREATE UNIQUE INDEX name ON table (column [, ...]);
```

Currently, only B-tree indexes can be declared unique.

When an index is declared unique, multiple table rows with equal indexed values are not allowed. Null values are not considered equal. A multicolumn unique index will only reject cases where all indexed columns are equal in multiple rows.

PostgreSQL automatically creates a unique index when a unique constraint or primary key is defined for a table. The index covers the columns that make up the primary key or unique constraint (a multicolumn index, if appropriate), and is the mechanism that enforces the constraint.

Note

There's no need to manually create indexes on unique columns; doing so would just duplicate the automatically-created index.

11.7. Indexes on Expressions

An index column need not be just a column of the underlying table, but can be a function or scalar expression computed from one or more columns of the table. This feature is useful to obtain fast access to tables based on the results of computations.

For example, a common way to do case-insensitive comparisons is to use the `lower` function:

```
SELECT * FROM test1 WHERE lower(coll) = 'value';
```

This query can use an index if one has been defined on the result of the `lower(coll)` function:

```
CREATE INDEX test1_lower_coll_idx ON test1 (lower(coll));
```

If we were to declare this index `UNIQUE`, it would prevent creation of rows whose `coll` values differ only in case, as well as rows whose `coll` values are actually identical. Thus, indexes on expressions can be used to enforce constraints that are not definable as simple unique constraints.

As another example, if one often does queries like:

```
SELECT * FROM people WHERE (first_name || ' ' || last_name) = 'John
    Smith';
```

then it might be worth creating an index like this:

```
CREATE INDEX people_names ON people ((first_name || ' ' ||
    last_name));
```

The syntax of the `CREATE INDEX` command normally requires writing parentheses around index expressions, as shown in the second example. The parentheses can be omitted when the expression is just a function call, as in the first example.

Index expressions are relatively expensive to maintain, because the derived expression(s) must be computed for each row upon insertion and whenever it is updated. However, the index expressions are *not* recomputed during an indexed search, since they are already stored in the index. In both examples above, the system sees the query as just `WHERE indexedcolumn = 'constant'` and so the speed of the search is equivalent to any other simple index query. Thus, indexes on expressions are useful when retrieval speed is more important than insertion and update speed.

11.8. Partial Indexes

A *partial index* is an index built over a subset of a table; the subset is defined by a conditional expression (called the *predicate* of the partial index). The index contains entries only for those table rows that satisfy the predicate. Partial indexes are a specialized feature, but there are several situations in which they are useful.

One major reason for using a partial index is to avoid indexing common values. Since a query searching for a common value (one that accounts for more than a few percent of all the table rows) will not use

the index anyway, there is no point in keeping those rows in the index at all. This reduces the size of the index, which will speed up those queries that do use the index. It will also speed up many table update operations because the index does not need to be updated in all cases. Example 11.1 shows a possible application of this idea.

Example 11.1. Setting up a Partial Index to Exclude Common Values

Suppose you are storing web server access logs in a database. Most accesses originate from the IP address range of your organization but some are from elsewhere (say, employees on dial-up connections). If your searches by IP are primarily for outside accesses, you probably do not need to index the IP range that corresponds to your organization's subnet.

Assume a table like this:

```
CREATE TABLE access_log (  
    url varchar,  
    client_ip inet,  
    ...  
);
```

To create a partial index that suits our example, use a command such as this:

```
CREATE INDEX access_log_client_ip_ix ON access_log (client_ip)  
WHERE NOT (client_ip > inet '192.168.100.0' AND  
          client_ip < inet '192.168.100.255');
```

A typical query that can use this index would be:

```
SELECT *  
FROM access_log  
WHERE url = '/index.html' AND client_ip = inet '212.78.10.32';
```

Here the query's IP address is covered by the partial index. The following query cannot use the partial index, as it uses an IP address that is excluded from the index:

```
SELECT *  
FROM access_log  
WHERE url = '/index.html' AND client_ip = inet '192.168.100.23';
```

Observe that this kind of partial index requires that the common values be predetermined, so such partial indexes are best used for data distributions that do not change. Such indexes can be recreated occasionally to adjust for new data distributions, but this adds maintenance effort.

Another possible use for a partial index is to exclude values from the index that the typical query workload is not interested in; this is shown in Example 11.2. This results in the same advantages as listed above, but it prevents the “uninteresting” values from being accessed via that index, even if an index scan might be profitable in that case. Obviously, setting up partial indexes for this kind of scenario will require a lot of care and experimentation.

Example 11.2. Setting up a Partial Index to Exclude Uninteresting Values

If you have a table that contains both billed and unbilled orders, where the unbilled orders take up a small fraction of the total table and yet those are the most-accessed rows, you can improve performance by creating an index on just the unbilled rows. The command to create the index would look like this:

```
CREATE INDEX orders_unbilled_index ON orders (order_nr)
WHERE billed is not true;
```

A possible query to use this index would be:

```
SELECT * FROM orders WHERE billed is not true AND order_nr < 10000;
```

However, the index can also be used in queries that do not involve `order_nr` at all, e.g.:

```
SELECT * FROM orders WHERE billed is not true AND amount > 5000.00;
```

This is not as efficient as a partial index on the `amount` column would be, since the system has to scan the entire index. Yet, if there are relatively few unbilled orders, using this partial index just to find the unbilled orders could be a win.

Note that this query cannot use this index:

```
SELECT * FROM orders WHERE order_nr = 3501;
```

The order 3501 might be among the billed or unbilled orders.

Example 11.2 also illustrates that the indexed column and the column used in the predicate do not need to match. PostgreSQL supports partial indexes with arbitrary predicates, so long as only columns of the table being indexed are involved. However, keep in mind that the predicate must match the conditions used in the queries that are supposed to benefit from the index. To be precise, a partial index can be used in a query only if the system can recognize that the `WHERE` condition of the query mathematically implies the predicate of the index. PostgreSQL does not have a sophisticated theorem prover that can recognize mathematically equivalent expressions that are written in different forms. (Not only is such a general theorem prover extremely difficult to create, it would probably be too slow to be of any real use.) The system can recognize simple inequality implications, for example “ $x < 1$ ” implies “ $x < 2$ ”; otherwise the predicate condition must exactly match part of the query's `WHERE` condition or the index will not be recognized as usable. Matching takes place at query planning time, not at run time. As a result, parameterized query clauses do not work with a partial index. For example a prepared query with a parameter might specify “ $x < ?$ ” which will never imply “ $x < 2$ ” for all possible values of the parameter.

A third possible use for partial indexes does not require the index to be used in queries at all. The idea here is to create a unique index over a subset of a table, as in Example 11.3. This enforces uniqueness among the rows that satisfy the index predicate, without constraining those that do not.

Example 11.3. Setting up a Partial Unique Index

Suppose that we have a table describing test outcomes. We wish to ensure that there is only one “successful” entry for a given subject and target combination, but there might be any number of “unsuccessful” entries. Here is one way to do it:

```
CREATE TABLE tests (
    subject text,
    target text,
    success boolean,
    ...
);

CREATE UNIQUE INDEX tests_success_constraint ON tests (subject,
target)
```

```
WHERE success;
```

This is a particularly efficient approach when there are few successful tests and many unsuccessful ones.

Finally, a partial index can also be used to override the system's query plan choices. Also, data sets with peculiar distributions might cause the system to use an index when it really should not. In that case the index can be set up so that it is not available for the offending query. Normally, PostgreSQL makes reasonable choices about index usage (e.g., it avoids them when retrieving common values, so the earlier example really only saves index size, it is not required to avoid index usage), and grossly incorrect plan choices are cause for a bug report.

Keep in mind that setting up a partial index indicates that you know at least as much as the query planner knows, in particular you know when an index might be profitable. Forming this knowledge requires experience and understanding of how indexes in PostgreSQL work. In most cases, the advantage of a partial index over a regular index will be minimal.

More information about partial indexes can be found in [ston89b], [olson93], and [seshadri95].

11.9. Index-Only Scans and Covering Indexes

All indexes in PostgreSQL are *secondary* indexes, meaning that each index is stored separately from the table's main data area (which is called the table's *heap* in PostgreSQL terminology). This means that in an ordinary index scan, each row retrieval requires fetching data from both the index and the heap. Furthermore, while the index entries that match a given indexable *WHERE* condition are usually close together in the index, the table rows they reference might be anywhere in the heap. The heap-access portion of an index scan thus involves a lot of random access into the heap, which can be slow, particularly on traditional rotating media. (As described in Section 11.5, bitmap scans try to alleviate this cost by doing the heap accesses in sorted order, but that only goes so far.)

To solve this performance problem, PostgreSQL supports *index-only scans*, which can answer queries from an index alone without any heap access. The basic idea is to return values directly out of each index entry instead of consulting the associated heap entry. There are two fundamental restrictions on when this method can be used:

1. The index type must support index-only scans. B-tree indexes always do. GiST and SP-GiST indexes support index-only scans for some operator classes but not others. Other index types have no support. The underlying requirement is that the index must physically store, or else be able to reconstruct, the original data value for each index entry. As a counterexample, GIN indexes cannot support index-only scans because each index entry typically holds only part of the original data value.
2. The query must reference only columns stored in the index. For example, given an index on columns *x* and *y* of a table that also has a column *z*, these queries could use index-only scans:

```
SELECT x, y FROM tab WHERE x = 'key';
SELECT x FROM tab WHERE x = 'key' AND y < 42;
```

but these queries could not:

```
SELECT x, z FROM tab WHERE x = 'key';
SELECT x FROM tab WHERE x = 'key' AND z < 42;
```

(Expression indexes and partial indexes complicate this rule, as discussed below.)

If these two fundamental requirements are met, then all the data values required by the query are available from the index, so an index-only scan is physically possible. But there is an additional requirement for any table scan in PostgreSQL: it must verify that each retrieved row be “visible” to

the query's MVCC snapshot, as discussed in Chapter 13. Visibility information is not stored in index entries, only in heap entries; so at first glance it would seem that every row retrieval would require a heap access anyway. And this is indeed the case, if the table row has been modified recently. However, for seldom-changing data there is a way around this problem. PostgreSQL tracks, for each page in a table's heap, whether all rows stored in that page are old enough to be visible to all current and future transactions. This information is stored in a bit in the table's *visibility map*. An index-only scan, after finding a candidate index entry, checks the visibility map bit for the corresponding heap page. If it's set, the row is known visible and so the data can be returned with no further work. If it's not set, the heap entry must be visited to find out whether it's visible, so no performance advantage is gained over a standard index scan. Even in the successful case, this approach trades visibility map accesses for heap accesses; but since the visibility map is four orders of magnitude smaller than the heap it describes, far less physical I/O is needed to access it. In most situations the visibility map remains cached in memory all the time.

In short, while an index-only scan is possible given the two fundamental requirements, it will be a win only if a significant fraction of the table's heap pages have their all-visible map bits set. But tables in which a large fraction of the rows are unchanging are common enough to make this type of scan very useful in practice.

To make effective use of the index-only scan feature, you might choose to create a *covering index*, which is an index specifically designed to include the columns needed by a particular type of query that you run frequently. Since queries typically need to retrieve more columns than just the ones they search on, PostgreSQL allows you to create an index in which some columns are just “payload” and are not part of the search key. This is done by adding an `INCLUDE` clause listing the extra columns. For example, if you commonly run queries like

```
SELECT y FROM tab WHERE x = 'key';
```

the traditional approach to speeding up such queries would be to create an index on `x` only. However, an index defined as

```
CREATE INDEX tab_x_y ON tab(x) INCLUDE (y);
```

could handle these queries as index-only scans, because `y` can be obtained from the index without visiting the heap.

Because column `y` is not part of the index's search key, it does not have to be of a data type that the index can handle; it's merely stored in the index and is not interpreted by the index machinery. Also, if the index is a unique index, that is

```
CREATE UNIQUE INDEX tab_x_y ON tab(x) INCLUDE (y);
```

the uniqueness condition applies to just column `x`, not to the combination of `x` and `y`. (An `INCLUDE` clause can also be written in `UNIQUE` and `PRIMARY KEY` constraints, providing alternative syntax for setting up an index like this.)

It's wise to be conservative about adding non-key payload columns to an index, especially wide columns. If an index tuple exceeds the maximum size allowed for the index type, data insertion will fail. In any case, non-key columns duplicate data from the index's table and bloat the size of the index, thus potentially slowing searches. And remember that there is little point in including payload columns in an index unless the table changes slowly enough that an index-only scan is likely to not need to access the heap. If the heap tuple must be visited anyway, it costs nothing more to get the column's value from there. Other restrictions are that expressions are not currently supported as included columns, and that only B-tree and GiST indexes currently support included columns.

Before PostgreSQL had the `INCLUDE` feature, people sometimes made covering indexes by writing the payload columns as ordinary index columns, that is writing

```
CREATE INDEX tab_x_y ON tab(x, y);
```

even though they had no intention of ever using `y` as part of a `WHERE` clause. This works fine as long as the extra columns are trailing columns; making them be leading columns is unwise for the reasons explained in Section 11.3. However, this method doesn't support the case where you want the index to enforce uniqueness on the key column(s).

Suffix truncation always removes non-key columns from upper B-Tree levels. As payload columns, they are never used to guide index scans. The truncation process also removes one or more trailing key column(s) when the remaining prefix of key column(s) happens to be sufficient to describe tuples on the lowest B-Tree level. In practice, covering indexes without an `INCLUDE` clause often avoid storing columns that are effectively payload in the upper levels. However, explicitly defining payload columns as non-key columns *reliably* keeps the tuples in upper levels small.

In principle, index-only scans can be used with expression indexes. For example, given an index on `f(x)` where `x` is a table column, it should be possible to execute

```
SELECT f(x) FROM tab WHERE f(x) < 1;
```

as an index-only scan; and this is very attractive if `f()` is an expensive-to-compute function. However, PostgreSQL's planner is currently not very smart about such cases. It considers a query to be potentially executable by index-only scan only when all *columns* needed by the query are available from the index. In this example, `x` is not needed except in the context `f(x)`, but the planner does not notice that and concludes that an index-only scan is not possible. If an index-only scan seems sufficiently worthwhile, this can be worked around by adding `x` as an included column, for example

```
CREATE INDEX tab_f_x ON tab (f(x)) INCLUDE (x);
```

An additional caveat, if the goal is to avoid recalculating `f(x)`, is that the planner won't necessarily match uses of `f(x)` that aren't in indexable `WHERE` clauses to the index column. It will usually get this right in simple queries such as shown above, but not in queries that involve joins. These deficiencies may be remedied in future versions of PostgreSQL.

Partial indexes also have interesting interactions with index-only scans. Consider the partial index shown in Example 11.3:

```
CREATE UNIQUE INDEX tests_success_constraint ON tests (subject,
    target)
    WHERE success;
```

In principle, we could do an index-only scan on this index to satisfy a query like

```
SELECT target FROM tests WHERE subject = 'some-subject' AND
    success;
```

But there's a problem: the `WHERE` clause refers to `success` which is not available as a result column of the index. Nonetheless, an index-only scan is possible because the plan does not need to recheck that part of the `WHERE` clause at run time: all entries found in the index necessarily have `success = true` so this need not be explicitly checked in the plan. PostgreSQL versions 9.6 and later will recognize such cases and allow index-only scans to be generated, but older versions will not.

11.10. Operator Classes and Operator Families

An index definition can specify an *operator class* for each column of an index.

```
CREATE INDEX name ON table (column opclass [sort options] [, ...]);
```

The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on the type `int4` would use the `int4_ops` class; this operator class includes comparison functions for values of type `int4`. In practice the default operator class for the column's data type is usually sufficient. The main reason for having operator classes is that for some data types, there could be more than one meaningful index behavior. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when making an index. The operator class determines the basic sort ordering (which can then be modified by adding sort options `COLLATE`, `ASC/DESC` and/or `NULLS FIRST/NULLS LAST`).

There are also some built-in operator classes besides the default ones:

- The operator classes `text_pattern_ops`, `varchar_pattern_ops`, and `bpchar_pattern_ops` support B-tree indexes on the types `text`, `varchar`, and `char` respectively. The difference from the default operator classes is that the values are compared strictly character by character rather than according to the locale-specific collation rules. This makes these operator classes suitable for use by queries involving pattern matching expressions (`LIKE` or POSIX regular expressions) when the database does not use the standard “C” locale. As an example, you might index a `varchar` column like this:

```
CREATE INDEX test_index ON test_table (col varchar_pattern_ops);
```

Note that you should also create an index with the default operator class if you want queries involving ordinary `<`, `<=`, `>`, or `>=` comparisons to use an index. Such queries cannot use the `xxx_pattern_ops` operator classes. (Ordinary equality comparisons can use these operator classes, however.) It is possible to create multiple indexes on the same column with different operator classes. If you do use the C locale, you do not need the `xxx_pattern_ops` operator classes, because an index with the default operator class is usable for pattern-matching queries in the C locale.

The following query shows all defined operator classes:

```
SELECT am.amname AS index_method,
       opc.opcname AS opclass_name,
       opc.opcintype::regtype AS indexed_type,
       opc.opcdefault AS is_default
FROM pg_am am, pg_opclass opc
WHERE opc.opcmethod = am.oid
ORDER BY index_method, opclass_name;
```

An operator class is actually just a subset of a larger structure called an *operator family*. In cases where several data types have similar behaviors, it is frequently useful to define cross-data-type operators and allow these to work with indexes. To do this, the operator classes for each of the types must be grouped into the same operator family. The cross-type operators are members of the family, but are not associated with any single class within the family.

This expanded version of the previous query shows the operator family each operator class belongs to:

```
SELECT am.amname AS index_method,
       opc.opcname AS opclass_name,
       opf.opfname AS opfamily_name,
       opc.opcintype::regtype AS indexed_type,
       opc.opcdefault AS is_default
```

```

FROM pg_am am, pg_opclass opc, pg_opfamily opf
WHERE opc.opcmethod = am.oid AND
      opc.opcfamily = opf.oid
ORDER BY index_method, opclass_name;

```

This query shows all defined operator families and all the operators included in each family:

```

SELECT am.amname AS index_method,
       opf.opfname AS opfamily_name,
       amop.amopr::regoperator AS opfamily_operator
FROM pg_am am, pg_opfamily opf, pg_amop amop
WHERE opf.opfmethod = am.oid AND
      amop.amopfamily = opf.oid
ORDER BY index_method, opfamily_name, opfamily_operator;

```

11.11. Indexes and Collations

An index can support only one collation per index column. If multiple collations are of interest, multiple indexes may be needed.

Consider these statements:

```

CREATE TABLE testlc (
    id integer,
    content varchar COLLATE "x"
);

CREATE INDEX testlc_content_index ON testlc (content);

```

The index automatically uses the collation of the underlying column. So a query of the form

```
SELECT * FROM testlc WHERE content > constant;
```

could use the index, because the comparison will by default use the collation of the column. However, this index cannot accelerate queries that involve some other collation. So if queries of the form, say,

```
SELECT * FROM testlc WHERE content > constant COLLATE "y";
```

are also of interest, an additional index could be created that supports the "y" collation, like this:

```
CREATE INDEX testlc_content_y_index ON testlc (content COLLATE
"y");
```

11.12. Examining Index Usage

Although indexes in PostgreSQL do not need maintenance or tuning, it is still important to check which indexes are actually used by the real-life query workload. Examining index usage for an individual query is done with the EXPLAIN command; its application for this purpose is illustrated in Section 14.1. It is also possible to gather overall statistics about index usage in a running server, as described in Section 27.2.

It is difficult to formulate a general procedure for determining which indexes to create. There are a number of typical cases that have been shown in the examples throughout the previous sections. A good deal of experimentation is often necessary. The rest of this section gives some tips for that:

- Always run `ANALYZE` first. This command collects statistics about the distribution of the values in the table. This information is required to estimate the number of rows returned by a query, which is needed by the planner to assign realistic costs to each possible query plan. In absence of any real statistics, some default values are assumed, which are almost certain to be inaccurate. Examining an application's index usage without having run `ANALYZE` is therefore a lost cause. See Section 24.1.3 and Section 24.1.6 for more information.
- Use real data for experimentation. Using test data for setting up indexes will tell you what indexes you need for the test data, but that is all.

It is especially fatal to use very small test data sets. While selecting 1000 out of 100000 rows could be a candidate for an index, selecting 1 out of 100 rows will hardly be, because the 100 rows probably fit within a single disk page, and there is no plan that can beat sequentially fetching 1 disk page.

Also be careful when making up test data, which is often unavoidable when the application is not yet in production. Values that are very similar, completely random, or inserted in sorted order will skew the statistics away from the distribution that real data would have.

- When indexes are not used, it can be useful for testing to force their use. There are run-time parameters that can turn off various plan types (see Section 19.7.1). For instance, turning off sequential scans (`enable_seqscan`) and nested-loop joins (`enable_nestloop`), which are the most basic plans, will force the system to use a different plan. If the system still chooses a sequential scan or nested-loop join then there is probably a more fundamental reason why the index is not being used; for example, the query condition does not match the index. (What kind of query can use what kind of index is explained in the previous sections.)
- If forcing index usage does use the index, then there are two possibilities: Either the system is right and using the index is indeed not appropriate, or the cost estimates of the query plans are not reflecting reality. So you should time your query with and without indexes. The `EXPLAIN ANALYZE` command can be useful here.
- If it turns out that the cost estimates are wrong, there are, again, two possibilities. The total cost is computed from the per-row costs of each plan node times the selectivity estimate of the plan node. The costs estimated for the plan nodes can be adjusted via run-time parameters (described in Section 19.7.2). An inaccurate selectivity estimate is due to insufficient statistics. It might be possible to improve this by tuning the statistics-gathering parameters (see `ALTER TABLE`).

If you do not succeed in adjusting the costs to be more appropriate, then you might have to resort to forcing index usage explicitly. You might also want to contact the PostgreSQL developers to examine the issue.

Chapter 12. Full Text Search

12.1. Introduction

Full Text Searching (or just *text search*) provides the capability to identify natural-language *documents* that satisfy a *query*, and optionally to sort them by relevance to the query. The most common type of search is to find all documents containing given *query terms* and return them in order of their *similarity* to the query. Notions of *query* and *similarity* are very flexible and depend on the specific application. The simplest search considers *query* as a set of words and *similarity* as the frequency of query words in the document.

Textual search operators have existed in databases for years. PostgreSQL has `~`, `~*`, `LIKE`, and `ILIKE` operators for textual data types, but they lack many essential properties required by modern information systems:

- There is no linguistic support, even for English. Regular expressions are not sufficient because they cannot easily handle derived words, e.g., *satisfies* and *satisfy*. You might miss documents that contain *satisfies*, although you probably would like to find them when searching for *satisfy*. It is possible to use `OR` to search for multiple derived forms, but this is tedious and error-prone (some words can have several thousand derivatives).
- They provide no ordering (ranking) of search results, which makes them ineffective when thousands of matching documents are found.
- They tend to be slow because there is no index support, so they must process all documents for every search.

Full text indexing allows documents to be *preprocessed* and an index saved for later rapid searching. Preprocessing includes:

Parsing documents into tokens. It is useful to identify various classes of tokens, e.g., numbers, words, complex words, email addresses, so that they can be processed differently. In principle token classes depend on the specific application, but for most purposes it is adequate to use a predefined set of classes. PostgreSQL uses a *parser* to perform this step. A standard parser is provided, and custom parsers can be created for specific needs.

Converting tokens into lexemes. A lexeme is a string, just like a token, but it has been *normalized* so that different forms of the same word are made alike. For example, normalization almost always includes folding upper-case letters to lower-case, and often involves removal of suffixes (such as *s* or *es* in English). This allows searches to find variant forms of the same word, without tediously entering all the possible variants. Also, this step typically eliminates *stop words*, which are words that are so common that they are useless for searching. (In short, then, tokens are raw fragments of the document text, while lexemes are words that are believed useful for indexing and searching.) PostgreSQL uses *dictionaries* to perform this step. Various standard dictionaries are provided, and custom ones can be created for specific needs.

Storing preprocessed documents optimized for searching. For example, each document can be represented as a sorted array of normalized lexemes. Along with the lexemes it is often desirable to store positional information to use for *proximity ranking*, so that a document that contains a more “dense” region of query words is assigned a higher rank than one with scattered query words.

Dictionaries allow fine-grained control over how tokens are normalized. With appropriate dictionaries, you can:

- Define stop words that should not be indexed.
- Map synonyms to a single word using `Ispell`.
- Map phrases to a single word using a thesaurus.
- Map different variations of a word to a canonical form using an `Ispell` dictionary.
- Map different variations of a word to a canonical form using `Snowball` stemmer rules.

A data type `tsvector` is provided for storing preprocessed documents, along with a type `tsquery` for representing processed queries (Section 8.11). There are many functions and operators available for these data types (Section 9.13), the most important of which is the match operator `@@`, which we introduce in Section 12.1.2. Full text searches can be accelerated using indexes (Section 12.9).

12.1.1. What Is a Document?

A *document* is the unit of searching in a full text search system; for example, a magazine article or email message. The text search engine must be able to parse documents and store associations of lexemes (key words) with their parent document. Later, these associations are used to search for documents that contain query words.

For searches within PostgreSQL, a document is normally a textual field within a row of a database table, or possibly a combination (concatenation) of such fields, perhaps stored in several tables or obtained dynamically. In other words, a document can be constructed from different parts for indexing and it might not be stored anywhere as a whole. For example:

```
SELECT title || ' ' || author || ' ' || abstract || ' ' || body
       AS document
FROM messages
WHERE mid = 12;
```

```
SELECT m.title || ' ' || m.author || ' ' || m.abstract || ' ' ||
       d.body AS document
FROM messages m, docs d
WHERE mid = did AND mid = 12;
```

Note

Actually, in these example queries, `coalesce` should be used to prevent a single `NULL` attribute from causing a `NULL` result for the whole document.

Another possibility is to store the documents as simple text files in the file system. In this case, the database can be used to store the full text index and to execute searches, and some unique identifier can be used to retrieve the document from the file system. However, retrieving files from outside the database requires superuser permissions or special function support, so this is usually less convenient than keeping all the data inside PostgreSQL. Also, keeping everything inside the database allows easy access to document metadata to assist in indexing and display.

For text search purposes, each document must be reduced to the preprocessed `tsvector` format. Searching and ranking are performed entirely on the `tsvector` representation of a document — the original text need only be retrieved when the document has been selected for display to a user. We therefore often speak of the `tsvector` as being the document, but of course it is only a compact representation of the full document.

12.1.2. Basic Text Matching

Full text searching in PostgreSQL is based on the match operator `@@`, which returns `true` if a `tsvector` (document) matches a `tsquery` (query). It doesn't matter which data type is written first:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector @@ 'cat
& rat'::tsquery;
?column?
-----
t
```

```
SELECT 'fat & cow'::tsquery @@ 'a fat cat sat on a mat and ate a
fat rat'::tsvector;
?column?
-----
f
```

As the above example suggests, a `tsquery` is not just raw text, any more than a `tsvector` is. A `tsquery` contains search terms, which must be already-normalized lexemes, and may combine multiple terms using AND, OR, NOT, and FOLLOWED BY operators. (For syntax details see Section 8.11.2.) There are functions `to_tsquery`, `plainto_tsquery`, and `phraseto_tsquery` that are helpful in converting user-written text into a proper `tsquery`, primarily by normalizing words appearing in the text. Similarly, `to_tsvector` is used to parse and normalize a document string. So in practice a text search match would look more like this:

```
SELECT to_tsvector('fat cats ate fat rats') @@ to_tsquery('fat &
rat');
?column?
-----
t
```

Observe that this match would not succeed if written as

```
SELECT 'fat cats ate fat rats'::tsvector @@ to_tsquery('fat &
rat');
?column?
-----
f
```

since here no normalization of the word `rats` will occur. The elements of a `tsvector` are lexemes, which are assumed already normalized, so `rats` does not match `rat`.

The `@@` operator also supports text input, allowing explicit conversion of a text string to `tsvector` or `tsquery` to be skipped in simple cases. The variants available are:

```
tsvector @@ tsquery
tsquery  @@ tsvector
text     @@ tsquery
text     @@ text
```

The first two of these we saw already. The form `text @@ tsquery` is equivalent to `to_tsvector(x) @@ y`. The form `text @@ text` is equivalent to `to_tsvector(x) @@ plainto_tsquery(y)`.

Within a `tsquery`, the `&` (AND) operator specifies that both its arguments must appear in the document to have a match. Similarly, the `|` (OR) operator specifies that at least one of its arguments must appear, while the `!` (NOT) operator specifies that its argument must *not* appear in order to have a match. For example, the query `fat & ! rat` matches documents that contain `fat` but not `rat`.

Searching for phrases is possible with the help of the `<->` (FOLLOWED BY) `tsquery` operator, which matches only if its arguments have matches that are adjacent and in the given order. For example:

```
SELECT to_tsvector('fatal error') @@ to_tsquery('fatal <-> error');
?column?
-----
t
```

```
SELECT to_tsvector('error is not fatal') @@ to_tsquery('fatal <->
error');
?column?
-----
f
```

There is a more general version of the FOLLOWED BY operator having the form `<N>`, where `N` is an integer standing for the difference between the positions of the matching lexemes. `<1>` is the same as `<->`, while `<2>` allows exactly one other lexeme to appear between the matches, and so on. The `phraseto_tsquery` function makes use of this operator to construct a `tsquery` that can match a multi-word phrase when some of the words are stop words. For example:

```
SELECT phraseto_tsquery('cats ate rats');
        phraseto_tsquery
-----
'cat' <-> 'ate' <-> 'rat'

SELECT phraseto_tsquery('the cats ate the rats');
        phraseto_tsquery
-----
'cat' <-> 'ate' <2> 'rat'
```

A special case that's sometimes useful is that `<0>` can be used to require that two patterns match the same word.

Parentheses can be used to control nesting of the `tsquery` operators. Without parentheses, `|` binds least tightly, then `&`, then `<->`, and `!` most tightly.

It's worth noticing that the AND/OR/NOT operators mean something subtly different when they are within the arguments of a FOLLOWED BY operator than when they are not, because within FOLLOWED BY the exact position of the match is significant. For example, normally `!x` matches only documents that do not contain `x` anywhere. But `!x <-> y` matches `y` if it is not immediately after an `x`; an occurrence of `x` elsewhere in the document does not prevent a match. Another example is that `x & y` normally only requires that `x` and `y` both appear somewhere in the document, but `(x & y) <-> z` requires `x` and `y` to match at the same place, immediately before a `z`. Thus this query behaves differently from `x <-> z & y <-> z`, which will match a document containing two separate sequences `x z` and `y z`. (This specific query is useless as written, since `x` and `y` could not match at the same place; but with more complex situations such as prefix-match patterns, a query of this form could be useful.)

12.1.3. Configurations

The above are all simple text search examples. As mentioned before, full text search functionality includes the ability to do many more things: skip indexing certain words (stop words), process synonyms, and use sophisticated parsing, e.g., parse based on more than just white space. This functionality is controlled by *text search configurations*. PostgreSQL comes with predefined configurations for many languages, and you can easily create your own configurations. (`psql`'s `\dF` command shows all available configurations.)

During installation an appropriate configuration is selected and `default_text_search_config` is set accordingly in `postgresql.conf`. If you are using the same text search configuration for the entire cluster you can use the value in `postgresql.conf`. To use different configurations throughout the cluster but the same configuration within any one database, use `ALTER DATABASE ... SET`. Otherwise, you can set `default_text_search_config` in each session.

Each text search function that depends on a configuration has an optional `regconfig` argument, so that the configuration to use can be specified explicitly. `default_text_search_config` is used only when this argument is omitted.

To make it easier to build custom text search configurations, a configuration is built up from simpler database objects. PostgreSQL's text search facility provides four types of configuration-related database objects:

- *Text search parsers* break documents into tokens and classify each token (for example, as words or numbers).
- *Text search dictionaries* convert tokens to normalized form and reject stop words.
- *Text search templates* provide the functions underlying dictionaries. (A dictionary simply specifies a template and a set of parameters for the template.)
- *Text search configurations* select a parser and a set of dictionaries to use to normalize the tokens produced by the parser.

Text search parsers and templates are built from low-level C functions; therefore it requires C programming ability to develop new ones, and superuser privileges to install one into a database. (There are examples of add-on parsers and templates in the `contrib/` area of the PostgreSQL distribution.) Since dictionaries and configurations just parameterize and connect together some underlying parsers and templates, no special privilege is needed to create a new dictionary or configuration. Examples of creating custom dictionaries and configurations appear later in this chapter.

12.2. Tables and Indexes

The examples in the previous section illustrated full text matching using simple constant strings. This section shows how to search table data, optionally using indexes.

12.2.1. Searching a Table

It is possible to do a full text search without an index. A simple query to print the `title` of each row that contains the word `friend` in its `body` field is:

```
SELECT title
FROM pgweb
WHERE to_tsvector('english', body) @@ to_tsquery('english',
'friend');
```

This will also find related words such as `friends` and `friendly`, since all these are reduced to the same normalized lexeme.

The query above specifies that the `english` configuration is to be used to parse and normalize the strings. Alternatively we could omit the configuration parameters:

```
SELECT title
FROM pgweb
WHERE to_tsvector(body) @@ to_tsquery('friend');
```

This query will use the configuration set by `default_text_search_config`.

A more complex example is to select the ten most recent documents that contain `create` and `table` in the `title` or `body`:

```
SELECT title
FROM pgweb
WHERE to_tsvector(title || ' ' || body) @@ to_tsquery('create &
table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

For clarity we omitted the `coalesce` function calls which would be needed to find rows that contain `NULL` in one of the two fields.

Although these queries will work without an index, most applications will find this approach too slow, except perhaps for occasional ad-hoc searches. Practical use of text searching usually requires creating an index.

12.2.2. Creating Indexes

We can create a GIN index (Section 12.9) to speed up text searches:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector('english',
body));
```

Notice that the 2-argument version of `to_tsvector` is used. Only text search functions that specify a configuration name can be used in expression indexes (Section 11.7). This is because the index contents must be unaffected by `default_text_search_config`. If they were affected, the index contents might be inconsistent because different entries could contain `tsvectors` that were created with different text search configurations, and there would be no way to guess which was which. It would be impossible to dump and restore such an index correctly.

Because the two-argument version of `to_tsvector` was used in the index above, only a query reference that uses the 2-argument version of `to_tsvector` with the same configuration name will use that index. That is, `WHERE to_tsvector('english', body) @@ 'a & b'` can use the index, but `WHERE to_tsvector(body) @@ 'a & b'` cannot. This ensures that an index will be used only with the same configuration used to create the index entries.

It is possible to set up more complex expression indexes wherein the configuration name is specified by another column, e.g.:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector(config_name,
body));
```

where `config_name` is a column in the `pgweb` table. This allows mixed configurations in the same index while recording which configuration was used for each index entry. This would be useful, for example, if the document collection contained documents in different languages. Again, queries that are meant to use the index must be phrased to match, e.g., `WHERE to_tsvector(config_name, body) @@ 'a & b'`.

Indexes can even concatenate columns:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector('english',
title || ' ' || body));
```

Another approach is to create a separate `tsvector` column to hold the output of `to_tsvector`. To keep this column automatically up to date with its source data, use a stored generated column. This example is a concatenation of `title` and `body`, using `coalesce` to ensure that one field will still be indexed when the other is `NULL`:

```
ALTER TABLE pgweb
  ADD COLUMN textsearchable_index_col tsvector
  GENERATED ALWAYS AS (to_tsvector('english',
  coalesce(title, '') || ' ' || coalesce(body, ''))) STORED;
```

Then we create a GIN index to speed up the search:

```
CREATE INDEX textsearch_idx ON pgweb USING GIN
(textsearchable_index_col);
```

Now we are ready to perform a fast full text search:

```
SELECT title
FROM pgweb
WHERE textsearchable_index_col @@ to_tsquery('create & table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

One advantage of the separate-column approach over an expression index is that it is not necessary to explicitly specify the text search configuration in queries in order to make use of the index. As shown in the example above, the query can depend on `default_text_search_config`. Another advantage is that searches will be faster, since it will not be necessary to redo the `to_tsvector` calls to verify index matches. (This is more important when using a GiST index than a GIN index; see Section 12.9.) The expression-index approach is simpler to set up, however, and it requires less disk space since the `tsvector` representation is not stored explicitly.

12.3. Controlling Text Search

To implement full text searching there must be a function to create a `tsvector` from a document and a `tsquery` from a user query. Also, we need to return results in a useful order, so we need a function that compares documents with respect to their relevance to the query. It's also important to be able to display the results nicely. PostgreSQL provides support for all of these functions.

12.3.1. Parsing Documents

PostgreSQL provides the function `to_tsvector` for converting a document to the `tsvector` data type.

```
to_tsvector([ config regconfig, ] document text) returns tsvector
```

`to_tsvector` parses a textual document into tokens, reduces the tokens to lexemes, and returns a `tsvector` which lists the lexemes together with their positions in the document. The document is processed according to the specified or default text search configuration. Here is a simple example:

```
SELECT to_tsvector('english', 'a fat  cat sat on a mat - it ate a
fat rats');
           to_tsvector
-----
'ate':9 'cat':3 'fat':2,11 'mat':7 'rat':12 'sat':4
```

In the example above we see that the resulting `tsvector` does not contain the words `a`, `on`, or `it`, the word `rats` became `rat`, and the punctuation sign `-` was ignored.

The `to_tsvector` function internally calls a parser which breaks the document text into tokens and assigns a type to each token. For each token, a list of dictionaries (Section 12.6) is consulted, where the list can vary depending on the token type. The first dictionary that *recognizes* the token emits one or more normalized *lexemes* to represent the token. For example, `rats` became `rat` because one of the dictionaries recognized that the word `rats` is a plural form of `rat`. Some words are recognized as *stop words* (Section 12.6.1), which causes them to be ignored since they occur too frequently to be useful in searching. In our example these are `a`, `on`, and `it`. If no dictionary in the list recognizes the token then it is also ignored. In this example that happened to the punctuation sign `-` because there are in fact

no dictionaries assigned for its token type (`Space symbols`), meaning space tokens will never be indexed. The choices of parser, dictionaries and which types of tokens to index are determined by the selected text search configuration (Section 12.7). It is possible to have many different configurations in the same database, and predefined configurations are available for various languages. In our example we used the default configuration `english` for the English language.

The function `setweight` can be used to label the entries of a `tsvector` with a given *weight*, where a weight is one of the letters A, B, C, or D. This is typically used to mark entries coming from different parts of a document, such as title versus body. Later, this information can be used for ranking of search results.

Because `to_tsvector(NULL)` will return `NULL`, it is recommended to use `coalesce` whenever a field might be null. Here is the recommended method for creating a `tsvector` from a structured document:

```
UPDATE tt SET ti =
    setweight(to_tsvector(coalesce(title, '')), 'A') ||
    setweight(to_tsvector(coalesce(keyword, '')), 'B') ||
    setweight(to_tsvector(coalesce(abstract, '')), 'C') ||
    setweight(to_tsvector(coalesce(body, '')), 'D');
```

Here we have used `setweight` to label the source of each lexeme in the finished `tsvector`, and then merged the labeled `tsvector` values using the `tsvector` concatenation operator `||`. (Section 12.4.1 gives details about these operations.)

12.3.2. Parsing Queries

PostgreSQL provides the functions `to_tsquery`, `plainto_tsquery`, `phraseto_tsquery` and `websearch_to_tsquery` for converting a query to the `tsquery` data type. `to_tsquery` offers access to more features than either `plainto_tsquery` or `phraseto_tsquery`, but it is less forgiving about its input. `websearch_to_tsquery` is a simplified version of `to_tsquery` with an alternative syntax, similar to the one used by web search engines.

`to_tsquery([config regconfig,] querytext text)` returns `tsquery`

`to_tsquery` creates a `tsquery` value from `querytext`, which must consist of single tokens separated by the `tsquery` operators `&` (AND), `|` (OR), `!` (NOT), and `<->` (FOLLOWED BY), possibly grouped using parentheses. In other words, the input to `to_tsquery` must already follow the general rules for `tsquery` input, as described in Section 8.11.2. The difference is that while basic `tsquery` input takes the tokens at face value, `to_tsquery` normalizes each token into a lexeme using the specified or default configuration, and discards any tokens that are stop words according to the configuration. For example:

```
SELECT to_tsquery('english', 'The & Fat & Rats');
 to_tsquery
-----
'fat' & 'rat'
```

As in basic `tsquery` input, `weight(s)` can be attached to each lexeme to restrict it to match only `tsvector` lexemes of those `weight(s)`. For example:

```
SELECT to_tsquery('english', 'Fat | Rats:AB');
 to_tsquery
-----
'fat' | 'rat':AB
```

Also, * can be attached to a lexeme to specify prefix matching:

```
SELECT to_tsquery('supern:*A & star:A*B');
       to_tsquery
-----
'supern':*A & 'star':*AB
```

Such a lexeme will match any word in a `tsvector` that begins with the given string.

`to_tsquery` can also accept single-quoted phrases. This is primarily useful when the configuration includes a thesaurus dictionary that may trigger on such phrases. In the example below, a thesaurus contains the rule `supernovae stars : sn`:

```
SELECT to_tsquery(''supernovae stars' & !crab');
       to_tsquery
-----
'sn' & !'crab'
```

Without quotes, `to_tsquery` will generate a syntax error for tokens that are not separated by an AND, OR, or FOLLOWED BY operator.

```
plainto_tsquery([ config regconfig, ] querytext text)
returns tsquery
```

`plainto_tsquery` transforms the unformatted text `querytext` to a `tsquery` value. The text is parsed and normalized much as for `to_tsvector`, then the & (AND) `tsquery` operator is inserted between surviving words.

Example:

```
SELECT plainto_tsquery('english', 'The Fat Rats');
       plainto_tsquery
-----
'fat' & 'rat'
```

Note that `plainto_tsquery` will not recognize `tsquery` operators, weight labels, or prefix-match labels in its input:

```
SELECT plainto_tsquery('english', 'The Fat & Rats:C');
       plainto_tsquery
-----
'fat' & 'rat' & 'c'
```

Here, all the input punctuation was discarded as being space symbols.

```
phraseto_tsquery([ config regconfig, ] querytext text)
returns tsquery
```

`phraseto_tsquery` behaves much like `plainto_tsquery`, except that it inserts the `<->` (FOLLOWED BY) operator between surviving words instead of the & (AND) operator. Also, stop words are not simply discarded, but are accounted for by inserting `<N>` operators rather than `<->` operators. This function is useful when searching for exact lexeme sequences, since the FOLLOWED BY operators check lexeme order not just the presence of all the lexemes.

Example:

```
SELECT phraseto_tsquery('english', 'The Fat Rats');
      phraseto_tsquery
-----
'fat' <-> 'rat'
```

Like `plainto_tsquery`, the `phraseto_tsquery` function will not recognize `tsquery` operators, weight labels, or prefix-match labels in its input:

```
SELECT phraseto_tsquery('english', 'The Fat & Rats:C');
      phraseto_tsquery
-----
'fat' <-> 'rat' <-> 'c'
```

```
websearch_to_tsquery([ config regconfig, ] querytext text)
returns tsquery
```

`websearch_to_tsquery` creates a `tsquery` value from `querytext` using an alternative syntax in which simple unformatted text is a valid query. Unlike `plainto_tsquery` and `phraseto_tsquery`, it also recognizes certain operators. Moreover, this function should never raise syntax errors, which makes it possible to use raw user-supplied input for search. The following syntax is supported:

- unquoted text: text not inside quote marks will be converted to terms separated by `&` operators, as if processed by `plainto_tsquery`.
- "quoted text": text inside quote marks will be converted to terms separated by `<->` operators, as if processed by `phraseto_tsquery`.
- OR: logical or will be converted to the `|` operator.
- -: the logical not operator, converted to the `!` operator.

Examples:

```
SELECT websearch_to_tsquery('english', 'The fat rats');
      websearch_to_tsquery
-----
'fat' & 'rat'
(1 row)
```

```
SELECT websearch_to_tsquery('english', '"supernovae stars" -crab');
      websearch_to_tsquery
-----
'supernova' <-> 'star' & !'crab'
(1 row)
```

```
SELECT websearch_to_tsquery('english', '"sad cat" or "fat rat"');
      websearch_to_tsquery
-----
'sad' <-> 'cat' | 'fat' <-> 'rat'
(1 row)
```

```
SELECT websearch_to_tsquery('english', 'signal -"segmentation
      fault"');
      websearch_to_tsquery
-----
'signal' & !( 'segment' <-> 'fault' )
```

```
(1 row)

SELECT websearch_to_tsquery('english', '""')(dummy \ query <-
>);
 websearch_to_tsquery
-----
 'dummi' & 'queri'
(1 row)
```

12.3.3. Ranking Search Results

Ranking attempts to measure how relevant documents are to a particular query, so that when there are many matches the most relevant ones can be shown first. PostgreSQL provides two predefined ranking functions, which take into account lexical, proximity, and structural information; that is, they consider how often the query terms appear in the document, how close together the terms are in the document, and how important is the part of the document where they occur. However, the concept of relevancy is vague and very application-specific. Different applications might require additional information for ranking, e.g., document modification time. The built-in ranking functions are only examples. You can write your own ranking functions and/or combine their results with additional factors to fit your specific needs.

The two ranking functions currently available are:

```
ts_rank([ weights float4[], ] vector tsvector, query tsquery [,
normalization integer ]) returns float4
```

Ranks vectors based on the frequency of their matching lexemes.

```
ts_rank_cd([ weights float4[], ] vector tsvector, query tsquery [,
normalization integer ]) returns float4
```

This function computes the *cover density* ranking for the given document vector and query, as described in Clarke, Cormack, and Tudhope's "Relevance Ranking for One to Three Term Queries" in the journal "Information Processing and Management", 1999. Cover density is similar to `ts_rank` ranking except that the proximity of matching lexemes to each other is taken into consideration.

This function requires lexeme positional information to perform its calculation. Therefore, it ignores any "stripped" lexemes in the `tsvector`. If there are no unstripped lexemes in the input, the result will be zero. (See Section 12.4.1 for more information about the `strip` function and positional information in `tsvectors`.)

For both these functions, the optional `weights` argument offers the ability to weigh word instances more or less heavily depending on how they are labeled. The weight arrays specify how heavily to weigh each category of word, in the order:

```
{D-weight, C-weight, B-weight, A-weight}
```

If no `weights` are provided, then these defaults are used:

```
{0.1, 0.2, 0.4, 1.0}
```

Typically weights are used to mark words from special areas of the document, like the title or an initial abstract, so they can be treated with more or less importance than words in the document body.

Since a longer document has a greater chance of containing a query term it is reasonable to take into account document size, e.g., a hundred-word document with five instances of a search word is probably more relevant than a thousand-word document with five instances. Both ranking functions take an integer `normalization` option that specifies whether and how a document's length should impact

its rank. The integer option controls several behaviors, so it is a bit mask: you can specify one or more behaviors using `|` (for example, `2 | 4`).

- 0 (the default) ignores the document length
- 1 divides the rank by 1 + the logarithm of the document length
- 2 divides the rank by the document length
- 4 divides the rank by the mean harmonic distance between extents (this is implemented only by `ts_rank_cd`)
- 8 divides the rank by the number of unique words in document
- 16 divides the rank by 1 + the logarithm of the number of unique words in document
- 32 divides the rank by itself + 1

If more than one flag bit is specified, the transformations are applied in the order listed.

It is important to note that the ranking functions do not use any global information, so it is impossible to produce a fair normalization to 1% or 100% as sometimes desired. Normalization option 32 (`rank / (rank+1)`) can be applied to scale all ranks into the range zero to one, but of course this is just a cosmetic change; it will not affect the ordering of the search results.

Here is an example that selects only the ten highest-ranked matches:

```
SELECT title, ts_rank_cd(textsearch, query) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
```

title	rank
Neutrinos in the Sun	3.1
The Sudbury Neutrino Detector	2.4
A MACHO View of Galactic Dark Matter	2.01317
Hot Gas and Dark Matter	1.91171
The Virgo Cluster: Hot Plasma and Dark Matter	1.90953
Rafting for Solar Neutrinos	1.9
NGC 4650A: Strange Galaxy and Dark Matter	1.85774
Hot Gas and Dark Matter	1.6123
Ice Fishing for Cosmic Neutrinos	1.6
Weak Lensing Distorts the Universe	0.818218

This is the same example using normalized ranking:

```
SELECT title, ts_rank_cd(textsearch, query, 32 /* rank/(rank+1)
*/ ) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
```

title	rank
Neutrinos in the Sun	0.756097569485493
The Sudbury Neutrino Detector	0.705882361190954
A MACHO View of Galactic Dark Matter	0.668123210574724
Hot Gas and Dark Matter	0.65655958650282
The Virgo Cluster: Hot Plasma and Dark Matter	0.656301290640973
Rafting for Solar Neutrinos	0.655172410958162
NGC 4650A: Strange Galaxy and Dark Matter	0.650072921219637
Hot Gas and Dark Matter	0.617195790024749

Ice Fishing for Cosmic Neutrinos	0.615384618911517
Weak Lensing Distorts the Universe	0.450010798361481

Ranking can be expensive since it requires consulting the `tsvector` of each matching document, which can be I/O bound and therefore slow. Unfortunately, it is almost impossible to avoid since practical queries often result in large numbers of matches.

12.3.4. Highlighting Results

To present search results it is ideal to show a part of each document and how it is related to the query. Usually, search engines show fragments of the document with marked search terms. PostgreSQL provides a function `ts_headline` that implements this functionality.

```
ts_headline([ config regconfig, ] document text, query tsquery
[, options text ]) returns text
```

`ts_headline` accepts a document along with a query, and returns an excerpt from the document in which terms from the query are highlighted. The configuration to be used to parse the document can be specified by `config`; if `config` is omitted, the `default_text_search_config` configuration is used.

If an `options` string is specified it must consist of a comma-separated list of one or more `option=value` pairs. The available options are:

- `StartSel`, `StopSel`: the strings with which to delimit query words appearing in the document, to distinguish them from other excerpted words. You must double-quote these strings if they contain spaces or commas.
- `MaxWords`, `MinWords`: these numbers determine the longest and shortest headlines to output.
- `ShortWord`: words of this length or less will be dropped at the start and end of a headline. The default value of three eliminates common English articles.
- `HighlightAll`: Boolean flag; if `true` the whole document will be used as the headline, ignoring the preceding three parameters.
- `MaxFragments`: maximum number of text excerpts or fragments to display. The default value of zero selects a non-fragment-oriented headline generation method. A value greater than zero selects fragment-based headline generation. This method finds text fragments with as many query words as possible and stretches those fragments around the query words. As a result query words are close to the middle of each fragment and have words on each side. Each fragment will be of at most `MaxWords` and words of length `ShortWord` or less are dropped at the start and end of each fragment. If not all query words are found in the document, then a single fragment of the first `MinWords` in the document will be displayed.
- `FragmentDelimiter`: When more than one fragment is displayed, the fragments will be separated by this string.

These option names are recognized case-insensitively. Any unspecified options receive these defaults:

```
StartSel=<b>, StopSel=</b>,
MaxWords=35, MinWords=15, ShortWord=3, HighlightAll=FALSE,
MaxFragments=0, FragmentDelimiter=" ... "
```

For example:

```
SELECT ts_headline('english',
  'The most common type of search
  is to find all documents containing given query terms
  and return them in order of their similarity to the
  query.',
```

```
to_tsquery('query & similarity');
      ts_headline
```

containing given **<query>** terms
and return them in order of their **<similarity>** to the
<query>.

```
SELECT ts_headline('english',
  'The most common type of search
is to find all documents containing given query terms
and return them in order of their similarity to the
query.',
  to_tsquery('query & similarity'),
  'StartSel = <, StopSel = >');
      ts_headline
```

containing given *<query>* terms
and return them in order of their *<similarity>* to the
<query>.

`ts_headline` uses the original document, not a `tsvector` summary, so it can be slow and should be used with care.

12.4. Additional Features

This section describes additional functions and operators that are useful in connection with text search.

12.4.1. Manipulating Documents

Section 12.3.1 showed how raw textual documents can be converted into `tsvector` values. PostgreSQL also provides functions and operators that can be used to manipulate documents that are already in `tsvector` form.

```
tsvector || tsvector
```

The `tsvector` concatenation operator returns a vector which combines the lexemes and positional information of the two vectors given as arguments. Positions and weight labels are retained during the concatenation. Positions appearing in the right-hand vector are offset by the largest position mentioned in the left-hand vector, so that the result is nearly equivalent to the result of performing `to_tsvector` on the concatenation of the two original document strings. (The equivalence is not exact, because any stop-words removed from the end of the left-hand argument will not affect the result, whereas they would have affected the positions of the lexemes in the right-hand argument if textual concatenation were used.)

One advantage of using concatenation in the vector form, rather than concatenating text before applying `to_tsvector`, is that you can use different configurations to parse different sections of the document. Also, because the `setweight` function marks all lexemes of the given vector the same way, it is necessary to parse the text and do `setweight` before concatenating if you want to label different parts of the document with different weights.

```
setweight(vector tsvector, weight "char") returns tsvector
```

`setweight` returns a copy of the input vector in which every position has been labeled with the given *weight*, either A, B, C, or D. (D is the default for new vectors and as such is not displayed on output.) These labels are retained when vectors are concatenated, allowing words from different parts of a document to be weighted differently by ranking functions.

Note that weight labels apply to *positions*, not *lexemes*. If the input vector has been stripped of positions then `setweight` does nothing.

`length(vector tsvector)` returns integer

Returns the number of lexemes stored in the vector.

`strip(vector tsvector)` returns tsvector

Returns a vector that lists the same lexemes as the given vector, but lacks any position or weight information. The result is usually much smaller than an unstripped vector, but it is also less useful. Relevance ranking does not work as well on stripped vectors as unstripped ones. Also, the `<->` (FOLLOWED BY) `tsquery` operator will never match stripped input, since it cannot determine the distance between lexeme occurrences.

A full list of `tsvector`-related functions is available in Table 9.42.

12.4.2. Manipulating Queries

Section 12.3.2 showed how raw textual queries can be converted into `tsquery` values. PostgreSQL also provides functions and operators that can be used to manipulate queries that are already in `tsquery` form.

`tsquery && tsquery`

Returns the AND-combination of the two given queries.

`tsquery || tsquery`

Returns the OR-combination of the two given queries.

`!! tsquery`

Returns the negation (NOT) of the given query.

`tsquery <-> tsquery`

Returns a query that searches for a match to the first given query immediately followed by a match to the second given query, using the `<->` (FOLLOWED BY) `tsquery` operator. For example:

```
SELECT to_tsquery('fat') <-> to_tsquery('cat | rat');
       ?column?
-----
'fat' <-> 'cat' | 'fat' <-> 'rat'
```

`tsquery_phrase(query1 tsquery, query2 tsquery [, distance integer])` returns `tsquery`

Returns a query that searches for a match to the first given query followed by a match to the second given query at a distance of at *distance* lexemes, using the `<N>` `tsquery` operator. For example:

```
SELECT tsquery_phrase(to_tsquery('fat'), to_tsquery('cat'), 10);
       tsquery_phrase
-----
'fat' <10> 'cat'
```

`numnode(query tsquery)` returns integer

Returns the number of nodes (lexemes plus operators) in a `tsquery`. This function is useful to determine if the *query* is meaningful (returns `> 0`), or contains only stop words (returns `0`). Examples:

```
SELECT numnode(plainto_tsquery('the any'));
NOTICE: query contains only stopword(s) or doesn't contain
lexeme(s), ignored
numnode
-----
0
```

```
SELECT numnode('foo & bar'::tsquery);
numnode
-----
3
```

`querytree(query tsquery)` returns text

Returns the portion of a `tsquery` that can be used for searching an index. This function is useful for detecting unindexable queries, for example those containing only stop words or only negated terms. For example:

```
SELECT querytree(to_tsquery('!defined'));
querytree
-----
```

12.4.2.1. Query Rewriting

The `ts_rewrite` family of functions search a given `tsquery` for occurrences of a target subquery, and replace each occurrence with a substitute subquery. In essence this operation is a `tsquery`-specific version of substring replacement. A target and substitute combination can be thought of as a *query rewrite rule*. A collection of such rewrite rules can be a powerful search aid. For example, you can expand the search using synonyms (e.g., `new york`, `big apple`, `nyc`, `gotham`) or narrow the search to direct the user to some hot topic. There is some overlap in functionality between this feature and thesaurus dictionaries (Section 12.6.4). However, you can modify a set of rewrite rules on-the-fly without reindexing, whereas updating a thesaurus requires reindexing to be effective.

`ts_rewrite(query tsquery, target tsquery, substitute tsquery)` returns `tsquery`

This form of `ts_rewrite` simply applies a single rewrite rule: *target* is replaced by *substitute* wherever it appears in *query*. For example:

```
SELECT ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'c'::tsquery);
ts_rewrite
-----
'b' & 'c'
```

`ts_rewrite(query tsquery, select text)` returns `tsquery`

This form of `ts_rewrite` accepts a starting *query* and a SQL *select* command, which is given as a text string. The *select* must yield two columns of `tsquery` type. For each row of the *select* result, occurrences of the first column value (the target) are replaced by the second column value (the substitute) within the current *query* value. For example:

```
CREATE TABLE aliases (t tsquery PRIMARY KEY, s tsquery);
INSERT INTO aliases VALUES('a', 'c');
```

```
SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases');
      ts_rewrite
-----
      'b' & 'c'
```

Note that when multiple rewrite rules are applied in this way, the order of application can be important; so in practice you will want the source query to ORDER BY some ordering key.

Let's consider a real-life astronomical example. We'll expand query `supernovae` using table-driven rewriting rules:

```
CREATE TABLE aliases (t tsquery primary key, s tsquery);
INSERT INTO aliases VALUES(to_tsquery('supernovae'),
  to_tsquery('supernovae|sn'));

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT * FROM
aliases');
      ts_rewrite
-----
      'crab' & ( 'supernova' | 'sn' )
```

We can change the rewriting rules just by updating the table:

```
UPDATE aliases
SET s = to_tsquery('supernovae|sn & !nebulae')
WHERE t = to_tsquery('supernovae');

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT * FROM
aliases');
      ts_rewrite
-----
      'crab' & ( 'supernova' | 'sn' & !'nebula' )
```

Rewriting can be slow when there are many rewriting rules, since it checks every rule for a possible match. To filter out obvious non-candidate rules we can use the containment operators for the `tsquery` type. In the example below, we select only those rules which might match the original query:

```
SELECT ts_rewrite('a & b'::tsquery,
                  'SELECT t,s FROM aliases WHERE 'a & b'::tsquery
                  @> t');
      ts_rewrite
-----
      'b' & 'c'
```

12.4.3. Triggers for Automatic Updates

Note

The method described in this section has been obsoleted by the use of stored generated columns, as described in Section 12.2.2.

When using a separate column to store the `tsvector` representation of your documents, it is necessary to create a trigger to update the `tsvector` column when the document content columns change. Two built-in trigger functions are available for this, or you can write your own.

```
tsvector_update_trigger(tsvector_column_name, config_name, text_column_name
[, ... ])
tsvector_update_trigger_column(tsvector_column_name, config_column_name, text_c
[, ... ])
```

These trigger functions automatically compute a `tsvector` column from one or more textual columns, under the control of parameters specified in the `CREATE TRIGGER` command. An example of their use is:

```
CREATE TABLE messages (
    title      text,
    body       text,
    tsv        tsvector
);

CREATE TRIGGER tsvectorupdate BEFORE INSERT OR UPDATE
ON messages FOR EACH ROW EXECUTE FUNCTION
tsvector_update_trigger(tsv, 'pg_catalog.english', title, body);

INSERT INTO messages VALUES('title here', 'the body text is here');

SELECT * FROM messages;
   title      |          body          |          tsv
-----+-----+-----
title here | the body text is here | 'bodi':4 'text':5 'titl':1

SELECT title, body FROM messages WHERE tsv @@ to_tsquery('title &
body');
```

title	body	tsv
title here	the body text is here	'bodi':4 'text':5 'titl':1

```

   title      |          body
-----+-----
title here | the body text is here
```

Having created this trigger, any change in `title` or `body` will automatically be reflected into `tsv`, without the application having to worry about it.

The first trigger argument must be the name of the `tsvector` column to be updated. The second argument specifies the text search configuration to be used to perform the conversion. For `tsvector_update_trigger`, the configuration name is simply given as the second trigger argument. It must be schema-qualified as shown above, so that the trigger behavior will not change with changes in `search_path`. For `tsvector_update_trigger_column`, the second trigger argument is the name of another table column, which must be of type `regconfig`. This allows a per-row selection of configuration to be made. The remaining argument(s) are the names of textual columns (of type `text`, `varchar`, or `char`). These will be included in the document in the order given. `NULL` values will be skipped (but the other columns will still be indexed).

A limitation of these built-in triggers is that they treat all the input columns alike. To process columns differently — for example, to weight `title` differently from `body` — it is necessary to write a custom trigger. Here is an example using PL/pgSQL as the trigger language:

```
CREATE FUNCTION messages_trigger() RETURNS trigger AS $$
begin
    new.tsv :=
        setweight(to_tsvector('pg_catalog.english',
coalesce(new.title,'')), 'A') ||
        setweight(to_tsvector('pg_catalog.english',
coalesce(new.body,'')), 'D');
```

```
    return new;
end
$$ LANGUAGE plpgsql;

CREATE TRIGGER tsvectorupdate BEFORE INSERT OR UPDATE
    ON messages FOR EACH ROW EXECUTE FUNCTION messages_trigger();
```

Keep in mind that it is important to specify the configuration name explicitly when creating `tsvector` values inside triggers, so that the column's contents will not be affected by changes to `default_text_search_config`. Failure to do this is likely to lead to problems such as search results changing after a dump and reload.

12.4.4. Gathering Document Statistics

The function `ts_stat` is useful for checking your configuration and for finding stop-word candidates.

```
ts_stat(sqlquery text, [ weights text, ]
        OUT word text, OUT ndoc integer,
        OUT nentry integer) returns setof record
```

sqlquery is a text value containing an SQL query which must return a single `tsvector` column. `ts_stat` executes the query and returns statistics about each distinct lexeme (word) contained in the `tsvector` data. The columns returned are

- *word* text — the value of a lexeme
- *ndoc* integer — number of documents (`tsvectors`) the word occurred in
- *nentry* integer — total number of occurrences of the word

If *weights* is supplied, only occurrences having one of those weights are counted.

For example, to find the ten most frequent words in a document collection:

```
SELECT * FROM ts_stat('SELECT vector FROM apod')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

The same, but counting only word occurrences with weight A or B:

```
SELECT * FROM ts_stat('SELECT vector FROM apod', 'ab')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

12.5. Parsers

Text search parsers are responsible for splitting raw document text into *tokens* and identifying each token's type, where the set of possible types is defined by the parser itself. Note that a parser does not modify the text at all — it simply identifies plausible word boundaries. Because of this limited scope, there is less need for application-specific custom parsers than there is for custom dictionaries. At present PostgreSQL provides just one built-in parser, which has been found to be useful for a wide range of applications.

The built-in parser is named `pg_catalog.default`. It recognizes 23 token types, shown in Table 12.1.

Table 12.1. Default Parser's Token Types

Alias	Description	Example
asciiword	Word, all ASCII letters	elephant
word	Word, all letters	mañana
numword	Word, letters and digits	beta1
asciihword	Hyphenated word, all ASCII	up-to-date
hword	Hyphenated word, all letters	lógico-matemática
numhword	Hyphenated word, letters and digits	postgresql-beta1
hword_asciipart	Hyphenated word part, all ASCII	postgresql in the context postgresql-beta1
hword_part	Hyphenated word part, all letters	lógico or matemática ca in the context lógico- co-matemática
hword_numpart	Hyphenated word part, letters and digits	beta1 in the context post- gresql-beta1
email	Email address	foo@example.com
protocol	Protocol head	http://
url	URL	example.com/stuff/ index.html
host	Host	example.com
url_path	URL path	/stuff/index.html, in the context of a URL
file	File or path name	/usr/local/foo.txt, if not within a URL
sfloat	Scientific notation	-1.234e56
float	Decimal notation	-1.234
int	Signed integer	-1234
uint	Unsigned integer	1234
version	Version number	8.3.0
tag	XML tag	
entity	XML entity	&
blank	Space symbols	(any whitespace or punctuation not otherwise recognized)

Note

The parser's notion of a “letter” is determined by the database's locale setting, specifically `lc_ctype`. Words containing only the basic ASCII letters are reported as a separate token type, since it is sometimes useful to distinguish them. In most European languages, token types `word` and `asciiword` should be treated alike.

`email` does not support all valid email characters as defined by RFC 5322. Specifically, the only non-alphanumeric characters supported for email user names are period, dash, and underscore.

It is possible for the parser to produce overlapping tokens from the same piece of text. As an example, a hyphenated word will be reported both as the entire word and as each component:

```
SELECT alias, description, token FROM ts_debug('foo-bar-beta1');
   alias      | description      | token
-----+-----+-----
 numhword     | Hyphenated word, letters and digits | foo-
bar-beta1
 hword_asciipart | Hyphenated word part, all ASCII | foo
 blank         | Space symbols    | -
 hword_asciipart | Hyphenated word part, all ASCII | bar
 blank         | Space symbols    | -
 hword_numpart  | Hyphenated word part, letters and digits | beta1
```

This behavior is desirable since it allows searches to work for both the whole compound word and for components. Here is another instructive example:

```
SELECT alias, description, token FROM ts_debug('http://example.com/
stuff/index.html');
   alias      | description      | token
-----+-----+-----
 protocol     | Protocol head    | http://
 url          | URL              | example.com/stuff/index.html
 host         | Host             | example.com
 url_path     | URL path         | /stuff/index.html
```

12.6. Dictionaries

Dictionaries are used to eliminate words that should not be considered in a search (*stop words*), and to *normalize* words so that different derived forms of the same word will match. A successfully normalized word is called a *lexeme*. Aside from improving search quality, normalization and removal of stop words reduce the size of the `tsvector` representation of a document, thereby improving performance. Normalization does not always have linguistic meaning and usually depends on application semantics.

Some examples of normalization:

- Linguistic - Ispell dictionaries try to reduce input words to a normalized form; stemmer dictionaries remove word endings
- URL locations can be canonicalized to make equivalent URLs match:
 - `http://www.pgsql.ru/db/mw/index.html`
 - `http://www.pgsql.ru/db/mw/`
 - `http://www.pgsql.ru/db/./db/mw/index.html`
- Color names can be replaced by their hexadecimal values, e.g., `red`, `green`, `blue`, `magenta` -> `FF0000`, `00FF00`, `0000FF`, `FF00FF`
- If indexing numbers, we can remove some fractional digits to reduce the range of possible numbers, so for example `3.14159265359`, `3.1415926`, `3.14` will be the same after normalization if only two digits are kept after the decimal point.

A dictionary is a program that accepts a token as input and returns:

- an array of lexemes if the input token is known to the dictionary (notice that one token can produce more than one lexeme)
- a single lexeme with the `TSL_FILTER` flag set, to replace the original token with a new token to be passed to subsequent dictionaries (a dictionary that does this is called a *filtering dictionary*)

- an empty array if the dictionary knows the token, but it is a stop word
- NULL if the dictionary does not recognize the input token

PostgreSQL provides predefined dictionaries for many languages. There are also several predefined templates that can be used to create new dictionaries with custom parameters. Each predefined dictionary template is described below. If no existing template is suitable, it is possible to create new ones; see the `contrib/` area of the PostgreSQL distribution for examples.

A text search configuration binds a parser together with a set of dictionaries to process the parser's output tokens. For each token type that the parser can return, a separate list of dictionaries is specified by the configuration. When a token of that type is found by the parser, each dictionary in the list is consulted in turn, until some dictionary recognizes it as a known word. If it is identified as a stop word, or if no dictionary recognizes the token, it will be discarded and not indexed or searched for. Normally, the first dictionary that returns a non-NULL output determines the result, and any remaining dictionaries are not consulted; but a filtering dictionary can replace the given word with a modified word, which is then passed to subsequent dictionaries.

The general rule for configuring a list of dictionaries is to place first the most narrow, most specific dictionary, then the more general dictionaries, finishing with a very general dictionary, like a Snowball stemmer or `simple`, which recognizes everything. For example, for an astronomy-specific search (`astro_en` configuration) one could bind token type `asciiword` (ASCII word) to a synonym dictionary of astronomical terms, a general English dictionary and a Snowball English stemmer:

```
ALTER TEXT SEARCH CONFIGURATION astro_en
    ADD MAPPING FOR asciiword WITH astrosyn, english_ispell,
    english_stem;
```

A filtering dictionary can be placed anywhere in the list, except at the end where it'd be useless. Filtering dictionaries are useful to partially normalize words to simplify the task of later dictionaries. For example, a filtering dictionary could be used to remove accents from accented letters, as is done by the `unaccent` module.

12.6.1. Stop Words

Stop words are words that are very common, appear in almost every document, and have no discrimination value. Therefore, they can be ignored in the context of full text searching. For example, every English text contains words like `a` and `the`, so it is useless to store them in an index. However, stop words do affect the positions in `tsvector`, which in turn affect ranking:

```
SELECT to_tsvector('english','in the list of stop words');
       to_tsvector
-----
 'list':3 'stop':5 'word':6
```

The missing positions 1,2,4 are because of stop words. Ranks calculated for documents with and without stop words are quite different:

```
SELECT ts_rank_cd (to_tsvector('english','in the list of stop
    words'), to_tsquery('list & stop'));
    ts_rank_cd
-----
          0.05

SELECT ts_rank_cd (to_tsvector('english','list stop words'),
    to_tsquery('list & stop'));
    ts_rank_cd
```

0.1

It is up to the specific dictionary how it treats stop words. For example, `ispell` dictionaries first normalize words and then look at the list of stop words, while `Snowball` stemmers first check the list of stop words. The reason for the different behavior is an attempt to decrease noise.

12.6.2. Simple Dictionary

The `simple` dictionary template operates by converting the input token to lower case and checking it against a file of stop words. If it is found in the file then an empty array is returned, causing the token to be discarded. If not, the lower-cased form of the word is returned as the normalized lexeme. Alternatively, the dictionary can be configured to report non-stop-words as unrecognized, allowing them to be passed on to the next dictionary in the list.

Here is an example of a dictionary definition using the `simple` template:

```
CREATE TEXT SEARCH DICTIONARY public.simple_dict (
    TEMPLATE = pg_catalog.simple,
    STOPWORDS = english
);
```

Here, `english` is the base name of a file of stop words. The file's full name will be `$SHAREDIR/tsearch_data/english.stop`, where `$SHAREDIR` means the PostgreSQL installation's shared-data directory, often `/usr/local/share/postgresql` (use `pg_config --sharedir` to determine it if you're not sure). The file format is simply a list of words, one per line. Blank lines and trailing spaces are ignored, and upper case is folded to lower case, but no other processing is done on the file contents.

Now we can test our dictionary:

```
SELECT ts_lexize('public.simple_dict','YeS');
 ts_lexize
-----
 {yes}

SELECT ts_lexize('public.simple_dict','The');
 ts_lexize
-----
 {}
```

We can also choose to return `NULL`, instead of the lower-cased word, if it is not found in the stop words file. This behavior is selected by setting the dictionary's `Accept` parameter to `false`. Continuing the example:

```
ALTER TEXT SEARCH DICTIONARY public.simple_dict ( Accept = false );

SELECT ts_lexize('public.simple_dict','YeS');
 ts_lexize
-----

SELECT ts_lexize('public.simple_dict','The');
 ts_lexize
-----
 {}
```

With the default setting of `Accept = true`, it is only useful to place a simple dictionary at the end of a list of dictionaries, since it will never pass on any token to a following dictionary. Conversely, `Accept = false` is only useful when there is at least one following dictionary.

Caution

Most types of dictionaries rely on configuration files, such as files of stop words. These files *must* be stored in UTF-8 encoding. They will be translated to the actual database encoding, if that is different, when they are read into the server.

Caution

Normally, a database session will read a dictionary configuration file only once, when it is first used within the session. If you modify a configuration file and want to force existing sessions to pick up the new contents, issue an `ALTER TEXT SEARCH DICTIONARY` command on the dictionary. This can be a “dummy” update that doesn't actually change any parameter values.

12.6.3. Synonym Dictionary

This dictionary template is used to create dictionaries that replace a word with a synonym. Phrases are not supported (use the thesaurus template (Section 12.6.4) for that). A synonym dictionary can be used to overcome linguistic problems, for example, to prevent an English stemmer dictionary from reducing the word “Paris” to “pari”. It is enough to have a `Paris pari` line in the synonym dictionary and put it before the `english_stem` dictionary. For example:

```
SELECT * FROM ts_debug('english', 'Paris');
  alias | description | token | dictionaries | dictionary
  | lexemes
-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
asciiword | Word, all ASCII | Paris | {english_stem} |
english_stem | {pari}

CREATE TEXT SEARCH DICTIONARY my_synonym (
  TEMPLATE = synonym,
  SYNONYMS = my_synonyms
);

ALTER TEXT SEARCH CONFIGURATION english
  ALTER MAPPING FOR asciiword
  WITH my_synonym, english_stem;

SELECT * FROM ts_debug('english', 'Paris');
  alias | description | token | dictionaries | dictionary
  | lexemes
-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
asciiword | Word, all ASCII | Paris | {my_synonym,english_stem} |
my_synonym | {pari}
```

The only parameter required by the `synonym` template is `SYNONYMS`, which is the base name of its configuration file — `my_synonyms` in the above example. The file's full name will be `$SHAREDIR/`

`tsearch_data/my_synonyms.syn` (where `$$SHAREDIR` means the PostgreSQL installation's shared-data directory). The file format is just one line per word to be substituted, with the word followed by its synonym, separated by white space. Blank lines and trailing spaces are ignored.

The synonym template also has an optional parameter `CaseSensitive`, which defaults to `false`. When `CaseSensitive` is `false`, words in the synonym file are folded to lower case, as are input tokens. When it is `true`, words and tokens are not folded to lower case, but are compared as-is.

An asterisk (*) can be placed at the end of a synonym in the configuration file. This indicates that the synonym is a prefix. The asterisk is ignored when the entry is used in `to_tsvector()`, but when it is used in `to_tsquery()`, the result will be a query item with the prefix match marker (see Section 12.3.2). For example, suppose we have these entries in `$$SHAREDIR/tsearch_data/synonym_sample.syn`:

```
postgres      pgsq1
postgresql    pgsq1
postgre pgsq1
gogle googl
indices index*
```

Then we will get these results:

```
mydb=# CREATE TEXT SEARCH DICTIONARY syn (template=synonym,
      synonyms='synonym_sample');
mydb=# SELECT ts_lexize('syn','indices');
      ts_lexize
-----
 {index}
(1 row)

mydb=# CREATE TEXT SEARCH CONFIGURATION tst (copy=simple);
mydb=# ALTER TEXT SEARCH CONFIGURATION tst ALTER MAPPING FOR
      asciiword WITH syn;
mydb=# SELECT to_tsvector('tst','indices');
      to_tsvector
-----
 'index':1
(1 row)

mydb=# SELECT to_tsquery('tst','indices');
      to_tsquery
-----
 'index':*
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector;
      tsvector
-----
 'are' 'indexes' 'useful' 'very'
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector @@
      to_tsquery('tst','indices');
      ?column?
-----
 t
(1 row)
```

12.6.4. Thesaurus Dictionary

A thesaurus dictionary (sometimes abbreviated as TZ) is a collection of words that includes information about the relationships of words and phrases, i.e., broader terms (BT), narrower terms (NT), preferred terms, non-preferred terms, related terms, etc.

Basically a thesaurus dictionary replaces all non-preferred terms by one preferred term and, optionally, preserves the original terms for indexing as well. PostgreSQL's current implementation of the thesaurus dictionary is an extension of the synonym dictionary with added *phrase* support. A thesaurus dictionary requires a configuration file of the following format:

```
# this is a comment
sample word(s) : indexed word(s)
more sample word(s) : more indexed word(s)
...
```

where the colon (:) symbol acts as a delimiter between a phrase and its replacement.

A thesaurus dictionary uses a *subdictionary* (which is specified in the dictionary's configuration) to normalize the input text before checking for phrase matches. It is only possible to select one *subdictionary*. An error is reported if the *subdictionary* fails to recognize a word. In that case, you should remove the use of the word or teach the *subdictionary* about it. You can place an asterisk (*) at the beginning of an indexed word to skip applying the *subdictionary* to it, but all sample words *must* be known to the *subdictionary*.

The thesaurus dictionary chooses the longest match if there are multiple phrases matching the input, and ties are broken by using the last definition.

Specific stop words recognized by the *subdictionary* cannot be specified; instead use ? to mark the location where any stop word can appear. For example, assuming that a and the are stop words according to the *subdictionary*:

```
? one ? two : ssw
```

matches a one the two and the one a two; both would be replaced by ssw.

Since a thesaurus dictionary has the capability to recognize phrases it must remember its state and interact with the parser. A thesaurus dictionary uses these assignments to check if it should handle the next word or stop accumulation. The thesaurus dictionary must be configured carefully. For example, if the thesaurus dictionary is assigned to handle only the `asciword` token, then a thesaurus dictionary definition like `one 7` will not work since token type `uint` is not assigned to the thesaurus dictionary.

Caution

Thesauruses are used during indexing so any change in the thesaurus dictionary's parameters *requires* reindexing. For most other dictionary types, small changes such as adding or removing stopwords does not force reindexing.

12.6.4.1. Thesaurus Configuration

To define a new thesaurus dictionary, use the `thesaurus` template. For example:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_simple (
```

```
    TEMPLATE = thesaurus,  
    DictFile = mythesaurus,  
    Dictionary = pg_catalog.english_stem  
);
```

Here:

- `thesaurus_simple` is the new dictionary's name
- `mythesaurus` is the base name of the thesaurus configuration file. (Its full name will be `$SHAREDIR/tsearch_data/mythesaurus.ths`, where `$SHAREDIR` means the installation shared-data directory.)
- `pg_catalog.english_stem` is the subdictionary (here, a Snowball English stemmer) to use for thesaurus normalization. Notice that the subdictionary will have its own configuration (for example, stop words), which is not shown here.

Now it is possible to bind the thesaurus dictionary `thesaurus_simple` to the desired token types in a configuration, for example:

```
ALTER TEXT SEARCH CONFIGURATION russian  
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart  
    WITH thesaurus_simple;
```

12.6.4.2. Thesaurus Example

Consider a simple astronomical thesaurus `thesaurus_astro`, which contains some astronomical word combinations:

```
supernovae stars : sn  
crab nebulae : crab
```

Below we create a dictionary and bind some token types to an astronomical thesaurus and English stemmer:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_astro (  
    TEMPLATE = thesaurus,  
    DictFile = thesaurus_astro,  
    Dictionary = english_stem  
);  
  
ALTER TEXT SEARCH CONFIGURATION russian  
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart  
    WITH thesaurus_astro, english_stem;
```

Now we can see how it works. `ts_lexize` is not very useful for testing a thesaurus, because it treats its input as a single token. Instead we can use `plainto_tsquery` and `to_tsvector` which will break their input strings into multiple tokens:

```
SELECT plainto_tsquery('supernova star');  
plainto_tsquery  
-----  
'sn'  
  
SELECT to_tsvector('supernova star');  
to_tsvector  
-----
```

```
'sn':1
```

In principle, one can use `to_tsquery` if you quote the argument:

```
SELECT to_tsquery('supernova star');
to_tsquery
-----
'sn'
```

Notice that `supernova star` matches `supernovae stars` in `thesaurus_astro` because we specified the `english_stem` stemmer in the thesaurus definition. The stemmer removed the `e` and `s`.

To index the original phrase as well as the substitute, just include it in the right-hand part of the definition:

```
supernovae stars : sn supernovae stars

SELECT plainto_tsquery('supernova star');
plainto_tsquery
-----
'sn' & 'supernova' & 'star'
```

12.6.5. Ispell Dictionary

The Ispell dictionary template supports *morphological dictionaries*, which can normalize many different linguistic forms of a word into the same lexeme. For example, an English Ispell dictionary can match all declensions and conjugations of the search term `bank`, e.g., `banking`, `banked`, `banks`, `banks'`, and `bank's`.

The standard PostgreSQL distribution does not include any Ispell configuration files. Dictionaries for a large number of languages are available from Ispell¹. Also, some more modern dictionary file formats are supported — MySpell² (OO < 2.0.1) and Hunspell³ (OO >= 2.0.2). A large list of dictionaries is available on the OpenOffice Wiki⁴.

To create an Ispell dictionary perform these steps:

- download dictionary configuration files. OpenOffice extension files have the `.oxt` extension. It is necessary to extract `.aff` and `.dic` files, change extensions to `.affix` and `.dict`. For some dictionary files it is also needed to convert characters to the UTF-8 encoding with commands (for example, for a Norwegian language dictionary):

```
iconv -f ISO_8859-1 -t UTF-8 -o nn_no.affix nn_NO.aff
iconv -f ISO_8859-1 -t UTF-8 -o nn_no.dict nn_NO.dic
```

- copy files to the `$SHAREDIR/tsearch_data` directory
- load files into PostgreSQL with the following command:

```
CREATE TEXT SEARCH DICTIONARY english_hunspell (
    TEMPLATE = ispell,
    DictFile = en_us,
    AffFile = en_us,
```

¹ <https://www.cs.hmc.edu/~geoff/ispell.html>

² <https://en.wikipedia.org/wiki/MySpell>

³ <https://sourceforge.net/projects/hunspell/>

⁴ <https://wiki.openoffice.org/wiki/Dictionaries>

```
Stopwords = english);
```

Here, `DictFile`, `AffFile`, and `StopWords` specify the base names of the dictionary, affixes, and stop-words files. The stop-words file has the same format explained above for the `simple` dictionary type. The format of the other files is not specified here but is available from the above-mentioned web sites.

Ispell dictionaries usually recognize a limited set of words, so they should be followed by another broader dictionary; for example, a Snowball dictionary, which recognizes everything.

The `.affix` file of Ispell has the following structure:

```
prefixes
flag *A:
. > RE # As in enter > reenter
suffixes
flag T:
E > ST # As in late > latest
[^AEIOU]Y > -Y, IEST # As in dirty > dirtiest
[AEIOU]Y > EST # As in gray > grayest
[^EY] > EST # As in small > smallest
```

And the `.dict` file has the following structure:

```
lapse/ADGRS
lard/DGRS
large/PRTY
lark/MRS
```

Format of the `.dict` file is:

```
basic_form/affix_class_name
```

In the `.affix` file every affix flag is described in the following format:

```
condition > [-stripping_letters,] adding_affix
```

Here, `condition` has a format similar to the format of regular expressions. It can use groupings `[...]` and `[^...]`. For example, `[AEIOU]Y` means that the last letter of the word is "y" and the penultimate letter is "a", "e", "i", "o" or "u". `[^EY]` means that the last letter is neither "e" nor "y".

Ispell dictionaries support splitting compound words; a useful feature. Notice that the affix file should specify a special flag using the `compoundwords controlled` statement that marks dictionary words that can participate in compound formation:

```
compoundwords controlled z
```

Here are some examples for the Norwegian language:

```
SELECT ts_lexize('norwegian_ispell',
  'overbuljongterningpakkmasterassistent');
  {over,buljong,terning,pakk,mester,assistent}
SELECT ts_lexize('norwegian_ispell', 'sjokoladefabrikk');
  {sjokoladefabrikk,sjokolade,fabrikk}
```

MySpell format is a subset of Hunspell. The `.affix` file of Hunspell has the following structure:

```
PFX A Y 1
PFX A 0 re .
SFX T N 4
SFX T 0 st e
SFX T y iest [^aeiouy]
SFX T 0 est [aeiouy]
SFX T 0 est [^ey]
```

The first line of an affix class is the header. Fields of an affix rules are listed after the header:

- parameter name (PFX or SFX)
- flag (name of the affix class)
- stripping characters from beginning (at prefix) or end (at suffix) of the word
- adding affix
- condition that has a format similar to the format of regular expressions.

The `.dict` file looks like the `.dict` file of Ispell:

```
larder/M
lardy/RT
large/RSPMYT
largehearted
```

Note

MySpell does not support compound words. Hunspell has sophisticated support for compound words. At present, PostgreSQL implements only the basic compound word operations of Hunspell.

12.6.6. Snowball Dictionary

The Snowball dictionary template is based on a project by Martin Porter, inventor of the popular Porter's stemming algorithm for the English language. Snowball now provides stemming algorithms for many languages (see the Snowball site⁵ for more information). Each algorithm understands how to reduce common variant forms of words to a base, or stem, spelling within its language. A Snowball dictionary requires a `language` parameter to identify which stemmer to use, and optionally can specify a `stopword` file name that gives a list of words to eliminate. (PostgreSQL's standard stopwords lists are also provided by the Snowball project.) For example, there is a built-in definition equivalent to

```
CREATE TEXT SEARCH DICTIONARY english_stem (
    TEMPLATE = snowball,
    Language = english,
    StopWords = english
);
```

The stopwords file format is the same as already explained.

A Snowball dictionary recognizes everything, whether or not it is able to simplify the word, so it should be placed at the end of the dictionary list. It is useless to have it before any other dictionary because a token will never pass through it to the next dictionary.

⁵ <http://snowballstem.org/>

12.7. Configuration Example

A text search configuration specifies all options necessary to transform a document into a `tsvector`: the parser to use to break text into tokens, and the dictionaries to use to transform each token into a lexeme. Every call of `to_tsvector` or `to_tsquery` needs a text search configuration to perform its processing. The configuration parameter `default_text_search_config` specifies the name of the default configuration, which is the one used by text search functions if an explicit configuration parameter is omitted. It can be set in `postgresql.conf`, or set for an individual session using the `SET` command.

Several predefined text search configurations are available, and you can create custom configurations easily. To facilitate management of text search objects, a set of SQL commands is available, and there are several `psql` commands that display information about text search objects (Section 12.10).

As an example we will create a configuration `pg`, starting by duplicating the built-in `english` configuration:

```
CREATE TEXT SEARCH CONFIGURATION public.pg ( COPY =
  pg_catalog.english );
```

We will use a PostgreSQL-specific synonym list and store it in `$SHAREDIR/tsearch_data/pg_dict.syn`. The file contents look like:

```
postgres    pg
pgsql       pg
postgresql  pg
```

We define the synonym dictionary like this:

```
CREATE TEXT SEARCH DICTIONARY pg_dict (
  TEMPLATE = synonym,
  SYNONYMS = pg_dict
);
```

Next we register the Ispell dictionary `english_ispell`, which has its own configuration files:

```
CREATE TEXT SEARCH DICTIONARY english_ispell (
  TEMPLATE = ispell,
  DictFile = english,
  AffFile = english,
  StopWords = english
);
```

Now we can set up the mappings for words in configuration `pg`:

```
ALTER TEXT SEARCH CONFIGURATION pg
  ALTER MAPPING FOR asciiword, asciihword, hword_asciipart,
  word, hword, hword_part
  WITH pg_dict, english_ispell, english_stem;
```

We choose not to index or search some token types that the built-in configuration does handle:

```
ALTER TEXT SEARCH CONFIGURATION pg
```

```
DROP MAPPING FOR email, url, url_path, sfloat, float;
```

Now we can test our configuration:

```
SELECT * FROM ts_debug('public.pg', '
PostgreSQL, the highly scalable, SQL compliant, open source object-
relational
database management system, is now undergoing beta testing of the
next
version of our software.
');
```

The next step is to set the session to use the new configuration, which was created in the public schema:

```
=> \dF
      List of text search configurations
 Schema | Name | Description
-----+-----+-----
 public | pg   |
SET default_text_search_config = 'public.pg';
SET

SHOW default_text_search_config;
 default_text_search_config
-----
 public.pg
```

12.8. Testing and Debugging Text Search

The behavior of a custom text search configuration can easily become confusing. The functions described in this section are useful for testing text search objects. You can test a complete configuration, or test parsers and dictionaries separately.

12.8.1. Configuration Testing

The function `ts_debug` allows easy testing of a text search configuration.

```
ts_debug([ config regconfig, ] document text,
         OUT alias text,
         OUT description text,
         OUT token text,
         OUT dictionaries regdictionary[],
         OUT dictionary regdictionary,
         OUT lexemes text[])
returns setof record
```

`ts_debug` displays information about every token of *document* as produced by the parser and processed by the configured dictionaries. It uses the configuration specified by *config*, or `default_text_search_config` if that argument is omitted.

`ts_debug` returns one row for each token identified in the text by the parser. The columns returned are

- *alias* text — short name of the token type
- *description* text — description of the token type
- *token* text — text of the token
- *dictionaries* regdictionary[] — the dictionaries selected by the configuration for this token type
- *dictionary* regdictionary — the dictionary that recognized the token, or NULL if none did
- *lexemes* text[] — the lexeme(s) produced by the dictionary that recognized the token, or NULL if none did; an empty array ({}) means it was recognized as a stop word

Here is a simple example:

```
SELECT * FROM ts_debug('english','a fat  cat sat on a mat - it ate
a fat rats');
  alias      |      description      | token | dictionaries | dictionary
  | lexemes
-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
asciiword | Word, all ASCII | a      | {english_stem} |
english_stem | {}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | fat    | {english_stem} |
english_stem | {fat}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | cat    | {english_stem} |
english_stem | {cat}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | sat    | {english_stem} |
english_stem | {sat}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | on     | {english_stem} |
english_stem | {}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | a      | {english_stem} |
english_stem | {}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | mat    | {english_stem} |
english_stem | {mat}
blank      | Space symbols   |        | {}              |
|
blank      | Space symbols   | -      | {}              |
|
asciiword | Word, all ASCII | it     | {english_stem} |
english_stem | {}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | ate    | {english_stem} |
english_stem | {ate}
blank      | Space symbols   |        | {}              |
|
asciiword | Word, all ASCII | a      | {english_stem} |
english_stem | {}
```

```

blank      | Space symbols |      | {} |
|
asciiword | Word, all ASCII | fat  | {english_stem} |
english_stem | {fat}
blank      | Space symbols |      | {} |
|
asciiword | Word, all ASCII | rats | {english_stem} |
english_stem | {rat}

```

For a more extensive demonstration, we first create a `public.english` configuration and Ispell dictionary for the English language:

```

CREATE TEXT SEARCH CONFIGURATION public.english ( COPY =
pg_catalog.english );

CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);

ALTER TEXT SEARCH CONFIGURATION public.english
    ALTER MAPPING FOR asciiword WITH english_ispell, english_stem;

SELECT * FROM ts_debug('public.english','The Brightest
supernovaes');

```

alias	description	token	dictionaries
	dictionary	lexemes	
asciiword	Word, all ASCII	The	{english_ispell,english_stem} english_ispell {}
blank	Space symbols		{}
asciiword	Word, all ASCII	Brightest	{english_ispell,english_stem} english_ispell {bright}
blank	Space symbols		{}
asciiword	Word, all ASCII	supernovaes	{english_ispell,english_stem} english_stem {supernova}

In this example, the word `Brightest` was recognized by the parser as an ASCII word (alias `asciiword`). For this token type the dictionary list is `english_ispell` and `english_stem`. The word was recognized by `english_ispell`, which reduced it to the noun `bright`. The word `supernovaes` is unknown to the `english_ispell` dictionary so it was passed to the next dictionary, and, fortunately, was recognized (in fact, `english_stem` is a Snowball dictionary which recognizes everything; that is why it was placed at the end of the dictionary list).

The word `The` was recognized by the `english_ispell` dictionary as a stop word (Section 12.6.1) and will not be indexed. The spaces are discarded too, since the configuration provides no dictionaries at all for them.

You can reduce the width of the output by explicitly specifying which columns you want to see:

```
SELECT alias, token, dictionary, lexemes
```

```

FROM ts_debug('public.english','The Brightest supernovaes');
  alias | token | dictionary | lexemes
-----+-----+-----+-----
asciiword | The | english_ispell | {}
blank | | | |
asciiword | Brightest | english_ispell | {bright}
blank | | | |
asciiword | supernovaes | english_stem | {supernova}

```

12.8.2. Parser Testing

The following functions allow direct testing of a text search parser.

```

ts_parse(parser_name text, document text,
         OUT tokid integer, OUT token text) returns setof record
ts_parse(parser_oid oid, document text,
         OUT tokid integer, OUT token text) returns setof record

```

`ts_parse` parses the given *document* and returns a series of records, one for each token produced by parsing. Each record includes a `tokid` showing the assigned token type and a `token` which is the text of the token. For example:

```

SELECT * FROM ts_parse('default', '123 - a number');
 tokid | token
-----+-----
    22 | 123
    12 |
    12 | -
     1 | a
    12 |
     1 | number

```

```

ts_token_type(parser_name text, OUT tokid integer,
              OUT alias text, OUT description text) returns setof
record
ts_token_type(parser_oid oid, OUT tokid integer,
              OUT alias text, OUT description text) returns setof
record

```

`ts_token_type` returns a table which describes each type of token the specified parser can recognize. For each token type, the table gives the integer `tokid` that the parser uses to label a token of that type, the `alias` that names the token type in configuration commands, and a short `description`. For example:

```

SELECT * FROM ts_token_type('default');
 tokid | alias | description
-----+-----+-----
     1 | asciiword | Word, all ASCII
     2 | word | Word, all letters
     3 | numword | Word, letters and digits
     4 | email | Email address

```

5	url	URL
6	host	Host
7	sfloat	Scientific notation
8	version	Version number
9	hword_numpart	Hyphenated word part, letters and digits
10	hword_part	Hyphenated word part, all letters
11	hword_asciipart	Hyphenated word part, all ASCII
12	blank	Space symbols
13	tag	XML tag
14	protocol	Protocol head
15	numhword	Hyphenated word, letters and digits
16	asciihword	Hyphenated word, all ASCII
17	hword	Hyphenated word, all letters
18	url_path	URL path
19	file	File or path name
20	float	Decimal notation
21	int	Signed integer
22	uint	Unsigned integer
23	entity	XML entity

12.8.3. Dictionary Testing

The `ts_lexize` function facilitates dictionary testing.

`ts_lexize(dict regdictionary, token text)` returns `text[]`

`ts_lexize` returns an array of lexemes if the input `token` is known to the dictionary, or an empty array if the token is known to the dictionary but it is a stop word, or NULL if it is an unknown word.

Examples:

```
SELECT ts_lexize('english_stem', 'stars');
ts_lexize
-----
{star}

SELECT ts_lexize('english_stem', 'a');
ts_lexize
-----
{}
```

Note

The `ts_lexize` function expects a single *token*, not text. Here is a case where this can be confusing:

```
SELECT ts_lexize('thesaurus_astro', 'supernovae stars')
is null;
?column?
-----
t
```

The thesaurus dictionary `thesaurus_astro` does know the phrase `supernovae stars`, but `ts_lexize` fails since it does not parse the input text but treats it as a

single token. Use `plainto_tsquery` or `to_tsvector` to test thesaurus dictionaries, for example:

```
SELECT plainto_tsquery('supernovae stars');
plainto_tsquery
-----
'sn'
```

12.9. GIN and GiST Index Types

There are two kinds of indexes that can be used to speed up full text searches. Note that indexes are not mandatory for full text searching, but in cases where a column is searched on a regular basis, an index is usually desirable.

```
CREATE INDEX name ON table USING GIN (column);
```

Creates a GIN (Generalized Inverted Index)-based index. The *column* must be of `tsvector` type.

```
CREATE INDEX name ON table USING GIST (column);
```

Creates a GiST (Generalized Search Tree)-based index. The *column* can be of `tsvector` or `tsquery` type.

GIN indexes are the preferred text search index type. As inverted indexes, they contain an index entry for each word (lexeme), with a compressed list of matching locations. Multi-word searches can find the first match, then use the index to remove rows that are lacking additional words. GIN indexes store only the words (lexemes) of `tsvector` values, and not their weight labels. Thus a table row recheck is needed when using a query that involves weights.

A GiST index is *lossy*, meaning that the index might produce false matches, and it is necessary to check the actual table row to eliminate such false matches. (PostgreSQL does this automatically when needed.) GiST indexes are lossy because each document is represented in the index by a fixed-length signature. The signature is generated by hashing each word into a single bit in an n-bit string, with all these bits OR-ed together to produce an n-bit document signature. When two words hash to the same bit position there will be a false match. If all words in the query have matches (real or false) then the table row must be retrieved to see if the match is correct.

A GiST index can be covering, i.e. use the `INCLUDE` clause. Included columns can have data types without any GiST operator class. Included attributes will be stored uncompressed.

Lossiness causes performance degradation due to unnecessary fetches of table records that turn out to be false matches. Since random access to table records is slow, this limits the usefulness of GiST indexes. The likelihood of false matches depends on several factors, in particular the number of unique words, so using dictionaries to reduce this number is recommended.

Note that GIN index build time can often be improved by increasing `maintenance_work_mem`, while GiST index build time is not sensitive to that parameter.

Partitioning of big collections and the proper use of GIN and GiST indexes allows the implementation of very fast searches with online update. Partitioning can be done at the database level using table inheritance, or by distributing documents over servers and collecting external search results, e.g. via Foreign Data access. The latter is possible because ranking functions use only local information.

12.10. psql Support

Information about text search configuration objects can be obtained in psql using a set of commands:

```
\dF{d,p,t}[+] [PATTERN]
```

An optional + produces more details.

The optional parameter *PATTERN* can be the name of a text search object, optionally schema-qualified. If *PATTERN* is omitted then information about all visible objects will be displayed. *PATTERN* can be a regular expression and can provide *separate* patterns for the schema and object names. The following examples illustrate this:

```
=> \dF *fulltext*
      List of text search configurations
 Schema | Name          | Description
-----+-----+-----
 public | fulltext_cfg |
```

```
=> \dF *.fulltext*
      List of text search configurations
 Schema | Name          | Description
-----+-----+-----
 fulltext | fulltext_cfg |
 public   | fulltext_cfg |
```

The available commands are:

```
\dF[+] [PATTERN]
```

List text search configurations (add + for more detail).

```
=> \dF russian
      List of text search configurations
 Schema | Name          | Description
-----+-----+-----
 pg_catalog | russian | configuration for russian language
```

```
=> \dF+ russian
Text search configuration "pg_catalog.russian"
Parser: "pg_catalog.default"
      Token          | Dictionaries
-----+-----
 asciihword         | english_stem
 asciihword         | english_stem
 email              | simple
 file               | simple
 float              | simple
 host               | simple
 hword              | russian_stem
 hword_asciipart    | english_stem
 hword_numpart      | simple
 hword_part         | russian_stem
 int                | simple
 numhword           | simple
 numword            | simple
 sfloat             | simple
 uint               | simple
 url                | simple
```

```

url_path      | simple
version       | simple
word          | russian_stem

```

```
\dFd[+] [PATTERN]
```

List text search dictionaries (add + for more detail).

```
=> \dFd
```

```

List of text search dictionaries
Schema | Name |
Description
-----+-----
pg_catalog | arabic_stem | snowball stemmer for arabic
language
pg_catalog | danish_stem | snowball stemmer for danish
language
pg_catalog | dutch_stem | snowball stemmer for dutch
language
pg_catalog | english_stem | snowball stemmer for english
language
pg_catalog | finnish_stem | snowball stemmer for finnish
language
pg_catalog | french_stem | snowball stemmer for french
language
pg_catalog | german_stem | snowball stemmer for german
language
pg_catalog | hungarian_stem | snowball stemmer for hungarian
language
pg_catalog | indonesian_stem | snowball stemmer for indonesian
language
pg_catalog | irish_stem | snowball stemmer for irish
language
pg_catalog | italian_stem | snowball stemmer for italian
language
pg_catalog | lithuanian_stem | snowball stemmer for lithuanian
language
pg_catalog | nepali_stem | snowball stemmer for nepali
language
pg_catalog | norwegian_stem | snowball stemmer for norwegian
language
pg_catalog | portuguese_stem | snowball stemmer for portuguese
language
pg_catalog | romanian_stem | snowball stemmer for romanian
language
pg_catalog | russian_stem | snowball stemmer for russian
language
pg_catalog | simple | simple dictionary: just lower
case and check for stopword
pg_catalog | spanish_stem | snowball stemmer for spanish
language
pg_catalog | swedish_stem | snowball stemmer for swedish
language
pg_catalog | tamil_stem | snowball stemmer for tamil
language
pg_catalog | turkish_stem | snowball stemmer for turkish
language

```

```
\dFp[+] [PATTERN]
```

List text search parsers (add + for more detail).

```
=> \dFp
```

List of text search parsers

Schema	Name	Description
pg_catalog	default	default word parser

```
=> \dFp+
```

Text search parser "pg_catalog.default"

Method	Function	Description
Start parse	prsd_start	
Get next token	prsd_nexttoken	
End parse	prsd_end	
Get headline	prsd_headline	
Get token types	prsd_lextype	

Token types for parser "pg_catalog.default"

Token name	Description
asciihword	Hyphenated word, all ASCII
asciiword	Word, all ASCII
blank	Space symbols
email	Email address
entity	XML entity
file	File or path name
float	Decimal notation
host	Host
hword	Hyphenated word, all letters
hword_asciipart	Hyphenated word part, all ASCII
hword_numpart	Hyphenated word part, letters and digits
hword_part	Hyphenated word part, all letters
int	Signed integer
numhword	Hyphenated word, letters and digits
numword	Word, letters and digits
protocol	Protocol head
sfloat	Scientific notation
tag	XML tag
uint	Unsigned integer
url	URL
url_path	URL path
version	Version number
word	Word, all letters

(23 rows)

```
\dFt[+] [PATTERN]
```

List text search templates (add + for more detail).

```
=> \dFt
```

List of text search templates

Schema	Name	Description
--------	------	-------------

```
pg_catalog | ispell      | ispell dictionary
pg_catalog | simple      | simple dictionary: just lower case and
check for stopword
pg_catalog | snowball    | snowball stemmer
pg_catalog | synonym     | synonym dictionary: replace word by
its synonym
pg_catalog | thesaurus   | thesaurus dictionary: phrase by phrase
substitution
```

12.11. Limitations

The current limitations of PostgreSQL's text search features are:

- The length of each lexeme must be less than 2K bytes
- The length of a `tsvector` (lexemes + positions) must be less than 1 megabyte
- The number of lexemes must be less than 2^{64}
- Position values in `tsvector` must be greater than 0 and no more than 16,383
- The match distance in a `<N> (FOLLOWED BY) tsquery` operator cannot be more than 16,384
- No more than 256 positions per lexeme
- The number of nodes (lexemes + operators) in a `tsquery` must be less than 32,768

For comparison, the PostgreSQL 8.1 documentation contained 10,441 unique words, a total of 335,420 words, and the most frequent word “postgresql” was mentioned 6,127 times in 655 documents.

Another example — the PostgreSQL mailing list archives contained 910,989 unique words with 57,491,343 lexemes in 461,020 messages.

Chapter 13. Concurrency Control

This chapter describes the behavior of the PostgreSQL database system when two or more sessions try to access the same data at the same time. The goals in that situation are to allow efficient access for all sessions while maintaining strict data integrity. Every developer of database applications should be familiar with the topics covered in this chapter.

13.1. Introduction

PostgreSQL provides a rich set of tools for developers to manage concurrent access to data. Internally, data consistency is maintained by using a multiversion model (Multiversion Concurrency Control, MVCC). This means that each SQL statement sees a snapshot of data (a *database version*) as it was some time ago, regardless of the current state of the underlying data. This prevents statements from viewing inconsistent data produced by concurrent transactions performing updates on the same data rows, providing *transaction isolation* for each database session. MVCC, by eschewing the locking methodologies of traditional database systems, minimizes lock contention in order to allow for reasonable performance in multiuser environments.

The main advantage of using the MVCC model of concurrency control rather than locking is that in MVCC locks acquired for querying (reading) data do not conflict with locks acquired for writing data, and so reading never blocks writing and writing never blocks reading. PostgreSQL maintains this guarantee even when providing the strictest level of transaction isolation through the use of an innovative *Serializable Snapshot Isolation* (SSI) level.

Table- and row-level locking facilities are also available in PostgreSQL for applications which don't generally need full transaction isolation and prefer to explicitly manage particular points of conflict. However, proper use of MVCC will generally provide better performance than locks. In addition, application-defined advisory locks provide a mechanism for acquiring locks that are not tied to a single transaction.

13.2. Transaction Isolation

The SQL standard defines four levels of transaction isolation. The most strict is Serializable, which is defined by the standard in a paragraph which says that any concurrent execution of a set of Serializable transactions is guaranteed to produce the same effect as running them one at a time in some order. The other three levels are defined in terms of phenomena, resulting from interaction between concurrent transactions, which must not occur at each level. The standard notes that due to the definition of Serializable, none of these phenomena are possible at that level. (This is hardly surprising -- if the effect of the transactions must be consistent with having been run one at a time, how could you see any phenomena caused by interactions?)

The phenomena which are prohibited at various levels are:

dirty read

A transaction reads data written by a concurrent uncommitted transaction.

nonrepeatable read

A transaction re-reads data it has previously read and finds that data has been modified by another transaction (that committed since the initial read).

phantom read

A transaction re-executes a query returning a set of rows that satisfy a search condition and finds that the set of rows satisfying the condition has changed due to another recently-committed transaction.

serialization anomaly

The result of successfully committing a group of transactions is inconsistent with all possible orderings of running those transactions one at a time.

The SQL standard and PostgreSQL-implemented transaction isolation levels are described in Table 13.1.

Table 13.1. Transaction Isolation Levels

Isolation Level	Dirty Read	Nonrepeatable Read	Phantom Read	Serialization Anomaly
Read uncommitted	Allowed, but not in PG	Possible	Possible	Possible
Read committed	Not possible	Possible	Possible	Possible
Repeatable read	Not possible	Not possible	Allowed, but not in PG	Possible
Serializable	Not possible	Not possible	Not possible	Not possible

In PostgreSQL, you can request any of the four standard transaction isolation levels, but internally only three distinct isolation levels are implemented, i.e. PostgreSQL's Read Uncommitted mode behaves like Read Committed. This is because it is the only sensible way to map the standard isolation levels to PostgreSQL's multiversion concurrency control architecture.

The table also shows that PostgreSQL's Repeatable Read implementation does not allow phantom reads. Stricter behavior is permitted by the SQL standard: the four isolation levels only define which phenomena must not happen, not which phenomena *must* happen. The behavior of the available isolation levels is detailed in the following subsections.

To set the transaction isolation level of a transaction, use the command SET TRANSACTION.

Important

Some PostgreSQL data types and functions have special rules regarding transactional behavior. In particular, changes made to a sequence (and therefore the counter of a column declared using `serial`) are immediately visible to all other transactions and are not rolled back if the transaction that made the changes aborts. See Section 9.16 and Section 8.1.4.

13.2.1. Read Committed Isolation Level

Read Committed is the default isolation level in PostgreSQL. When a transaction uses this isolation level, a `SELECT` query (without a `FOR UPDATE/SHARE` clause) sees only data committed before the query began; it never sees either uncommitted data or changes committed during query execution by concurrent transactions. In effect, a `SELECT` query sees a snapshot of the database as of the instant the query begins to run. However, `SELECT` does see the effects of previous updates executed within its own transaction, even though they are not yet committed. Also note that two successive `SELECT` commands can see different data, even though they are within a single transaction, if other transactions commit changes after the first `SELECT` starts and before the second `SELECT` starts.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the command start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the would-be updater will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first

updater rolls back, then its effects are negated and the second updater can proceed with updating the originally found row. If the first updater commits, the second updater will ignore the row if the first updater deleted it, otherwise it will attempt to apply its operation to the updated version of the row. The search condition of the command (the `WHERE` clause) is re-evaluated to see if the updated version of the row still matches the search condition. If so, the second updater proceeds with its operation using the updated version of the row. In the case of `SELECT FOR UPDATE` and `SELECT FOR SHARE`, this means it is the updated version of the row that is locked and returned to the client.

`INSERT` with an `ON CONFLICT DO UPDATE` clause behaves similarly. In Read Committed mode, each row proposed for insertion will either insert or update. Unless there are unrelated errors, one of those two outcomes is guaranteed. If a conflict originates in another transaction whose effects are not yet visible to the `INSERT`, the `UPDATE` clause will affect that row, even though possibly *no* version of that row is conventionally visible to the command.

`INSERT` with an `ON CONFLICT DO NOTHING` clause may have insertion not proceed for a row due to the outcome of another transaction whose effects are not visible to the `INSERT` snapshot. Again, this is only the case in Read Committed mode.

Because of the above rules, it is possible for an updating command to see an inconsistent snapshot: it can see the effects of concurrent updating commands on the same rows it is trying to update, but it does not see effects of those commands on other rows in the database. This behavior makes Read Committed mode unsuitable for commands that involve complex search conditions; however, it is just right for simpler cases. For example, consider updating bank balances with transactions like:

```
BEGIN;
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
  12345;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
  7534;
COMMIT;
```

If two such transactions concurrently try to change the balance of account 12345, we clearly want the second transaction to start with the updated version of the account's row. Because each command is affecting only a predetermined row, letting it see the updated version of the row does not create any troublesome inconsistency.

More complex usage can produce undesirable results in Read Committed mode. For example, consider a `DELETE` command operating on data that is being both added and removed from its restriction criteria by another command, e.g., assume `website` is a two-row table with `website.hits` equaling 9 and 10:

```
BEGIN;
UPDATE website SET hits = hits + 1;
-- run from another session: DELETE FROM website WHERE hits = 10;
COMMIT;
```

The `DELETE` will have no effect even though there is a `website.hits = 10` row before and after the `UPDATE`. This occurs because the pre-update row value 9 is skipped, and when the `UPDATE` completes and `DELETE` obtains a lock, the new row value is no longer 10 but 11, which no longer matches the criteria.

Because Read Committed mode starts each command with a new snapshot that includes all transactions committed up to that instant, subsequent commands in the same transaction will see the effects of the committed concurrent transaction in any case. The point at issue above is whether or not a *single* command sees an absolutely consistent view of the database.

The partial transaction isolation provided by Read Committed mode is adequate for many applications, and this mode is fast and simple to use; however, it is not sufficient for all cases. Applications that

do complex queries and updates might require a more rigorously consistent view of the database than Read Committed mode provides.

13.2.2. Repeatable Read Isolation Level

The *Repeatable Read* isolation level only sees data committed before the transaction began; it never sees either uncommitted data or changes committed during transaction execution by concurrent transactions. (However, the query does see the effects of previous updates executed within its own transaction, even though they are not yet committed.) This is a stronger guarantee than is required by the SQL standard for this isolation level, and prevents all of the phenomena described in Table 13.1 except for serialization anomalies. As mentioned above, this is specifically allowed by the standard, which only describes the *minimum* protections each isolation level must provide.

This level is different from Read Committed in that a query in a repeatable read transaction sees a snapshot as of the start of the first non-transaction-control statement in the *transaction*, not as of the start of the current statement within the transaction. Thus, successive `SELECT` commands within a *single* transaction see the same data, i.e., they do not see changes made by other transactions that committed after their own transaction started.

Applications using this level must be prepared to retry transactions due to serialization failures.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the transaction start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the repeatable read transaction will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first updater rolls back, then its effects are negated and the repeatable read transaction can proceed with updating the originally found row. But if the first updater commits (and actually updated or deleted the row, not just locked it) then the repeatable read transaction will be rolled back with the message

```
ERROR: could not serialize access due to concurrent update
```

because a repeatable read transaction cannot modify or lock rows changed by other transactions after the repeatable read transaction began.

When an application receives this error message, it should abort the current transaction and retry the whole transaction from the beginning. The second time through, the transaction will see the previously-committed change as part of its initial view of the database, so there is no logical conflict in using the new version of the row as the starting point for the new transaction's update.

Note that only updating transactions might need to be retried; read-only transactions will never have serialization conflicts.

The Repeatable Read mode provides a rigorous guarantee that each transaction sees a completely stable view of the database. However, this view will not necessarily always be consistent with some serial (one at a time) execution of concurrent transactions of the same level. For example, even a read only transaction at this level may see a control record updated to show that a batch has been completed but *not* see one of the detail records which is logically part of the batch because it read an earlier revision of the control record. Attempts to enforce business rules by transactions running at this isolation level are not likely to work correctly without careful use of explicit locks to block conflicting transactions.

Note

Prior to PostgreSQL version 9.1, a request for the Serializable transaction isolation level provided exactly the same behavior described here. To retain the legacy Serializable behavior, Repeatable Read should now be requested.

13.2.3. Serializable Isolation Level

The *Serializable* isolation level provides the strictest transaction isolation. This level emulates serial transaction execution for all committed transactions; as if transactions had been executed one after another, serially, rather than concurrently. However, like the Repeatable Read level, applications using this level must be prepared to retry transactions due to serialization failures. In fact, this isolation level works exactly the same as Repeatable Read except that it monitors for conditions which could make execution of a concurrent set of serializable transactions behave in a manner inconsistent with all possible serial (one at a time) executions of those transactions. This monitoring does not introduce any blocking beyond that present in repeatable read, but there is some overhead to the monitoring, and detection of the conditions which could cause a *serialization anomaly* will trigger a *serialization failure*.

As an example, consider a table `mytab`, initially containing:

class	value
1	10
1	20
2	100
2	200

Suppose that serializable transaction A computes:

```
SELECT SUM(value) FROM mytab WHERE class = 1;
```

and then inserts the result (30) as the `value` in a new row with `class = 2`. Concurrently, serializable transaction B computes:

```
SELECT SUM(value) FROM mytab WHERE class = 2;
```

and obtains the result 300, which it inserts in a new row with `class = 1`. Then both transactions try to commit. If either transaction were running at the Repeatable Read isolation level, both would be allowed to commit; but since there is no serial order of execution consistent with the result, using Serializable transactions will allow one transaction to commit and will roll the other back with this message:

```
ERROR: could not serialize access due to read/write dependencies
among transactions
```

This is because if A had executed before B, B would have computed the sum 330, not 300, and similarly the other order would have resulted in a different sum computed by A.

When relying on Serializable transactions to prevent anomalies, it is important that any data read from a permanent user table not be considered valid until the transaction which read it has successfully committed. This is true even for read-only transactions, except that data read within a *deferrable* read-only transaction is known to be valid as soon as it is read, because such a transaction waits until it can acquire a snapshot guaranteed to be free from such problems before starting to read any data. In all other cases applications must not depend on results read during a transaction that later aborted; instead, they should retry the transaction until it succeeds.

To guarantee true serializability PostgreSQL uses *predicate locking*, which means that it keeps locks which allow it to determine when a write would have had an impact on the result of a previous read from a concurrent transaction, had it run first. In PostgreSQL these locks do not cause any blocking and therefore can *not* play any part in causing a deadlock. They are used to identify and flag dependencies

among concurrent Serializable transactions which in certain combinations can lead to serialization anomalies. In contrast, a Read Committed or Repeatable Read transaction which wants to ensure data consistency may need to take out a lock on an entire table, which could block other users attempting to use that table, or it may use `SELECT FOR UPDATE` or `SELECT FOR SHARE` which not only can block other transactions but cause disk access.

Predicate locks in PostgreSQL, like in most other database systems, are based on data actually accessed by a transaction. These will show up in the `pg_locks` system view with a mode of `SIReadLock`. The particular locks acquired during execution of a query will depend on the plan used by the query, and multiple finer-grained locks (e.g., tuple locks) may be combined into fewer coarser-grained locks (e.g., page locks) during the course of the transaction to prevent exhaustion of the memory used to track the locks. A `READ ONLY` transaction may be able to release its `SIRead` locks before completion, if it detects that no conflicts can still occur which could lead to a serialization anomaly. In fact, `READ ONLY` transactions will often be able to establish that fact at startup and avoid taking any predicate locks. If you explicitly request a `SERIALIZABLE READ ONLY DEFERRABLE` transaction, it will block until it can establish this fact. (This is the *only* case where Serializable transactions block but Repeatable Read transactions don't.) On the other hand, `SIRead` locks often need to be kept past transaction commit, until overlapping read write transactions complete.

Consistent use of Serializable transactions can simplify development. The guarantee that any set of successfully committed concurrent Serializable transactions will have the same effect as if they were run one at a time means that if you can demonstrate that a single transaction, as written, will do the right thing when run by itself, you can have confidence that it will do the right thing in any mix of Serializable transactions, even without any information about what those other transactions might do, or it will not successfully commit. It is important that an environment which uses this technique have a generalized way of handling serialization failures (which always return with a `SQLSTATE` value of '40001'), because it will be very hard to predict exactly which transactions might contribute to the read/write dependencies and need to be rolled back to prevent serialization anomalies. The monitoring of read/write dependencies has a cost, as does the restart of transactions which are terminated with a serialization failure, but balanced against the cost and blocking involved in use of explicit locks and `SELECT FOR UPDATE` or `SELECT FOR SHARE`, Serializable transactions are the best performance choice for some environments.

While PostgreSQL's Serializable transaction isolation level only allows concurrent transactions to commit if it can prove there is a serial order of execution that would produce the same effect, it doesn't always prevent errors from being raised that would not occur in true serial execution. In particular, it is possible to see unique constraint violations caused by conflicts with overlapping Serializable transactions even after explicitly checking that the key isn't present before attempting to insert it. This can be avoided by making sure that *all* Serializable transactions that insert potentially conflicting keys explicitly check if they can do so first. For example, imagine an application that asks the user for a new key and then checks that it doesn't exist already by trying to select it first, or generates a new key by selecting the maximum existing key and adding one. If some Serializable transactions insert new keys directly without following this protocol, unique constraints violations might be reported even in cases where they could not occur in a serial execution of the concurrent transactions.

For optimal performance when relying on Serializable transactions for concurrency control, these issues should be considered:

- Declare transactions as `READ ONLY` when possible.
- Control the number of active connections, using a connection pool if needed. This is always an important performance consideration, but it can be particularly important in a busy system using Serializable transactions.
- Don't put more into a single transaction than needed for integrity purposes.
- Don't leave connections dangling "idle in transaction" longer than necessary. The configuration parameter `idle_in_transaction_session_timeout` may be used to automatically disconnect lingering sessions.

- Eliminate explicit locks, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` where no longer needed due to the protections automatically provided by Serializable transactions.
- When the system is forced to combine multiple page-level predicate locks into a single relation-level predicate lock because the predicate lock table is short of memory, an increase in the rate of serialization failures may occur. You can avoid this by increasing `max_pred_locks_per_transaction`, `max_pred_locks_per_relation`, and/or `max_pred_locks_per_page`.
- A sequential scan will always necessitate a relation-level predicate lock. This can result in an increased rate of serialization failures. It may be helpful to encourage the use of index scans by reducing `random_page_cost` and/or increasing `cpu_tuple_cost`. Be sure to weigh any decrease in transaction rollbacks and restarts against any overall change in query execution time.

13.3. Explicit Locking

PostgreSQL provides various lock modes to control concurrent access to data in tables. These modes can be used for application-controlled locking in situations where MVCC does not give the desired behavior. Also, most PostgreSQL commands automatically acquire locks of appropriate modes to ensure that referenced tables are not dropped or modified in incompatible ways while the command executes. (For example, `TRUNCATE` cannot safely be executed concurrently with other operations on the same table, so it obtains an exclusive lock on the table to enforce that.)

To examine a list of the currently outstanding locks in a database server, use the `pg_locks` system view. For more information on monitoring the status of the lock manager subsystem, refer to Chapter 27.

13.3.1. Table-Level Locks

The list below shows the available lock modes and the contexts in which they are used automatically by PostgreSQL. You can also acquire any of these locks explicitly with the command `LOCK`. Remember that all of these lock modes are table-level locks, even if the name contains the word “row”; the names of the lock modes are historical. To some extent the names reflect the typical usage of each lock mode — but the semantics are all the same. The only real difference between one lock mode and another is the set of lock modes with which each conflicts (see Table 13.2). Two transactions cannot hold locks of conflicting modes on the same table at the same time. (However, a transaction never conflicts with itself. For example, it might acquire `ACCESS EXCLUSIVE` lock and later acquire `ACCESS SHARE` lock on the same table.) Non-conflicting lock modes can be held concurrently by many transactions. Notice in particular that some lock modes are self-conflicting (for example, an `ACCESS EXCLUSIVE` lock cannot be held by more than one transaction at a time) while others are not self-conflicting (for example, an `ACCESS SHARE` lock can be held by multiple transactions).

Table-Level Lock Modes

`ACCESS SHARE`

Conflicts with the `ACCESS EXCLUSIVE` lock mode only.

The `SELECT` command acquires a lock of this mode on referenced tables. In general, any query that only *reads* a table and does not modify it will acquire this lock mode.

`ROW SHARE`

Conflicts with the `EXCLUSIVE` and `ACCESS EXCLUSIVE` lock modes.

The `SELECT FOR UPDATE` and `SELECT FOR SHARE` commands acquire a lock of this mode on the target table(s) (in addition to `ACCESS SHARE` locks on any other tables that are referenced but not selected `FOR UPDATE/FOR SHARE`).

ROW EXCLUSIVE

Conflicts with the SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes.

The commands UPDATE, DELETE, and INSERT acquire this lock mode on the target table (in addition to ACCESS SHARE locks on any other referenced tables). In general, this lock mode will be acquired by any command that *modifies data* in a table.

SHARE UPDATE EXCLUSIVE

Conflicts with the SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode protects a table against concurrent schema changes and VACUUM runs.

Acquired by VACUUM (without FULL), ANALYZE, CREATE INDEX CONCURRENTLY, REINDEX CONCURRENTLY, CREATE STATISTICS, and certain ALTER INDEX and ALTER TABLE variants (for full details see ALTER INDEX and ALTER TABLE).

SHARE

Conflicts with the ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode protects a table against concurrent data changes.

Acquired by CREATE INDEX (without CONCURRENTLY).

SHARE ROW EXCLUSIVE

Conflicts with the ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode protects a table against concurrent data changes, and is self-exclusive so that only one session can hold it at a time.

Acquired by CREATE TRIGGER and some forms of ALTER TABLE (see ALTER TABLE).

EXCLUSIVE

Conflicts with the ROW SHARE, ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode allows only concurrent ACCESS SHARE locks, i.e., only reads from the table can proceed in parallel with a transaction holding this lock mode.

Acquired by REFRESH MATERIALIZED VIEW CONCURRENTLY.

ACCESS EXCLUSIVE

Conflicts with locks of all modes (ACCESS SHARE, ROW SHARE, ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE). This mode guarantees that the holder is the only transaction accessing the table in any way.

Acquired by the DROP TABLE, TRUNCATE, REINDEX, CLUSTER, VACUUM FULL, and REFRESH MATERIALIZED VIEW (without CONCURRENTLY) commands. Many forms of ALTER INDEX and ALTER TABLE also acquire a lock at this level. This is also the default lock mode for LOCK TABLE statements that do not specify a mode explicitly.

Tip

Only an ACCESS EXCLUSIVE lock blocks a SELECT (without FOR UPDATE/SHARE) statement.

Once acquired, a lock is normally held till end of transaction. But if a lock is acquired after establishing a savepoint, the lock is released immediately if the savepoint is rolled back to. This is consistent with the principle that ROLLBACK cancels all effects of the commands since the savepoint. The same holds for locks acquired within a PL/pgSQL exception block: an error escape from the block releases locks acquired within it.

Table 13.2. Conflicting Lock Modes

Request- ed Lock Mode	Current Lock Mode							
	ACCESS SHARE	ROW SHARE	ROW EX- CLUSIVE	SHARE UP- DATE EX- CLUSIVE	SHARE	SHARE ROW EX- CLUSIVE	EX- CLUSIVE	ACCESS EX- CLUSIVE
ACCESS SHARE								X
ROW SHARE							X	X
ROW EX- CLUSIVE					X	X	X	X
SHARE UPDATE EX- CLUSIVE				X	X	X	X	X
SHARE			X	X		X	X	X
SHARE ROW EX- CLUSIVE			X	X	X	X	X	X
EX- CLUSIVE		X	X	X	X	X	X	X
ACCESS EX- CLUSIVE	X	X	X	X	X	X	X	X

13.3.2. Row-Level Locks

In addition to table-level locks, there are row-level locks, which are listed as below with the contexts in which they are used automatically by PostgreSQL. See Table 13.3 for a complete table of row-level lock conflicts. Note that a transaction can hold conflicting locks on the same row, even in different subtransactions; but other than that, two transactions can never hold conflicting locks on the same row. Row-level locks do not affect data querying; they block only *writers and lockers* to the same row.

Row-Level Lock Modes

FOR UPDATE

FOR UPDATE causes the rows retrieved by the SELECT statement to be locked as though for update. This prevents them from being locked, modified or deleted by other transactions until the current transaction ends. That is, other transactions that attempt UPDATE, DELETE, SELECT FOR UPDATE, SELECT FOR NO KEY UPDATE, SELECT FOR SHARE or SELECT FOR KEY SHARE of these rows will be blocked until the current transaction ends; conversely, SELECT FOR UPDATE will wait for a concurrent transaction that has run any of those commands on the same row, and will then lock and return the updated row (or no row, if the row was deleted). Within

a REPEATABLE READ or SERIALIZABLE transaction, however, an error will be thrown if a row to be locked has changed since the transaction started. For further discussion see Section 13.4.

The FOR UPDATE lock mode is also acquired by any DELETE on a row, and also by an UPDATE that modifies the values on certain columns. Currently, the set of columns considered for the UPDATE case are those that have a unique index on them that can be used in a foreign key (so partial indexes and expressional indexes are not considered), but this may change in the future.

FOR NO KEY UPDATE

Behaves similarly to FOR UPDATE, except that the lock acquired is weaker: this lock will not block SELECT FOR KEY SHARE commands that attempt to acquire a lock on the same rows. This lock mode is also acquired by any UPDATE that does not acquire a FOR UPDATE lock.

FOR SHARE

Behaves similarly to FOR NO KEY UPDATE, except that it acquires a shared lock rather than exclusive lock on each retrieved row. A shared lock blocks other transactions from performing UPDATE, DELETE, SELECT FOR UPDATE or SELECT FOR NO KEY UPDATE on these rows, but it does not prevent them from performing SELECT FOR SHARE or SELECT FOR KEY SHARE.

FOR KEY SHARE

Behaves similarly to FOR SHARE, except that the lock is weaker: SELECT FOR UPDATE is blocked, but not SELECT FOR NO KEY UPDATE. A key-shared lock blocks other transactions from performing DELETE or any UPDATE that changes the key values, but not other UPDATE, and neither does it prevent SELECT FOR NO KEY UPDATE, SELECT FOR SHARE, or SELECT FOR KEY SHARE.

PostgreSQL doesn't remember any information about modified rows in memory, so there is no limit on the number of rows locked at one time. However, locking a row might cause a disk write, e.g., SELECT FOR UPDATE modifies selected rows to mark them locked, and so will result in disk writes.

Table 13.3. Conflicting Row-Level Locks

Requested Lock Mode	Current Lock Mode			
	FOR KEY SHARE	FOR SHARE	FOR NO KEY UPDATE	FOR UPDATE
FOR KEY SHARE				X
FOR SHARE			X	X
FOR NO KEY UPDATE		X	X	X
FOR UPDATE	X	X	X	X

13.3.3. Page-Level Locks

In addition to table and row locks, page-level share/exclusive locks are used to control read/write access to table pages in the shared buffer pool. These locks are released immediately after a row is fetched or updated. Application developers normally need not be concerned with page-level locks, but they are mentioned here for completeness.

13.3.4. Deadlocks

The use of explicit locking can increase the likelihood of *deadlocks*, wherein two (or more) transactions each hold locks that the other wants. For example, if transaction 1 acquires an exclusive lock on table A and then tries to acquire an exclusive lock on table B, while transaction 2 has already

exclusive-locked table B and now wants an exclusive lock on table A, then neither one can proceed. PostgreSQL automatically detects deadlock situations and resolves them by aborting one of the transactions involved, allowing the other(s) to complete. (Exactly which transaction will be aborted is difficult to predict and should not be relied upon.)

Note that deadlocks can also occur as the result of row-level locks (and thus, they can occur even if explicit locking is not used). Consider the case in which two concurrent transactions modify a table. The first transaction executes:

```
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
  11111;
```

This acquires a row-level lock on the row with the specified account number. Then, the second transaction executes:

```
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
  22222;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
  11111;
```

The first UPDATE statement successfully acquires a row-level lock on the specified row, so it succeeds in updating that row. However, the second UPDATE statement finds that the row it is attempting to update has already been locked, so it waits for the transaction that acquired the lock to complete. Transaction two is now waiting on transaction one to complete before it continues execution. Now, transaction one executes:

```
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
  22222;
```

Transaction one attempts to acquire a row-level lock on the specified row, but it cannot: transaction two already holds such a lock. So it waits for transaction two to complete. Thus, transaction one is blocked on transaction two, and transaction two is blocked on transaction one: a deadlock condition. PostgreSQL will detect this situation and abort one of the transactions.

The best defense against deadlocks is generally to avoid them by being certain that all applications using a database acquire locks on multiple objects in a consistent order. In the example above, if both transactions had updated the rows in the same order, no deadlock would have occurred. One should also ensure that the first lock acquired on an object in a transaction is the most restrictive mode that will be needed for that object. If it is not feasible to verify this in advance, then deadlocks can be handled on-the-fly by retrying transactions that abort due to deadlocks.

So long as no deadlock situation is detected, a transaction seeking either a table-level or row-level lock will wait indefinitely for conflicting locks to be released. This means it is a bad idea for applications to hold transactions open for long periods of time (e.g., while waiting for user input).

13.3.5. Advisory Locks

PostgreSQL provides a means for creating locks that have application-defined meanings. These are called *advisory locks*, because the system does not enforce their use — it is up to the application to use them correctly. Advisory locks can be useful for locking strategies that are an awkward fit for the MVCC model. For example, a common use of advisory locks is to emulate pessimistic locking strategies typical of so-called “flat file” data management systems. While a flag stored in a table could be used for the same purpose, advisory locks are faster, avoid table bloat, and are automatically cleaned up by the server at the end of the session.

There are two ways to acquire an advisory lock in PostgreSQL: at session level or at transaction level. Once acquired at session level, an advisory lock is held until explicitly released or the session ends.

Unlike standard lock requests, session-level advisory lock requests do not honor transaction semantics: a lock acquired during a transaction that is later rolled back will still be held following the rollback, and likewise an unlock is effective even if the calling transaction fails later. A lock can be acquired multiple times by its owning process; for each completed lock request there must be a corresponding unlock request before the lock is actually released. Transaction-level lock requests, on the other hand, behave more like regular lock requests: they are automatically released at the end of the transaction, and there is no explicit unlock operation. This behavior is often more convenient than the session-level behavior for short-term usage of an advisory lock. Session-level and transaction-level lock requests for the same advisory lock identifier will block each other in the expected way. If a session already holds a given advisory lock, additional requests by it will always succeed, even if other sessions are awaiting the lock; this statement is true regardless of whether the existing lock hold and new request are at session level or transaction level.

Like all locks in PostgreSQL, a complete list of advisory locks currently held by any session can be found in the `pg_locks` system view.

Both advisory locks and regular locks are stored in a shared memory pool whose size is defined by the configuration variables `max_locks_per_transaction` and `max_connections`. Care must be taken not to exhaust this memory or the server will be unable to grant any locks at all. This imposes an upper limit on the number of advisory locks grantable by the server, typically in the tens to hundreds of thousands depending on how the server is configured.

In certain cases using advisory locking methods, especially in queries involving explicit ordering and `LIMIT` clauses, care must be taken to control the locks acquired because of the order in which SQL expressions are evaluated. For example:

```
SELECT pg_advisory_lock(id) FROM foo WHERE id = 12345; -- ok
SELECT pg_advisory_lock(id) FROM foo WHERE id > 12345 LIMIT 100; --
danger!
SELECT pg_advisory_lock(q.id) FROM
(
  SELECT id FROM foo WHERE id > 12345 LIMIT 100
) q; -- ok
```

In the above queries, the second form is dangerous because the `LIMIT` is not guaranteed to be applied before the locking function is executed. This might cause some locks to be acquired that the application was not expecting, and hence would fail to release (until it ends the session). From the point of view of the application, such locks would be dangling, although still viewable in `pg_locks`.

The functions provided to manipulate advisory locks are described in Section 9.26.10.

13.4. Data Consistency Checks at the Application Level

It is very difficult to enforce business rules regarding data integrity using Read Committed transactions because the view of the data is shifting with each statement, and even a single statement may not restrict itself to the statement's snapshot if a write conflict occurs.

While a Repeatable Read transaction has a stable view of the data throughout its execution, there is a subtle issue with using MVCC snapshots for data consistency checks, involving something known as *read/write conflicts*. If one transaction writes data and a concurrent transaction attempts to read the same data (whether before or after the write), it cannot see the work of the other transaction. The reader then appears to have executed first regardless of which started first or which committed first. If that is as far as it goes, there is no problem, but if the reader also writes data which is read by a concurrent transaction there is now a transaction which appears to have run before either of the previously mentioned transactions. If the transaction which appears to have executed last actually

commits first, it is very easy for a cycle to appear in a graph of the order of execution of the transactions. When such a cycle appears, integrity checks will not work correctly without some help.

As mentioned in Section 13.2.3, Serializable transactions are just Repeatable Read transactions which add nonblocking monitoring for dangerous patterns of read/write conflicts. When a pattern is detected which could cause a cycle in the apparent order of execution, one of the transactions involved is rolled back to break the cycle.

13.4.1. Enforcing Consistency with Serializable Transactions

If the Serializable transaction isolation level is used for all writes and for all reads which need a consistent view of the data, no other effort is required to ensure consistency. Software from other environments which is written to use serializable transactions to ensure consistency should “just work” in this regard in PostgreSQL.

When using this technique, it will avoid creating an unnecessary burden for application programmers if the application software goes through a framework which automatically retries transactions which are rolled back with a serialization failure. It may be a good idea to set `default_transaction_isolation` to `serializable`. It would also be wise to take some action to ensure that no other transaction isolation level is used, either inadvertently or to subvert integrity checks, through checks of the transaction isolation level in triggers.

See Section 13.2.3 for performance suggestions.

Warning

This level of integrity protection using Serializable transactions does not yet extend to hot standby mode (Section 26.5). Because of that, those using hot standby may want to use Repeatable Read and explicit locking on the master.

13.4.2. Enforcing Consistency with Explicit Blocking Locks

When non-serializable writes are possible, to ensure the current validity of a row and protect it against concurrent updates one must use `SELECT FOR UPDATE`, `SELECT FOR SHARE`, or an appropriate `LOCK TABLE` statement. (`SELECT FOR UPDATE` and `SELECT FOR SHARE` lock just the returned rows against concurrent updates, while `LOCK TABLE` locks the whole table.) This should be taken into account when porting applications to PostgreSQL from other environments.

Also of note to those converting from other environments is the fact that `SELECT FOR UPDATE` does not ensure that a concurrent transaction will not update or delete a selected row. To do that in PostgreSQL you must actually update the row, even if no values need to be changed. `SELECT FOR UPDATE` temporarily blocks other transactions from acquiring the same lock or executing an `UPDATE` or `DELETE` which would affect the locked row, but once the transaction holding this lock commits or rolls back, a blocked transaction will proceed with the conflicting operation unless an actual `UPDATE` of the row was performed while the lock was held.

Global validity checks require extra thought under non-serializable MVCC. For example, a banking application might wish to check that the sum of all credits in one table equals the sum of debits in another table, when both tables are being actively updated. Comparing the results of two successive `SELECT sum(. . .)` commands will not work reliably in Read Committed mode, since the second query will likely include the results of transactions not counted by the first. Doing the two sums in a single repeatable read transaction will give an accurate picture of only the effects of transactions that committed before the repeatable read transaction started — but one might legitimately wonder whether

the answer is still relevant by the time it is delivered. If the repeatable read transaction itself applied some changes before trying to make the consistency check, the usefulness of the check becomes even more debatable, since now it includes some but not all post-transaction-start changes. In such cases a careful person might wish to lock all tables needed for the check, in order to get an indisputable picture of current reality. A `SHARE` mode (or higher) lock guarantees that there are no uncommitted changes in the locked table, other than those of the current transaction.

Note also that if one is relying on explicit locking to prevent concurrent changes, one should either use Read Committed mode, or in Repeatable Read mode be careful to obtain locks before performing queries. A lock obtained by a repeatable read transaction guarantees that no other transactions modifying the table are still running, but if the snapshot seen by the transaction predates obtaining the lock, it might predate some now-committed changes in the table. A repeatable read transaction's snapshot is actually frozen at the start of its first query or data-modification command (`SELECT`, `INSERT`, `UPDATE`, or `DELETE`), so it is possible to obtain locks explicitly before the snapshot is frozen.

13.5. Caveats

Some DDL commands, currently only `TRUNCATE` and the table-rewriting forms of `ALTER TABLE`, are not MVCC-safe. This means that after the truncation or rewrite commits, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the DDL command committed. This will only be an issue for a transaction that did not access the table in question before the DDL command started — any transaction that has done so would hold at least an `ACCESS SHARE` table lock, which would block the DDL command until that transaction completes. So these commands will not cause any apparent inconsistency in the table contents for successive queries on the target table, but they could cause visible inconsistency between the contents of the target table and other tables in the database.

Support for the Serializable transaction isolation level has not yet been added to Hot Standby replication targets (described in Section 26.5). The strictest isolation level currently supported in hot standby mode is Repeatable Read. While performing all permanent database writes within Serializable transactions on the master will ensure that all standbys will eventually reach a consistent state, a Repeatable Read transaction run on the standby can sometimes see a transient state that is inconsistent with any serial execution of the transactions on the master.

13.6. Locking and Indexes

Though PostgreSQL provides nonblocking read/write access to table data, nonblocking read/write access is not currently offered for every index access method implemented in PostgreSQL. The various index types are handled as follows:

B-tree, GiST and SP-GiST indexes

Short-term share/exclusive page-level locks are used for read/write access. Locks are released immediately after each index row is fetched or inserted. These index types provide the highest concurrency without deadlock conditions.

Hash indexes

Share/exclusive hash-bucket-level locks are used for read/write access. Locks are released after the whole bucket is processed. Bucket-level locks provide better concurrency than index-level ones, but deadlock is possible since the locks are held longer than one index operation.

GIN indexes

Short-term share/exclusive page-level locks are used for read/write access. Locks are released immediately after each index row is fetched or inserted. But note that insertion of a GIN-indexed value usually produces several index key insertions per row, so GIN might do substantial work for a single value's insertion.

Currently, B-tree indexes offer the best performance for concurrent applications; since they also have more features than hash indexes, they are the recommended index type for concurrent applications that need to index scalar data. When dealing with non-scalar data, B-trees are not useful, and GiST, SP-GiST or GIN indexes should be used instead.

Chapter 14. Performance Tips

Query performance can be affected by many things. Some of these can be controlled by the user, while others are fundamental to the underlying design of the system. This chapter provides some hints about understanding and tuning PostgreSQL performance.

14.1. Using EXPLAIN

PostgreSQL devises a *query plan* for each query it receives. Choosing the right plan to match the query structure and the properties of the data is absolutely critical for good performance, so the system includes a complex *planner* that tries to choose good plans. You can use the EXPLAIN command to see what query plan the planner creates for any query. Plan-reading is an art that requires some experience to master, but this section attempts to cover the basics.

Examples in this section are drawn from the regression test database after doing a VACUUM ANALYZE, using 9.3 development sources. You should be able to get similar results if you try the examples yourself, but your estimated costs and row counts might vary slightly because ANALYZE's statistics are random samples rather than exact, and because costs are inherently somewhat platform-dependent.

The examples use EXPLAIN's default “text” output format, which is compact and convenient for humans to read. If you want to feed EXPLAIN's output to a program for further analysis, you should use one of its machine-readable output formats (XML, JSON, or YAML) instead.

14.1.1. EXPLAIN Basics

The structure of a query plan is a tree of *plan nodes*. Nodes at the bottom level of the tree are scan nodes: they return raw rows from a table. There are different types of scan nodes for different table access methods: sequential scans, index scans, and bitmap index scans. There are also non-table row sources, such as VALUES clauses and set-returning functions in FROM, which have their own scan node types. If the query requires joining, aggregation, sorting, or other operations on the raw rows, then there will be additional nodes above the scan nodes to perform these operations. Again, there is usually more than one possible way to do these operations, so different node types can appear here too. The output of EXPLAIN has one line for each node in the plan tree, showing the basic node type plus the cost estimates that the planner made for the execution of that plan node. Additional lines might appear, indented from the node's summary line, to show additional properties of the node. The very first line (the summary line for the topmost node) has the estimated total execution cost for the plan; it is this number that the planner seeks to minimize.

Here is a trivial example, just to show what the output looks like:

```
EXPLAIN SELECT * FROM tenk1;

              QUERY PLAN
-----
Seq Scan on tenk1  (cost=0.00..458.00 rows=10000 width=244)
```

Since this query has no WHERE clause, it must scan all the rows of the table, so the planner has chosen to use a simple sequential scan plan. The numbers that are quoted in parentheses are (left to right):

- Estimated start-up cost. This is the time expended before the output phase can begin, e.g., time to do the sorting in a sort node.
- Estimated total cost. This is stated on the assumption that the plan node is run to completion, i.e., all available rows are retrieved. In practice a node's parent node might stop short of reading all available rows (see the LIMIT example below).

- Estimated number of rows output by this plan node. Again, the node is assumed to be run to completion.
- Estimated average width of rows output by this plan node (in bytes).

The costs are measured in arbitrary units determined by the planner's cost parameters (see Section 19.7.2). Traditional practice is to measure the costs in units of disk page fetches; that is, `seq_page_cost` is conventionally set to 1.0 and the other cost parameters are set relative to that. The examples in this section are run with the default cost parameters.

It's important to understand that the cost of an upper-level node includes the cost of all its child nodes. It's also important to realize that the cost only reflects things that the planner cares about. In particular, the cost does not consider the time spent transmitting result rows to the client, which could be an important factor in the real elapsed time; but the planner ignores it because it cannot change it by altering the plan. (Every correct plan will output the same row set, we trust.)

The `rows` value is a little tricky because it is not the number of rows processed or scanned by the plan node, but rather the number emitted by the node. This is often less than the number scanned, as a result of filtering by any `WHERE`-clause conditions that are being applied at the node. Ideally the top-level rows estimate will approximate the number of rows actually returned, updated, or deleted by the query.

Returning to our example:

```
EXPLAIN SELECT * FROM tenk1;
```

QUERY PLAN

```
-----
Seq Scan on tenk1  (cost=0.00..458.00 rows=10000 width=244)
```

These numbers are derived very straightforwardly. If you do:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 'tenk1';
```

you will find that `tenk1` has 358 disk pages and 10000 rows. The estimated cost is computed as (disk pages read * `seq_page_cost`) + (rows scanned * `cpu_tuple_cost`). By default, `seq_page_cost` is 1.0 and `cpu_tuple_cost` is 0.01, so the estimated cost is $(358 * 1.0) + (10000 * 0.01) = 458$.

Now let's modify the query to add a `WHERE` condition:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 7000;
```

QUERY PLAN

```
-----
Seq Scan on tenk1  (cost=0.00..483.00 rows=7001 width=244)
  Filter: (unique1 < 7000)
```

Notice that the `EXPLAIN` output shows the `WHERE` clause being applied as a “filter” condition attached to the `Seq Scan` plan node. This means that the plan node checks the condition for each row it scans, and outputs only the ones that pass the condition. The estimate of output rows has been reduced because of the `WHERE` clause. However, the scan will still have to visit all 10000 rows, so the cost hasn't decreased; in fact it has gone up a bit (by $10000 * \text{cpu_operator_cost}$, to be exact) to reflect the extra CPU time spent checking the `WHERE` condition.

The actual number of rows this query would select is 7000, but the `rows` estimate is only approximate. If you try to duplicate this experiment, you will probably get a slightly different estimate; moreover, it can change after each `ANALYZE` command, because the statistics produced by `ANALYZE` are taken from a randomized sample of the table.

Now, let's make the condition more restrictive:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100;
```

QUERY PLAN

```
-----
Bitmap Heap Scan on tenk1 (cost=5.07..229.20 rows=101 width=244)
  Recheck Cond: (unique1 < 100)
  -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0)
    Index Cond: (unique1 < 100)
```

Here the planner has decided to use a two-step plan: the child plan node visits an index to find the locations of rows matching the index condition, and then the upper plan node actually fetches those rows from the table itself. Fetching rows separately is much more expensive than reading them sequentially, but because not all the pages of the table have to be visited, this is still cheaper than a sequential scan. (The reason for using two plan levels is that the upper plan node sorts the row locations identified by the index into physical order before reading them, to minimize the cost of separate fetches. The “bitmap” mentioned in the node names is the mechanism that does the sorting.)

Now let's add another condition to the WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND stringul =
'xxx';
```

QUERY PLAN

```
-----
Bitmap Heap Scan on tenk1 (cost=5.04..229.43 rows=1 width=244)
  Recheck Cond: (unique1 < 100)
  Filter: (stringul = 'xxx'::name)
  -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0)
    Index Cond: (unique1 < 100)
```

The added condition `stringul = 'xxx'` reduces the output row count estimate, but not the cost because we still have to visit the same set of rows. Notice that the `stringul` clause cannot be applied as an index condition, since this index is only on the `unique1` column. Instead it is applied as a filter on the rows retrieved by the index. Thus the cost has actually gone up slightly to reflect this extra checking.

In some cases the planner will prefer a “simple” index scan plan:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 = 42;
```

QUERY PLAN

```
-----
Index Scan using tenk1_unique1 on tenk1 (cost=0.29..8.30 rows=1
width=244)
  Index Cond: (unique1 = 42)
```

In this type of plan the table rows are fetched in index order, which makes them even more expensive to read, but there are so few that the extra cost of sorting the row locations is not worth it. You'll most often see this plan type for queries that fetch just a single row. It's also often used for queries that have an `ORDER BY` condition that matches the index order, because then no extra sorting step is needed to satisfy the `ORDER BY`.

If there are separate indexes on several of the columns referenced in `WHERE`, the planner might choose to use an `AND` or `OR` combination of the indexes:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000;
```

QUERY PLAN

```
-----
Bitmap Heap Scan on tenk1 (cost=25.08..60.21 rows=10 width=244)
  Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
  -> BitmapAnd (cost=25.08..25.08 rows=10 width=0)
      -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0)
          Index Cond: (unique1 < 100)
      -> Bitmap Index Scan on tenk1_unique2 (cost=0.00..19.78
rows=999 width=0)
          Index Cond: (unique2 > 9000)
```

But this requires visiting both indexes, so it's not necessarily a win compared to using just one index and treating the other condition as a filter. If you vary the ranges involved you'll see the plan change accordingly.

Here is an example showing the effects of LIMIT:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000
LIMIT 2;
```

QUERY PLAN

```
-----
Limit (cost=0.29..14.48 rows=2 width=244)
  -> Index Scan using tenk1_unique2 on tenk1 (cost=0.29..71.27
rows=10 width=244)
      Index Cond: (unique2 > 9000)
      Filter: (unique1 < 100)
```

This is the same query as above, but we added a LIMIT so that not all the rows need be retrieved, and the planner changed its mind about what to do. Notice that the total cost and row count of the Index Scan node are shown as if it were run to completion. However, the Limit node is expected to stop after retrieving only a fifth of those rows, so its total cost is only a fifth as much, and that's the actual estimated cost of the query. This plan is preferred over adding a Limit node to the previous plan because the Limit could not avoid paying the startup cost of the bitmap scan, so the total cost would be something over 25 units with that approach.

Let's try joining two tables, using the columns we have been discussing:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t1.unique2 = t2.unique2;
```

QUERY PLAN

```
-----
Nested Loop (cost=4.65..118.62 rows=10 width=488)
  -> Bitmap Heap Scan on tenk1 t1 (cost=4.36..39.47 rows=10
width=244)
      Recheck Cond: (unique1 < 10)
      -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.36
rows=10 width=0)
          Index Cond: (unique1 < 10)
  -> Index Scan using tenk2_unique2 on tenk2 t2 (cost=0.29..7.91
rows=1 width=244)
```

```
Index Cond: (unique2 = t1.unique2)
```

In this plan, we have a nested-loop join node with two table scans as inputs, or children. The indentation of the node summary lines reflects the plan tree structure. The join's first, or “outer”, child is a bitmap scan similar to those we saw before. Its cost and row count are the same as we'd get from `SELECT ... WHERE unique1 < 10` because we are applying the `WHERE` clause `unique1 < 10` at that node. The `t1.unique2 = t2.unique2` clause is not relevant yet, so it doesn't affect the row count of the outer scan. The nested-loop join node will run its second, or “inner” child once for each row obtained from the outer child. Column values from the current outer row can be plugged into the inner scan; here, the `t1.unique2` value from the outer row is available, so we get a plan and costs similar to what we saw above for a simple `SELECT ... WHERE t2.unique2 = constant` case. (The estimated cost is actually a bit lower than what was seen above, as a result of caching that's expected to occur during the repeated index scans on `t2`.) The costs of the loop node are then set on the basis of the cost of the outer scan, plus one repetition of the inner scan for each outer row ($10 * 7.91$, here), plus a little CPU time for join processing.

In this example the join's output row count is the same as the product of the two scans' row counts, but that's not true in all cases because there can be additional `WHERE` clauses that mention both tables and so can only be applied at the join point, not to either input scan. Here's an example:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t2.unique2 < 10 AND t1.hundred <
      t2.hundred;
```

QUERY PLAN

```
-----
Nested Loop  (cost=4.65..49.46 rows=33 width=488)
  Join Filter: (t1.hundred < t2.hundred)
    -> Bitmap Heap Scan on tenk1 t1  (cost=4.36..39.47 rows=10
        width=244)
      Recheck Cond: (unique1 < 10)
        -> Bitmap Index Scan on tenk1_unique1  (cost=0.00..4.36
            rows=10 width=0)
          Index Cond: (unique1 < 10)
        -> Materialize  (cost=0.29..8.51 rows=10 width=244)
          -> Index Scan using tenk2_unique2 on tenk2 t2
              (cost=0.29..8.46 rows=10 width=244)
            Index Cond: (unique2 < 10)
```

The condition `t1.hundred < t2.hundred` can't be tested in the `tenk2_unique2` index, so it's applied at the join node. This reduces the estimated output row count of the join node, but does not change either input scan.

Notice that here the planner has chosen to “materialize” the inner relation of the join, by putting a `Materialize` plan node atop it. This means that the `t2` index scan will be done just once, even though the nested-loop join node needs to read that data ten times, once for each row from the outer relation. The `Materialize` node saves the data in memory as it's read, and then returns the data from memory on each subsequent pass.

When dealing with outer joins, you might see join plan nodes with both “Join Filter” and plain “Filter” conditions attached. Join Filter conditions come from the outer join's `ON` clause, so a row that fails the Join Filter condition could still get emitted as a null-extended row. But a plain Filter condition is applied after the outer-join rules and so acts to remove rows unconditionally. In an inner join there is no semantic difference between these types of filters.

If we change the query's selectivity a bit, we might get a very different join plan:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;
```

QUERY PLAN

```
-----
Hash Join (cost=230.47..713.98 rows=101 width=488)
  Hash Cond: (t2.unique2 = t1.unique2)
    -> Seq Scan on tenk2 t2 (cost=0.00..445.00 rows=10000
width=244)
    -> Hash (cost=229.20..229.20 rows=101 width=244)
      -> Bitmap Heap Scan on tenk1 t1 (cost=5.07..229.20
rows=101 width=244)
        Recheck Cond: (unique1 < 100)
        -> Bitmap Index Scan on tenk1_unique1
(cost=0.00..5.04 rows=101 width=0)
          Index Cond: (unique1 < 100)
```

Here, the planner has chosen to use a hash join, in which rows of one table are entered into an in-memory hash table, after which the other table is scanned and the hash table is probed for matches to each row. Again note how the indentation reflects the plan structure: the bitmap scan on `tenk1` is the input to the Hash node, which constructs the hash table. That's then returned to the Hash Join node, which reads rows from its outer child plan and searches the hash table for each one.

Another possible type of join is a merge join, illustrated here:

```
EXPLAIN SELECT *
FROM tenk1 t1, onek t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;
```

QUERY PLAN

```
-----
Merge Join (cost=198.11..268.19 rows=10 width=488)
  Merge Cond: (t1.unique2 = t2.unique2)
    -> Index Scan using tenk1_unique2 on tenk1 t1
(cost=0.29..656.28 rows=101 width=244)
      Filter: (unique1 < 100)
    -> Sort (cost=197.83..200.33 rows=1000 width=244)
      Sort Key: t2.unique2
      -> Seq Scan on onek t2 (cost=0.00..148.00 rows=1000
width=244)
```

Merge join requires its input data to be sorted on the join keys. In this plan the `tenk1` data is sorted by using an index scan to visit the rows in the correct order, but a sequential scan and sort is preferred for `onek`, because there are many more rows to be visited in that table. (Sequential-scan-and-sort frequently beats an index scan for sorting many rows, because of the nonsequential disk access required by the index scan.)

One way to look at variant plans is to force the planner to disregard whatever strategy it thought was the cheapest, using the enable/disable flags described in Section 19.7.1. (This is a crude tool, but useful. See also Section 14.3.) For example, if we're unconvinced that sequential-scan-and-sort is the best way to deal with table `onek` in the previous example, we could try

```
SET enable_sort = off;
```

```
EXPLAIN SELECT *
FROM tenk1 t1, onek t2
```

```
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;
```

QUERY PLAN

```
-----
Merge Join (cost=0.56..292.65 rows=10 width=488)
  Merge Cond: (t1.unique2 = t2.unique2)
    -> Index Scan using tenk1_unique2 on tenk1 t1
        (cost=0.29..656.28 rows=101 width=244)
          Filter: (unique1 < 100)
    -> Index Scan using onek_unique2 on onek t2 (cost=0.28..224.79
        rows=1000 width=244)
```

which shows that the planner thinks that sorting onek by index-scanning is about 12% more expensive than sequential-scan-and-sort. Of course, the next question is whether it's right about that. We can investigate that using `EXPLAIN ANALYZE`, as discussed below.

14.1.2. EXPLAIN ANALYZE

It is possible to check the accuracy of the planner's estimates by using `EXPLAIN`'s `ANALYZE` option. With this option, `EXPLAIN` actually executes the query, and then displays the true row counts and true run time accumulated within each plan node, along with the same estimates that a plain `EXPLAIN` shows. For example, we might get a result like this:

```
EXPLAIN ANALYZE SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t1.unique2 = t2.unique2;
```

QUERY

PLAN

```
-----
Nested Loop (cost=4.65..118.62 rows=10 width=488) (actual
time=0.128..0.377 rows=10 loops=1)
  -> Bitmap Heap Scan on tenk1 t1 (cost=4.36..39.47 rows=10
width=244) (actual time=0.057..0.121 rows=10 loops=1)
    Recheck Cond: (unique1 < 10)
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.36
rows=10 width=0) (actual time=0.024..0.024 rows=10 loops=1)
        Index Cond: (unique1 < 10)
    -> Index Scan using tenk2_unique2 on tenk2 t2 (cost=0.29..7.91
rows=1 width=244) (actual time=0.021..0.022 rows=1 loops=10)
        Index Cond: (unique2 = t1.unique2)
Planning time: 0.181 ms
Execution time: 0.501 ms
```

Note that the “actual time” values are in milliseconds of real time, whereas the `cost` estimates are expressed in arbitrary units; so they are unlikely to match up. The thing that's usually most important to look for is whether the estimated row counts are reasonably close to reality. In this example the estimates were all dead-on, but that's quite unusual in practice.

In some query plans, it is possible for a subplan node to be executed more than once. For example, the inner index scan will be executed once per outer row in the above nested-loop plan. In such cases, the `loops` value reports the total number of executions of the node, and the actual time and rows values shown are averages per-execution. This is done to make the numbers comparable with the way that the cost estimates are shown. Multiply by the `loops` value to get the total time actually spent in the node. In the above example, we spent a total of 0.220 milliseconds executing the index scans on `tenk2`.

In some cases `EXPLAIN ANALYZE` shows additional execution statistics beyond the plan node execution times and row counts. For example, Sort and Hash nodes provide extra information:

```
EXPLAIN ANALYZE SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2 ORDER BY
t1.fivethous;
```

QUERY PLAN

```
Sort (cost=717.34..717.59 rows=101 width=488) (actual
time=7.761..7.774 rows=100 loops=1)
  Sort Key: t1.fivethous
  Sort Method: quicksort Memory: 77kB
  -> Hash Join (cost=230.47..713.98 rows=101 width=488) (actual
time=0.711..7.427 rows=100 loops=1)
    Hash Cond: (t2.unique2 = t1.unique2)
    -> Seq Scan on tenk2 t2 (cost=0.00..445.00 rows=10000
width=244) (actual time=0.007..2.583 rows=10000 loops=1)
    -> Hash (cost=229.20..229.20 rows=101 width=244) (actual
time=0.659..0.659 rows=100 loops=1)
      Buckets: 1024 Batches: 1 Memory Usage: 28kB
      -> Bitmap Heap Scan on tenk1 t1 (cost=5.07..229.20
rows=101 width=244) (actual time=0.080..0.526 rows=100 loops=1)
        Recheck Cond: (unique1 < 100)
        -> Bitmap Index Scan on tenk1_unique1
(cost=0.00..5.04 rows=101 width=0) (actual time=0.049..0.049
rows=100 loops=1)
          Index Cond: (unique1 < 100)
Planning time: 0.194 ms
Execution time: 8.008 ms
```

The Sort node shows the sort method used (in particular, whether the sort was in-memory or on-disk) and the amount of memory or disk space needed. The Hash node shows the number of hash buckets and batches as well as the peak amount of memory used for the hash table. (If the number of batches exceeds one, there will also be disk space usage involved, but that is not shown.)

Another type of extra information is the number of rows removed by a filter condition:

```
EXPLAIN ANALYZE SELECT * FROM tenk1 WHERE ten < 7;
```

QUERY PLAN

```
Seq Scan on tenk1 (cost=0.00..483.00 rows=7000 width=244) (actual
time=0.016..5.107 rows=7000 loops=1)
  Filter: (ten < 7)
  Rows Removed by Filter: 3000
Planning time: 0.083 ms
Execution time: 5.905 ms
```

These counts can be particularly valuable for filter conditions applied at join nodes. The “Rows Removed” line only appears when at least one scanned row, or potential join pair in the case of a join node, is rejected by the filter condition.

A case similar to filter conditions occurs with “lossy” index scans. For example, consider this search for polygons containing a specific point:

```
EXPLAIN ANALYZE SELECT * FROM polygon_tbl WHERE f1 @> polygon
'(0.5,2.0)';
```

QUERY PLAN

```
-----
Seq Scan on polygon_tbl (cost=0.00..1.05 rows=1 width=32) (actual
time=0.044..0.044 rows=0 loops=1)
  Filter: (f1 @> '((0.5,2))':polygon)
  Rows Removed by Filter: 4
Planning time: 0.040 ms
Execution time: 0.083 ms
```

The planner thinks (quite correctly) that this sample table is too small to bother with an index scan, so we have a plain sequential scan in which all the rows got rejected by the filter condition. But if we force an index scan to be used, we see:

```
SET enable_seqscan TO off;
```

```
EXPLAIN ANALYZE SELECT * FROM polygon_tbl WHERE f1 @> polygon
 '(0.5,2.0)';
```

QUERY PLAN

```
-----
Index Scan using gpolygonind on polygon_tbl (cost=0.13..8.15
rows=1 width=32) (actual time=0.062..0.062 rows=0 loops=1)
  Index Cond: (f1 @> '((0.5,2))':polygon)
  Rows Removed by Index Recheck: 1
Planning time: 0.034 ms
Execution time: 0.144 ms
```

Here we can see that the index returned one candidate row, which was then rejected by a recheck of the index condition. This happens because a GiST index is “lossy” for polygon containment tests: it actually returns the rows with polygons that overlap the target, and then we have to do the exact containment test on those rows.

EXPLAIN has a BUFFERS option that can be used with ANALYZE to get even more run time statistics:

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM tenk1 WHERE unique1 < 100
AND unique2 > 9000;
```

QUERY

PLAN

```
-----
Bitmap Heap Scan on tenk1 (cost=25.08..60.21 rows=10 width=244)
(actual time=0.323..0.342 rows=10 loops=1)
  Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
  Buffers: shared hit=15
  -> BitmapAnd (cost=25.08..25.08 rows=10 width=0) (actual
time=0.309..0.309 rows=0 loops=1)
    Buffers: shared hit=7
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0) (actual time=0.043..0.043 rows=100 loops=1)
      Index Cond: (unique1 < 100)
      Buffers: shared hit=2
    -> Bitmap Index Scan on tenk1_unique2 (cost=0.00..19.78
rows=999 width=0) (actual time=0.227..0.227 rows=999 loops=1)
      Index Cond: (unique2 > 9000)
      Buffers: shared hit=5
Planning time: 0.088 ms
```

Execution time: 0.423 ms

The numbers provided by BUFFERS help to identify which parts of the query are the most I/O-intensive.

Keep in mind that because EXPLAIN ANALYZE actually runs the query, any side-effects will happen as usual, even though whatever results the query might output are discarded in favor of printing the EXPLAIN data. If you want to analyze a data-modifying query without changing your tables, you can roll the command back afterwards, for example:

```
BEGIN;

EXPLAIN ANALYZE UPDATE tenk1 SET hundred = hundred + 1 WHERE
unique1 < 100;

                                                    QUERY
PLAN
-----
Update on tenk1 (cost=5.07..229.46 rows=101 width=250) (actual
time=14.628..14.628 rows=0 loops=1)
  -> Bitmap Heap Scan on tenk1 (cost=5.07..229.46 rows=101
width=250) (actual time=0.101..0.439 rows=100 loops=1)
    Recheck Cond: (unique1 < 100)
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..5.04
rows=101 width=0) (actual time=0.043..0.043 rows=100 loops=1)
        Index Cond: (unique1 < 100)
Planning time: 0.079 ms
Execution time: 14.727 ms
```

ROLLBACK;

As seen in this example, when the query is an INSERT, UPDATE, or DELETE command, the actual work of applying the table changes is done by a top-level Insert, Update, or Delete plan node. The plan nodes underneath this node perform the work of locating the old rows and/or computing the new data. So above, we see the same sort of bitmap table scan we've seen already, and its output is fed to an Update node that stores the updated rows. It's worth noting that although the data-modifying node can take a considerable amount of run time (here, it's consuming the lion's share of the time), the planner does not currently add anything to the cost estimates to account for that work. That's because the work to be done is the same for every correct query plan, so it doesn't affect planning decisions.

When an UPDATE or DELETE command affects an inheritance hierarchy, the output might look like this:

```
EXPLAIN UPDATE parent SET f2 = f2 + 1 WHERE f1 = 101;
                        QUERY PLAN
-----
Update on parent (cost=0.00..24.53 rows=4 width=14)
  Update on parent
    Update on child1
    Update on child2
    Update on child3
  -> Seq Scan on parent (cost=0.00..0.00 rows=1 width=14)
      Filter: (f1 = 101)
  -> Index Scan using child1_f1_key on child1 (cost=0.15..8.17
rows=1 width=14)
      Index Cond: (f1 = 101)
  -> Index Scan using child2_f1_key on child2 (cost=0.15..8.17
rows=1 width=14)
```

```

      Index Cond: (f1 = 101)
-> Index Scan using child3_f1_key on child3 (cost=0.15..8.17
rows=1 width=14)
      Index Cond: (f1 = 101)

```

In this example the Update node needs to consider three child tables as well as the originally-mentioned parent table. So there are four input scanning subplans, one per table. For clarity, the Update node is annotated to show the specific target tables that will be updated, in the same order as the corresponding subplans. (These annotations are new as of PostgreSQL 9.5; in prior versions the reader had to intuit the target tables by inspecting the subplans.)

The `Planning time` shown by `EXPLAIN ANALYZE` is the time it took to generate the query plan from the parsed query and optimize it. It does not include parsing or rewriting.

The `Execution time` shown by `EXPLAIN ANALYZE` includes executor start-up and shut-down time, as well as the time to run any triggers that are fired, but it does not include parsing, rewriting, or planning time. Time spent executing `BEFORE` triggers, if any, is included in the time for the related Insert, Update, or Delete node; but time spent executing `AFTER` triggers is not counted there because `AFTER` triggers are fired after completion of the whole plan. The total time spent in each trigger (either `BEFORE` or `AFTER`) is also shown separately. Note that deferred constraint triggers will not be executed until end of transaction and are thus not considered at all by `EXPLAIN ANALYZE`.

14.1.3. Caveats

There are two significant ways in which run times measured by `EXPLAIN ANALYZE` can deviate from normal execution of the same query. First, since no output rows are delivered to the client, network transmission costs and I/O conversion costs are not included. Second, the measurement overhead added by `EXPLAIN ANALYZE` can be significant, especially on machines with slow `gettimeofday()` operating-system calls. You can use the `pg_test_timing` tool to measure the overhead of timing on your system.

`EXPLAIN` results should not be extrapolated to situations much different from the one you are actually testing; for example, results on a toy-sized table cannot be assumed to apply to large tables. The planner's cost estimates are not linear and so it might choose a different plan for a larger or smaller table. An extreme example is that on a table that only occupies one disk page, you'll nearly always get a sequential scan plan whether indexes are available or not. The planner realizes that it's going to take one disk page read to process the table in any case, so there's no value in expending additional page reads to look at an index. (We saw this happening in the `polygon_tbl` example above.)

There are cases in which the actual and estimated values won't match up well, but nothing is really wrong. One such case occurs when plan node execution is stopped short by a `LIMIT` or similar effect. For example, in the `LIMIT` query we used before,

```
EXPLAIN ANALYZE SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2
> 9000 LIMIT 2;
```

PLAN

QUERY

```

-----
Limit (cost=0.29..14.71 rows=2 width=244) (actual
time=0.177..0.249 rows=2 loops=1)
-> Index Scan using tenk1_unique2 on tenk1 (cost=0.29..72.42
rows=10 width=244) (actual time=0.174..0.244 rows=2 loops=1)
      Index Cond: (unique2 > 9000)
      Filter: (unique1 < 100)
      Rows Removed by Filter: 287
Planning time: 0.096 ms
Execution time: 0.336 ms

```

the estimated cost and row count for the Index Scan node are shown as though it were run to completion. But in reality the Limit node stopped requesting rows after it got two, so the actual row count is only 2 and the run time is less than the cost estimate would suggest. This is not an estimation error, only a discrepancy in the way the estimates and true values are displayed.

Merge joins also have measurement artifacts that can confuse the unwary. A merge join will stop reading one input if it's exhausted the other input and the next key value in the one input is greater than the last key value of the other input; in such a case there can be no more matches and so no need to scan the rest of the first input. This results in not reading all of one child, with results like those mentioned for LIMIT. Also, if the outer (first) child contains rows with duplicate key values, the inner (second) child is backed up and rescanned for the portion of its rows matching that key value. EXPLAIN ANALYZE counts these repeated emissions of the same inner rows as if they were real additional rows. When there are many outer duplicates, the reported actual row count for the inner child plan node can be significantly larger than the number of rows that are actually in the inner relation.

BitmapAnd and BitmapOr nodes always report their actual row counts as zero, due to implementation limitations.

Generally, the EXPLAIN output will display details for every plan node which was generated by the query planner. However, there are cases where the executor is able to determine that certain nodes are not required; currently, the only node types to support this are the Append and MergeAppend nodes. These node types have the ability to discard subnodes which they are able to determine won't contain any records required by the query. It is possible to determine that nodes have been removed in this way by the presence of a "Subplans Removed" property in the EXPLAIN output.

14.2. Statistics Used by the Planner

14.2.1. Single-Column Statistics

As we saw in the previous section, the query planner needs to estimate the number of rows retrieved by a query in order to make good choices of query plans. This section provides a quick look at the statistics that the system uses for these estimates.

One component of the statistics is the total number of entries in each table and index, as well as the number of disk blocks occupied by each table and index. This information is kept in the table `pg_class`, in the columns `reltuples` and `relpages`. We can look at it with queries similar to this one:

```
SELECT relname, relkind, reltuples, relpages
FROM pg_class
WHERE relname LIKE 'tenk1%';
```

relname	relkind	reltuples	relpages
tenk1	r	10000	358
tenk1_hundred	i	10000	30
tenk1_thous_tenthous	i	10000	30
tenk1_unique1	i	10000	30
tenk1_unique2	i	10000	30

(5 rows)

Here we can see that `tenk1` contains 10000 rows, as do its indexes, but the indexes are (unsurprisingly) much smaller than the table.

For efficiency reasons, `reltuples` and `relpages` are not updated on-the-fly, and so they usually contain somewhat out-of-date values. They are updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`. A `VACUUM` or `ANALYZE` operation that does not scan the entire

table (which is commonly the case) will incrementally update the `reltuples` count on the basis of the part of the table it did scan, resulting in an approximate value. In any case, the planner will scale the values it finds in `pg_class` to match the current physical table size, thus obtaining a closer approximation.

Most queries retrieve only a fraction of the rows in a table, due to `WHERE` clauses that restrict the rows to be examined. The planner thus needs to make an estimate of the *selectivity* of `WHERE` clauses, that is, the fraction of rows that match each condition in the `WHERE` clause. The information used for this task is stored in the `pg_statistic` system catalog. Entries in `pg_statistic` are updated by the `ANALYZE` and `VACUUM ANALYZE` commands, and are always approximate even when freshly updated.

Rather than look at `pg_statistic` directly, it's better to look at its view `pg_stats` when examining the statistics manually. `pg_stats` is designed to be more easily readable. Furthermore, `pg_stats` is readable by all, whereas `pg_statistic` is only readable by a superuser. (This prevents unprivileged users from learning something about the contents of other people's tables from the statistics. The `pg_stats` view is restricted to show only rows about tables that the current user can read.) For example, we might do:

```
SELECT attname, inherited, n_distinct,
       array_to_string(most_common_vals, E'\n') as most_common_vals
FROM pg_stats
WHERE tablename = 'road';
```

attname	inherited	n_distinct	most_common_vals
name	f	-0.363388	I- 580
Ramp+			I- 880
Ramp+			Sp Railroad
+			I- 580
+			I- 680
Ramp			I- 680
name	t	-0.284859	I- 880
Ramp+			I- 580
Ramp+			I- 680
Ramp+			I- 580
+			I- 580
Ramp			State Hwy 13

(2 rows)

Note that two rows are displayed for the same column, one corresponding to the complete inheritance hierarchy starting at the `road` table (`inherited=t`), and another one including only the `road` table itself (`inherited=f`).

The amount of information stored in `pg_statistic` by `ANALYZE`, in particular the maximum number of entries in the `most_common_vals` and `histogram_bounds` arrays for each column, can be set on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command,

or globally by setting the `default_statistics_target` configuration variable. The default limit is presently 100 entries. Raising the limit might allow more accurate planner estimates to be made, particularly for columns with irregular data distributions, at the price of consuming more space in `pg_statistic` and slightly more time to compute the estimates. Conversely, a lower limit might be sufficient for columns with simple data distributions.

Further details about the planner's use of statistics can be found in Chapter 70.

14.2.2. Extended Statistics

It is common to see slow queries running bad execution plans because multiple columns used in the query clauses are correlated. The planner normally assumes that multiple conditions are independent of each other, an assumption that does not hold when column values are correlated. Regular statistics, because of their per-individual-column nature, cannot capture any knowledge about cross-column correlation. However, PostgreSQL has the ability to compute *multivariate statistics*, which can capture such information.

Because the number of possible column combinations is very large, it's impractical to compute multivariate statistics automatically. Instead, *extended statistics objects*, more often called just *statistics objects*, can be created to instruct the server to obtain statistics across interesting sets of columns.

Statistics objects are created using the `CREATE STATISTICS` command. Creation of such an object merely creates a catalog entry expressing interest in the statistics. Actual data collection is performed by `ANALYZE` (either a manual command, or background auto-analyze). The collected values can be examined in the `pg_statistic_ext_data` catalog.

`ANALYZE` computes extended statistics based on the same sample of table rows that it takes for computing regular single-column statistics. Since the sample size is increased by increasing the statistics target for the table or any of its columns (as described in the previous section), a larger statistics target will normally result in more accurate extended statistics, as well as more time spent calculating them.

The following subsections describe the kinds of extended statistics that are currently supported.

14.2.2.1. Functional Dependencies

The simplest kind of extended statistics tracks *functional dependencies*, a concept used in definitions of database normal forms. We say that column `b` is functionally dependent on column `a` if knowledge of the value of `a` is sufficient to determine the value of `b`, that is there are no two rows having the same value of `a` but different values of `b`. In a fully normalized database, functional dependencies should exist only on primary keys and superkeys. However, in practice many data sets are not fully normalized for various reasons; intentional denormalization for performance reasons is a common example. Even in a fully normalized database, there may be partial correlation between some columns, which can be expressed as partial functional dependency.

The existence of functional dependencies directly affects the accuracy of estimates in certain queries. If a query contains conditions on both the independent and the dependent column(s), the conditions on the dependent columns do not further reduce the result size; but without knowledge of the functional dependency, the query planner will assume that the conditions are independent, resulting in underestimating the result size.

To inform the planner about functional dependencies, `ANALYZE` can collect measurements of cross-column dependency. Assessing the degree of dependency between all sets of columns would be prohibitively expensive, so data collection is limited to those groups of columns appearing together in a statistics object defined with the `dependencies` option. It is advisable to create `dependencies` statistics only for column groups that are strongly correlated, to avoid unnecessary overhead in both `ANALYZE` and later query planning.

Here is an example of collecting functional-dependency statistics:

```

CREATE STATISTICS stts (dependencies) ON city, zip FROM zipcodes;

ANALYZE zipcodes;

SELECT stxname, stxkeys, stxddependencies
  FROM pg_statistic_ext join pg_statistic_ext_data on (oid =
  stxoid)
  WHERE stxname = 'stts';
 stxname | stxkeys | stxddependencies
-----+-----+-----
 stts   | 1 5    | {"1 => 5": 1.000000, "5 => 1": 0.423130}
(1 row)

```

Here it can be seen that column 1 (zip code) fully determines column 5 (city) so the coefficient is 1.0, while city only determines zip code about 42% of the time, meaning that there are many cities (58%) that are represented by more than a single ZIP code.

When computing the selectivity for a query involving functionally dependent columns, the planner adjusts the per-condition selectivity estimates using the dependency coefficients so as not to produce an underestimate.

14.2.2.1.1. Limitations of Functional Dependencies

Functional dependencies are currently only applied when considering simple equality conditions that compare columns to constant values. They are not used to improve estimates for equality conditions comparing two columns or comparing a column to an expression, nor for range clauses, LIKE or any other type of condition.

When estimating with functional dependencies, the planner assumes that conditions on the involved columns are compatible and hence redundant. If they are incompatible, the correct estimate would be zero rows, but that possibility is not considered. For example, given a query like

```

SELECT * FROM zipcodes WHERE city = 'San Francisco' AND zip =
'94105';

```

the planner will disregard the `city` clause as not changing the selectivity, which is correct. However, it will make the same assumption about

```

SELECT * FROM zipcodes WHERE city = 'San Francisco' AND zip =
'90210';

```

even though there will really be zero rows satisfying this query. Functional dependency statistics do not provide enough information to conclude that, however.

In many practical situations, this assumption is usually satisfied; for example, there might be a GUI in the application that only allows selecting compatible city and ZIP code values to use in a query. But if that's not the case, functional dependencies may not be a viable option.

14.2.2.2. Multivariate N-Distinct Counts

Single-column statistics store the number of distinct values in each column. Estimates of the number of distinct values when combining more than one column (for example, for `GROUP BY a, b`) are frequently wrong when the planner only has single-column statistical data, causing it to select bad plans.

To improve such estimates, `ANALYZE` can collect n-distinct statistics for groups of columns. As before, it's impractical to do this for every possible column grouping, so data is collected only for those

groups of columns appearing together in a statistics object defined with the `ndistinct` option. Data will be collected for each possible combination of two or more columns from the set of listed columns.

Continuing the previous example, the n-distinct counts in a table of ZIP codes might look like the following:

```
CREATE STATISTICS stts2 (ndistinct) ON city, state, zip FROM
zipcodes;

ANALYZE zipcodes;

SELECT stxkeys AS k, stxdndistinct AS nd
FROM pg_statistic_ext join pg_statistic_ext_data on (oid =
stxoid)
WHERE stxname = 'stts2';
-[ RECORD
1 ]-----
k | 1 2 5
nd | {"1, 2": 33178, "1, 5": 33178, "2, 5": 27435, "1, 2, 5":
33178}
(1 row)
```

This indicates that there are three combinations of columns that have 33178 distinct values: ZIP code and state; ZIP code and city; and ZIP code, city and state (the fact that they are all equal is expected given that ZIP code alone is unique in this table). On the other hand, the combination of city and state has only 27435 distinct values.

It's advisable to create `ndistinct` statistics objects only on combinations of columns that are actually used for grouping, and for which misestimation of the number of groups is resulting in bad plans. Otherwise, the `ANALYZE` cycles are just wasted.

14.2.2.3. Multivariate MCV Lists

Another type of statistics stored for each column are most-common value lists. This allows very accurate estimates for individual columns, but may result in significant misestimates for queries with conditions on multiple columns.

To improve such estimates, `ANALYZE` can collect MCV lists on combinations of columns. Similarly to functional dependencies and n-distinct coefficients, it's impractical to do this for every possible column grouping. Even more so in this case, as the MCV list (unlike functional dependencies and n-distinct coefficients) does store the common column values. So data is collected only for those groups of columns appearing together in a statistics object defined with the `mcv` option.

Continuing the previous example, the MCV list for a table of ZIP codes might look like the following (unlike for simpler types of statistics, a function is required for inspection of MCV contents):

```
CREATE STATISTICS stts3 (mcv) ON city, state FROM zipcodes;

ANALYZE zipcodes;

SELECT m.* FROM pg_statistic_ext join pg_statistic_ext_data on (oid
= stxoid),
pg_mcv_list_items(stxdmcv) m WHERE stxname =
'stts3';

index |          values          | nulls | frequency |
base_frequency
```

```

-----+-----+-----+-----
+-----
  0 | {Washington, DC}      | {f,f} | 0.003467 |
2.7e-05
  1 | {Apo, AE}              | {f,f} | 0.003067 |
1.9e-05
  2 | {Houston, TX}          | {f,f} | 0.002167 |
0.000133
  3 | {El Paso, TX}          | {f,f} | 0.002    |
0.000113
  4 | {New York, NY}         | {f,f} | 0.001967 |
0.000114
  5 | {Atlanta, GA}          | {f,f} | 0.001633 |
3.3e-05
  6 | {Sacramento, CA}       | {f,f} | 0.001433 |
7.8e-05
  7 | {Miami, FL}            | {f,f} | 0.0014   |
6e-05
  8 | {Dallas, TX}           | {f,f} | 0.001367 |
8.8e-05
  9 | {Chicago, IL}          | {f,f} | 0.001333 |
5.1e-05
  ...
(99 rows)

```

This indicates that the most common combination of city and state is Washington in DC, with actual frequency (in the sample) about 0.35%. The base frequency of the combination (as computed from the simple per-column frequencies) is only 0.0027%, resulting in two orders of magnitude under-estimates.

It's advisable to create MCV statistics objects only on combinations of columns that are actually used in conditions together, and for which misestimation of the number of groups is resulting in bad plans. Otherwise, the ANALYZE and planning cycles are just wasted.

14.3. Controlling the Planner with Explicit JOIN Clauses

It is possible to control the query planner to some extent by using the explicit JOIN syntax. To see why this matters, we first need some background.

In a simple join query, such as:

```
SELECT * FROM a, b, c WHERE a.id = b.id AND b.ref = c.id;
```

the planner is free to join the given tables in any order. For example, it could generate a query plan that joins A to B, using the WHERE condition `a.id = b.id`, and then joins C to this joined table, using the other WHERE condition. Or it could join B to C and then join A to that result. Or it could join A to C and then join them with B — but that would be inefficient, since the full Cartesian product of A and C would have to be formed, there being no applicable condition in the WHERE clause to allow optimization of the join. (All joins in the PostgreSQL executor happen between two input tables, so it's necessary to build up the result in one or another of these fashions.) The important point is that these different join possibilities give semantically equivalent results but might have hugely different execution costs. Therefore, the planner will explore all of them to try to find the most efficient query plan.

When a query only involves two or three tables, there aren't many join orders to worry about. But the number of possible join orders grows exponentially as the number of tables expands. Beyond ten or so

input tables it's no longer practical to do an exhaustive search of all the possibilities, and even for six or seven tables planning might take an annoyingly long time. When there are too many input tables, the PostgreSQL planner will switch from exhaustive search to a *genetic* probabilistic search through a limited number of possibilities. (The switch-over threshold is set by the `geqo_threshold` run-time parameter.) The genetic search takes less time, but it won't necessarily find the best possible plan.

When the query involves outer joins, the planner has less freedom than it does for plain (inner) joins. For example, consider:

```
SELECT * FROM a LEFT JOIN (b JOIN c ON (b.ref = c.id)) ON (a.id = b.id);
```

Although this query's restrictions are superficially similar to the previous example, the semantics are different because a row must be emitted for each row of A that has no matching row in the join of B and C. Therefore the planner has no choice of join order here: it must join B to C and then join A to that result. Accordingly, this query takes less time to plan than the previous query. In other cases, the planner might be able to determine that more than one join order is safe. For example, given:

```
SELECT * FROM a LEFT JOIN b ON (a.bid = b.id) LEFT JOIN c ON (a.cid = c.id);
```

it is valid to join A to either B or C first. Currently, only `FULL JOIN` completely constrains the join order. Most practical cases involving `LEFT JOIN` or `RIGHT JOIN` can be rearranged to some extent.

Explicit inner join syntax (`INNER JOIN`, `CROSS JOIN`, or unadorned `JOIN`) is semantically the same as listing the input relations in `FROM`, so it does not constrain the join order.

Even though most kinds of `JOIN` don't completely constrain the join order, it is possible to instruct the PostgreSQL query planner to treat all `JOIN` clauses as constraining the join order anyway. For example, these three queries are logically equivalent:

```
SELECT * FROM a, b, c WHERE a.id = b.id AND b.ref = c.id;
SELECT * FROM a CROSS JOIN b CROSS JOIN c WHERE a.id = b.id AND b.ref = c.id;
SELECT * FROM a JOIN (b JOIN c ON (b.ref = c.id)) ON (a.id = b.id);
```

But if we tell the planner to honor the `JOIN` order, the second and third take less time to plan than the first. This effect is not worth worrying about for only three tables, but it can be a lifesaver with many tables.

To force the planner to follow the join order laid out by explicit `JOINS`, set the `join_collapse_limit` run-time parameter to 1. (Other possible values are discussed below.)

You do not need to constrain the join order completely in order to cut search time, because it's OK to use `JOIN` operators within items of a plain `FROM` list. For example, consider:

```
SELECT * FROM a CROSS JOIN b, c, d, e WHERE ...;
```

With `join_collapse_limit = 1`, this forces the planner to join A to B before joining them to other tables, but doesn't constrain its choices otherwise. In this example, the number of possible join orders is reduced by a factor of 5.

Constraining the planner's search in this way is a useful technique both for reducing planning time and for directing the planner to a good query plan. If the planner chooses a bad join order by default, you can force it to choose a better order via `JOIN` syntax — assuming that you know of a better order, that is. Experimentation is recommended.

A closely related issue that affects planning time is collapsing of subqueries into their parent query. For example, consider:

```
SELECT *
FROM x, y,
      (SELECT * FROM a, b, c WHERE something) AS ss
WHERE somethingelse;
```

This situation might arise from use of a view that contains a join; the view's `SELECT` rule will be inserted in place of the view reference, yielding a query much like the above. Normally, the planner will try to collapse the subquery into the parent, yielding:

```
SELECT * FROM x, y, a, b, c WHERE something AND somethingelse;
```

This usually results in a better plan than planning the subquery separately. (For example, the outer `WHERE` conditions might be such that joining `X` to `A` first eliminates many rows of `A`, thus avoiding the need to form the full logical output of the subquery.) But at the same time, we have increased the planning time; here, we have a five-way join problem replacing two separate three-way join problems. Because of the exponential growth of the number of possibilities, this makes a big difference. The planner tries to avoid getting stuck in huge join search problems by not collapsing a subquery if more than `from_collapse_limit` `FROM` items would result in the parent query. You can trade off planning time against quality of plan by adjusting this run-time parameter up or down.

`from_collapse_limit` and `join_collapse_limit` are similarly named because they do almost the same thing: one controls when the planner will “flatten out” subqueries, and the other controls when it will flatten out explicit joins. Typically you would either set `join_collapse_limit` equal to `from_collapse_limit` (so that explicit joins and subqueries act similarly) or set `join_collapse_limit` to 1 (if you want to control join order with explicit joins). But you might set them differently if you are trying to fine-tune the trade-off between planning time and run time.

14.4. Populating a Database

One might need to insert a large amount of data when first populating a database. This section contains some suggestions on how to make this process as efficient as possible.

14.4.1. Disable Autocommit

When using multiple `INSERTs`, turn off autocommit and just do one commit at the end. (In plain SQL, this means issuing `BEGIN` at the start and `COMMIT` at the end. Some client libraries might do this behind your back, in which case you need to make sure the library does it when you want it done.) If you allow each insertion to be committed separately, PostgreSQL is doing a lot of work for each row that is added. An additional benefit of doing all insertions in one transaction is that if the insertion of one row were to fail then the insertion of all rows inserted up to that point would be rolled back, so you won't be stuck with partially loaded data.

14.4.2. Use COPY

Use `COPY` to load all the rows in one command, instead of using a series of `INSERT` commands. The `COPY` command is optimized for loading large numbers of rows; it is less flexible than `INSERT`, but incurs significantly less overhead for large data loads. Since `COPY` is a single command, there is no need to disable autocommit if you use this method to populate a table.

If you cannot use `COPY`, it might help to use `PREPARE` to create a prepared `INSERT` statement, and then use `EXECUTE` as many times as required. This avoids some of the overhead of repeatedly parsing and planning `INSERT`. Different interfaces provide this facility in different ways; look for “prepared statements” in the interface documentation.

Note that loading a large number of rows using `COPY` is almost always faster than using `INSERT`, even if `PREPARE` is used and multiple insertions are batched into a single transaction.

`COPY` is fastest when used within the same transaction as an earlier `CREATE TABLE` or `TRUNCATE` command. In such cases no WAL needs to be written, because in case of an error, the files containing the newly loaded data will be removed anyway. However, this consideration only applies when `wal_level` is `minimal` for non-partitioned tables as all commands must write WAL otherwise.

14.4.3. Remove Indexes

If you are loading a freshly created table, the fastest method is to create the table, bulk load the table's data using `COPY`, then create any indexes needed for the table. Creating an index on pre-existing data is quicker than updating it incrementally as each row is loaded.

If you are adding large amounts of data to an existing table, it might be a win to drop the indexes, load the table, and then recreate the indexes. Of course, the database performance for other users might suffer during the time the indexes are missing. One should also think twice before dropping a unique index, since the error checking afforded by the unique constraint will be lost while the index is missing.

14.4.4. Remove Foreign Key Constraints

Just as with indexes, a foreign key constraint can be checked “in bulk” more efficiently than row-by-row. So it might be useful to drop foreign key constraints, load data, and re-create the constraints. Again, there is a trade-off between data load speed and loss of error checking while the constraint is missing.

What's more, when you load data into a table with existing foreign key constraints, each new row requires an entry in the server's list of pending trigger events (since it is the firing of a trigger that checks the row's foreign key constraint). Loading many millions of rows can cause the trigger event queue to overflow available memory, leading to intolerable swapping or even outright failure of the command. Therefore it may be *necessary*, not just desirable, to drop and re-apply foreign keys when loading large amounts of data. If temporarily removing the constraint isn't acceptable, the only other recourse may be to split up the load operation into smaller transactions.

14.4.5. Increase `maintenance_work_mem`

Temporarily increasing the `maintenance_work_mem` configuration variable when loading large amounts of data can lead to improved performance. This will help to speed up `CREATE INDEX` commands and `ALTER TABLE ADD FOREIGN KEY` commands. It won't do much for `COPY` itself, so this advice is only useful when you are using one or both of the above techniques.

14.4.6. Increase `max_wal_size`

Temporarily increasing the `max_wal_size` configuration variable can also make large data loads faster. This is because loading a large amount of data into PostgreSQL will cause checkpoints to occur more often than the normal checkpoint frequency (specified by the `checkpoint_timeout` configuration variable). Whenever a checkpoint occurs, all dirty pages must be flushed to disk. By increasing `max_wal_size` temporarily during bulk data loads, the number of checkpoints that are required can be reduced.

14.4.7. Disable WAL Archival and Streaming Replication

When loading large amounts of data into an installation that uses WAL archiving or streaming replication, it might be faster to take a new base backup after the load has completed than to process a large amount of incremental WAL data. To prevent incremental WAL logging while loading, disable

archiving and streaming replication, by setting `wal_level` to `minimal`, `archive_mode` to `off`, and `max_wal_senders` to zero. But note that changing these settings requires a server restart.

Aside from avoiding the time for the archiver or WAL sender to process the WAL data, doing this will actually make certain commands faster, because they are designed not to write WAL at all if `wal_level` is `minimal`. (They can guarantee crash safety more cheaply by doing an `fsync` at the end than by writing WAL.) This applies to the following commands:

- `CREATE TABLE AS SELECT`
- `CREATE INDEX` (and variants such as `ALTER TABLE ADD PRIMARY KEY`)
- `ALTER TABLE SET TABLESPACE`
- `CLUSTER`
- `COPY FROM`, when the target table has been created or truncated earlier in the same transaction

14.4.8. Run `ANALYZE` Afterwards

Whenever you have significantly altered the distribution of data within a table, running `ANALYZE` is strongly recommended. This includes bulk loading large amounts of data into the table. Running `ANALYZE` (or `VACUUM ANALYZE`) ensures that the planner has up-to-date statistics about the table. With no statistics or obsolete statistics, the planner might make poor decisions during query planning, leading to poor performance on any tables with inaccurate or nonexistent statistics. Note that if the autovacuum daemon is enabled, it might run `ANALYZE` automatically; see Section 24.1.3 and Section 24.1.6 for more information.

14.4.9. Some Notes about `pg_dump`

Dump scripts generated by `pg_dump` automatically apply several, but not all, of the above guidelines. To reload a `pg_dump` dump as quickly as possible, you need to do a few extra things manually. (Note that these points apply while *restoring* a dump, not while *creating* it. The same points apply whether loading a text dump with `psql` or using `pg_restore` to load from a `pg_dump` archive file.)

By default, `pg_dump` uses `COPY`, and when it is generating a complete schema-and-data dump, it is careful to load data before creating indexes and foreign keys. So in this case several guidelines are handled automatically. What is left for you to do is to:

- Set appropriate (i.e., larger than normal) values for `maintenance_work_mem` and `max_wal_size`.
- If using WAL archiving or streaming replication, consider disabling them during the restore. To do that, set `archive_mode` to `off`, `wal_level` to `minimal`, and `max_wal_senders` to zero before loading the dump. Afterwards, set them back to the right values and take a fresh base backup.
- Experiment with the parallel dump and restore modes of both `pg_dump` and `pg_restore` and find the optimal number of concurrent jobs to use. Dumping and restoring in parallel by means of the `-j` option should give you a significantly higher performance over the serial mode.
- Consider whether the whole dump should be restored as a single transaction. To do that, pass the `-1` or `--single-transaction` command-line option to `psql` or `pg_restore`. When using this mode, even the smallest of errors will rollback the entire restore, possibly discarding many hours of processing. Depending on how interrelated the data is, that might seem preferable to manual cleanup, or not. `COPY` commands will run fastest if you use a single transaction and have WAL archiving turned off.
- If multiple CPUs are available in the database server, consider using `pg_restore`'s `--jobs` option. This allows concurrent data loading and index creation.

- Run `ANALYZE` afterwards.

A data-only dump will still use `COPY`, but it does not drop or recreate indexes, and it does not normally touch foreign keys.¹ So when loading a data-only dump, it is up to you to drop and recreate indexes and foreign keys if you wish to use those techniques. It's still useful to increase `max_wal_size` while loading the data, but don't bother increasing `maintenance_work_mem`; rather, you'd do that while manually recreating indexes and foreign keys afterwards. And don't forget to `ANALYZE` when you're done; see Section 24.1.3 and Section 24.1.6 for more information.

14.5. Non-Durable Settings

Durability is a database feature that guarantees the recording of committed transactions even if the server crashes or loses power. However, durability adds significant database overhead, so if your site does not require such a guarantee, PostgreSQL can be configured to run much faster. The following are configuration changes you can make to improve performance in such cases. Except as noted below, durability is still guaranteed in case of a crash of the database software; only abrupt operating system stoppage creates a risk of data loss or corruption when these settings are used.

- Place the database cluster's data directory in a memory-backed file system (i.e. RAM disk). This eliminates all database disk I/O, but limits data storage to the amount of available memory (and perhaps swap).
- Turn off `fsync`; there is no need to flush data to disk.
- Turn off `synchronous_commit`; there might be no need to force WAL writes to disk on every commit. This setting does risk transaction loss (though not data corruption) in case of a crash of the *database*.
- Turn off `full_page_writes`; there is no need to guard against partial page writes.
- Increase `max_wal_size` and `checkpoint_timeout`; this reduces the frequency of checkpoints, but increases the storage requirements of `/pg_wal`.
- Create unlogged tables to avoid WAL writes, though it makes the tables non-crash-safe.

¹ You can get the effect of disabling foreign keys by using the `--disable-triggers` option — but realize that that eliminates, rather than just postpones, foreign key validation, and so it is possible to insert bad data if you use it.

Chapter 15. Parallel Query

PostgreSQL can devise query plans which can leverage multiple CPUs in order to answer queries faster. This feature is known as parallel query. Many queries cannot benefit from parallel query, either due to limitations of the current implementation or because there is no imaginable query plan which is any faster than the serial query plan. However, for queries that can benefit, the speedup from parallel query is often very significant. Many queries can run more than twice as fast when using parallel query, and some queries can run four times faster or even more. Queries that touch a large amount of data but return only a few rows to the user will typically benefit most. This chapter explains some details of how parallel query works and in which situations it can be used so that users who wish to make use of it can understand what to expect.

15.1. How Parallel Query Works

When the optimizer determines that parallel query is the fastest execution strategy for a particular query, it will create a query plan which includes a *Gather* or *Gather Merge* node. Here is a simple example:

```
EXPLAIN SELECT * FROM pgbench_accounts WHERE filler LIKE '%x%';
                                QUERY PLAN
-----
Gather  (cost=1000.00..217018.43 rows=1 width=97)
  Workers Planned: 2
  -> Parallel Seq Scan on pgbench_accounts  (cost=0.00..216018.33
rows=1 width=97)
    Filter: (filler ~~ '%x%'::text)
(4 rows)
```

In all cases, the *Gather* or *Gather Merge* node will have exactly one child plan, which is the portion of the plan that will be executed in parallel. If the *Gather* or *Gather Merge* node is at the very top of the plan tree, then the entire query will execute in parallel. If it is somewhere else in the plan tree, then only the portion of the plan below it will run in parallel. In the example above, the query accesses only one table, so there is only one plan node other than the *Gather* node itself; since that plan node is a child of the *Gather* node, it will run in parallel.

Using `EXPLAIN`, you can see the number of workers chosen by the planner. When the *Gather* node is reached during query execution, the process which is implementing the user's session will request a number of background worker processes equal to the number of workers chosen by the planner. The number of background workers that the planner will consider using is limited to at most `max_parallel_workers_per_gather`. The total number of background workers that can exist at any one time is limited by both `max_worker_processes` and `max_parallel_workers`. Therefore, it is possible for a parallel query to run with fewer workers than planned, or even with no workers at all. The optimal plan may depend on the number of workers that are available, so this can result in poor query performance. If this occurrence is frequent, consider increasing `max_worker_processes` and `max_parallel_workers` so that more workers can be run simultaneously or alternatively reducing `max_parallel_workers_per_gather` so that the planner requests fewer workers.

Every background worker process which is successfully started for a given parallel query will execute the parallel portion of the plan. The leader will also execute that portion of the plan, but it has an additional responsibility: it must also read all of the tuples generated by the workers. When the parallel portion of the plan generates only a small number of tuples, the leader will often behave very much like an additional worker, speeding up query execution. Conversely, when the parallel portion of the plan generates a large number of tuples, the leader may be almost entirely occupied with reading the tuples generated by the workers and performing any further processing steps which are required by

plan nodes above the level of the `Gather` node or `Gather Merge` node. In such cases, the leader will do very little of the work of executing the parallel portion of the plan.

When the node at the top of the parallel portion of the plan is `Gather Merge` rather than `Gather`, it indicates that each process executing the parallel portion of the plan is producing tuples in sorted order, and that the leader is performing an order-preserving merge. In contrast, `Gather` reads tuples from the workers in whatever order is convenient, destroying any sort order that may have existed.

15.2. When Can Parallel Query Be Used?

There are several settings which can cause the query planner not to generate a parallel query plan under any circumstances. In order for any parallel query plans whatsoever to be generated, the following settings must be configured as indicated.

- `max_parallel_workers_per_gather` must be set to a value which is greater than zero. This is a special case of the more general principle that no more workers should be used than the number configured via `max_parallel_workers_per_gather`.

In addition, the system must not be running in single-user mode. Since the entire database system is running in single process in this situation, no background workers will be available.

Even when it is in general possible for parallel query plans to be generated, the planner will not generate them for a given query if any of the following are true:

- The query writes any data or locks any database rows. If a query contains a data-modifying operation either at the top level or within a CTE, no parallel plans for that query will be generated. As an exception, the commands `CREATE TABLE ... AS`, `SELECT INTO`, and `CREATE MATERIALIZED VIEW` which create a new table and populate it can use a parallel plan.
- The query might be suspended during execution. In any situation in which the system thinks that partial or incremental execution might occur, no parallel plan is generated. For example, a cursor created using `DECLARE CURSOR` will never use a parallel plan. Similarly, a PL/pgSQL loop of the form `FOR x IN query LOOP ... END LOOP` will never use a parallel plan, because the parallel query system is unable to verify that the code in the loop is safe to execute while parallel query is active.
- The query uses any function marked `PARALLEL UNSAFE`. Most system-defined functions are `PARALLEL SAFE`, but user-defined functions are marked `PARALLEL UNSAFE` by default. See the discussion of Section 15.4.
- The query is running inside of another query that is already parallel. For example, if a function called by a parallel query issues an SQL query itself, that query will never use a parallel plan. This is a limitation of the current implementation, but it may not be desirable to remove this limitation, since it could result in a single query using a very large number of processes.

Even when parallel query plan is generated for a particular query, there are several circumstances under which it will be impossible to execute that plan in parallel at execution time. If this occurs, the leader will execute the portion of the plan below the `Gather` node entirely by itself, almost as if the `Gather` node were not present. This will happen if any of the following conditions are met:

- No background workers can be obtained because of the limitation that the total number of background workers cannot exceed `max_worker_processes`.
- No background workers can be obtained because of the limitation that the total number of background workers launched for purposes of parallel query cannot exceed `max_parallel_workers`.
- The client sends an Execute message with a non-zero fetch count. See the discussion of the extended query protocol. Since `libpq` currently provides no way to send such a message, this can only occur when using a client that does not rely on `libpq`. If this is a frequent occurrence, it may be a good

idea to set `max_parallel_workers_per_gather` to zero in sessions where it is likely, so as to avoid generating query plans that may be suboptimal when run serially.

15.3. Parallel Plans

Because each worker executes the parallel portion of the plan to completion, it is not possible to simply take an ordinary query plan and run it using multiple workers. Each worker would produce a full copy of the output result set, so the query would not run any faster than normal but would produce incorrect results. Instead, the parallel portion of the plan must be what is known internally to the query optimizer as a *partial plan*; that is, it must be constructed so that each process which executes the plan will generate only a subset of the output rows in such a way that each required output row is guaranteed to be generated by exactly one of the cooperating processes. Generally, this means that the scan on the driving table of the query must be a parallel-aware scan.

15.3.1. Parallel Scans

The following types of parallel-aware table scans are currently supported.

- In a *parallel sequential scan*, the table's blocks will be divided among the cooperating processes. Blocks are handed out one at a time, so that access to the table remains sequential.
- In a *parallel bitmap heap scan*, one process is chosen as the leader. That process performs a scan of one or more indexes and builds a bitmap indicating which table blocks need to be visited. These blocks are then divided among the cooperating processes as in a parallel sequential scan. In other words, the heap scan is performed in parallel, but the underlying index scan is not.
- In a *parallel index scan* or *parallel index-only scan*, the cooperating processes take turns reading data from the index. Currently, parallel index scans are supported only for btree indexes. Each process will claim a single index block and will scan and return all tuples referenced by that block; other process can at the same time be returning tuples from a different index block. The results of a parallel btree scan are returned in sorted order within each worker process.

Other scan types, such as scans of non-btree indexes, may support parallel scans in the future.

15.3.2. Parallel Joins

Just as in a non-parallel plan, the driving table may be joined to one or more other tables using a nested loop, hash join, or merge join. The inner side of the join may be any kind of non-parallel plan that is otherwise supported by the planner provided that it is safe to run within a parallel worker. Depending on the join type, the inner side may also be a parallel plan.

- In a *nested loop join*, the inner side is always non-parallel. Although it is executed in full, this is efficient if the inner side is an index scan, because the outer tuples and thus the loops that look up values in the index are divided over the cooperating processes.
- In a *merge join*, the inner side is always a non-parallel plan and therefore executed in full. This may be inefficient, especially if a sort must be performed, because the work and resulting data are duplicated in every cooperating process.
- In a *hash join* (without the "parallel" prefix), the inner side is executed in full by every cooperating process to build identical copies of the hash table. This may be inefficient if the hash table is large or the plan is expensive. In a *parallel hash join*, the inner side is a *parallel hash* that divides the work of building a shared hash table over the cooperating processes.

15.3.3. Parallel Aggregation

PostgreSQL supports parallel aggregation by aggregating in two stages. First, each process participating in the parallel portion of the query performs an aggregation step, producing a partial result for each

group of which that process is aware. This is reflected in the plan as a `Partial Aggregate` node. Second, the partial results are transferred to the leader via `Gather` or `Gather Merge`. Finally, the leader re-aggregates the results across all workers in order to produce the final result. This is reflected in the plan as a `Finalize Aggregate` node.

Because the `Finalize Aggregate` node runs on the leader process, queries which produce a relatively large number of groups in comparison to the number of input rows will appear less favorable to the query planner. For example, in the worst-case scenario the number of groups seen by the `Finalize Aggregate` node could be as many as the number of input rows which were seen by all worker processes in the `Partial Aggregate` stage. For such cases, there is clearly going to be no performance benefit to using parallel aggregation. The query planner takes this into account during the planning process and is unlikely to choose parallel aggregate in this scenario.

Parallel aggregation is not supported in all situations. Each aggregate must be safe for parallelism and must have a combine function. If the aggregate has a transition state of type `internal`, it must have serialization and deserialization functions. See `CREATE AGGREGATE` for more details. Parallel aggregation is not supported if any aggregate function call contains `DISTINCT` or `ORDER BY` clause and is also not supported for ordered set aggregates or when the query involves `GROUPING SETS`. It can only be used when all joins involved in the query are also part of the parallel portion of the plan.

15.3.4. Parallel Append

Whenever PostgreSQL needs to combine rows from multiple sources into a single result set, it uses an `Append` or `MergeAppend` plan node. This commonly happens when implementing `UNION ALL` or when scanning a partitioned table. Such nodes can be used in parallel plans just as they can in any other plan. However, in a parallel plan, the planner may instead use a `Parallel Append` node.

When an `Append` node is used in a parallel plan, each process will execute the child plans in the order in which they appear, so that all participating processes cooperate to execute the first child plan until it is complete and then move to the second plan at around the same time. When a `Parallel Append` is used instead, the executor will instead spread out the participating processes as evenly as possible across its child plans, so that multiple child plans are executed simultaneously. This avoids contention, and also avoids paying the startup cost of a child plan in those processes that never execute it.

Also, unlike a regular `Append` node, which can only have partial children when used within a parallel plan, a `Parallel Append` node can have both partial and non-partial child plans. Non-partial children will be scanned by only a single process, since scanning them more than once would produce duplicate results. Plans that involve appending multiple results sets can therefore achieve coarse-grained parallelism even when efficient partial plans are not available. For example, consider a query against a partitioned table which can be only be implemented efficiently by using an index that does not support parallel scans. The planner might choose a `Parallel Append` of regular `Index Scan` plans; each individual index scan would have to be executed to completion by a single process, but different scans could be performed at the same time by different processes.

`enable_parallel_append` can be used to disable this feature.

15.3.5. Parallel Plan Tips

If a query that is expected to do so does not produce a parallel plan, you can try reducing `parallel_setup_cost` or `parallel_tuple_cost`. Of course, this plan may turn out to be slower than the serial plan which the planner preferred, but this will not always be the case. If you don't get a parallel plan even with very small values of these settings (e.g. after setting them both to zero), there may be some reason why the query planner is unable to generate a parallel plan for your query. See Section 15.2 and Section 15.4 for information on why this may be the case.

When executing a parallel plan, you can use `EXPLAIN (ANALYZE, VERBOSE)` to display per-worker statistics for each plan node. This may be useful in determining whether the work is being evenly distributed between all plan nodes and more generally in understanding the performance characteristics of the plan.

15.4. Parallel Safety

The planner classifies operations involved in a query as either *parallel safe*, *parallel restricted*, or *parallel unsafe*. A parallel safe operation is one which does not conflict with the use of parallel query. A parallel restricted operation is one which cannot be performed in a parallel worker, but which can be performed in the leader while parallel query is in use. Therefore, parallel restricted operations can never occur below a `Gather` or `Gather Merge` node, but can occur elsewhere in a plan which contains such a node. A parallel unsafe operation is one which cannot be performed while parallel query is in use, not even in the leader. When a query contains anything which is parallel unsafe, parallel query is completely disabled for that query.

The following operations are always parallel restricted.

- Scans of common table expressions (CTEs).
- Scans of temporary tables.
- Scans of foreign tables, unless the foreign data wrapper has an `IsForeignScanParallelSafe` API which indicates otherwise.
- Plan nodes to which an `InitPlan` is attached.
- Plan nodes which reference a correlated `SubPlan`.

15.4.1. Parallel Labeling for Functions and Aggregates

The planner cannot automatically determine whether a user-defined function or aggregate is parallel safe, parallel restricted, or parallel unsafe, because this would require predicting every operation which the function could possibly perform. In general, this is equivalent to the Halting Problem and therefore impossible. Even for simple functions where it could conceivably be done, we do not try, since this would be expensive and error-prone. Instead, all user-defined functions are assumed to be parallel unsafe unless otherwise marked. When using `CREATE FUNCTION` or `ALTER FUNCTION`, markings can be set by specifying `PARALLEL SAFE`, `PARALLEL RESTRICTED`, or `PARALLEL UNSAFE` as appropriate. When using `CREATE AGGREGATE`, the `PARALLEL` option can be specified with `SAFE`, `RESTRICTED`, or `UNSAFE` as the corresponding value.

Functions and aggregates must be marked `PARALLEL UNSAFE` if they write to the database, access sequences, change the transaction state even temporarily (e.g. a PL/pgSQL function which establishes an `EXCEPTION` block to catch errors), or make persistent changes to settings. Similarly, functions must be marked `PARALLEL RESTRICTED` if they access temporary tables, client connection state, cursors, prepared statements, or miscellaneous backend-local state which the system cannot synchronize across workers. For example, `setseed` and `random` are parallel restricted for this last reason.

In general, if a function is labeled as being safe when it is restricted or unsafe, or if it is labeled as being restricted when it is in fact unsafe, it may throw errors or produce wrong answers when used in a parallel query. C-language functions could in theory exhibit totally undefined behavior if mislabeled, since there is no way for the system to protect itself against arbitrary C code, but in most likely cases the result will be no worse than for any other function. If in doubt, it is probably best to label functions as `UNSAFE`.

If a function executed within a parallel worker acquires locks which are not held by the leader, for example by querying a table not referenced in the query, those locks will be released at worker exit, not end of transaction. If you write a function which does this, and this behavior difference is important to you, mark such functions as `PARALLEL RESTRICTED` to ensure that they execute only in the leader.

Note that the query planner does not consider deferring the evaluation of parallel-restricted functions or aggregates involved in the query in order to obtain a superior plan. So, for example, if a `WHERE` clause applied to a particular table is parallel restricted, the query planner will not consider performing a scan of that table in the parallel portion of a plan. In some cases, it would be possible (and perhaps even

efficient) to include the scan of that table in the parallel portion of the query and defer the evaluation of the `WHERE` clause so that it happens above the `Gather` node. However, the planner does not do this.

Part III. Server Administration

This part covers topics that are of interest to a PostgreSQL database administrator. This includes installation of the software, set up and configuration of the server, management of users and databases, and maintenance tasks. Anyone who runs a PostgreSQL server, even for personal use, but especially in production, should be familiar with the topics covered in this part.

The information in this part is arranged approximately in the order in which a new user should read it. But the chapters are self-contained and can be read individually as desired. The information in this part is presented in a narrative fashion in topical units. Readers looking for a complete description of a particular command should see Part VI.

The first few chapters are written so they can be understood without prerequisite knowledge, so new users who need to set up their own server can begin their exploration with this part. The rest of this part is about tuning and management; that material assumes that the reader is familiar with the general use of the PostgreSQL database system. Readers are encouraged to look at Part I and Part II for additional information.

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Chapter 16. Installation from Source Code

This chapter describes the installation of PostgreSQL using the source code distribution. If you are installing a pre-packaged distribution, such as an RPM or Debian package, ignore this chapter and read the packager's instructions instead.

If you are building PostgreSQL for Microsoft Windows, read this chapter if you intend to build with MinGW or Cygwin; but if you intend to build with Microsoft's Visual C++, see Chapter 17 instead.

16.1. Short Version

```
./configure
make
su
make install
adduser postgres
mkdir /usr/local/pgsql/data
chown postgres /usr/local/pgsql/data
su - postgres
/usr/local/pgsql/bin/initdb -D /usr/local/pgsql/data
/usr/local/pgsql/bin/pg_ctl -D /usr/local/pgsql/data -l logfile
start
/usr/local/pgsql/bin/createdb test
/usr/local/pgsql/bin/psql test
```

The long version is the rest of this chapter.

16.2. Requirements

In general, a modern Unix-compatible platform should be able to run PostgreSQL. The platforms that had received specific testing at the time of release are described in Section 16.6 below.

The following software packages are required for building PostgreSQL:

- GNU make version 3.80 or newer is required; other make programs or older GNU make versions will *not* work. (GNU make is sometimes installed under the name `gmake`.) To test for GNU make enter:

```
make --version
```

- You need an ISO/ANSI C compiler (at least C99-compliant). Recent versions of GCC are recommended, but PostgreSQL is known to build using a wide variety of compilers from different vendors.
- tar is required to unpack the source distribution, in addition to either `gzip` or `bzip2`.
- The GNU Readline library is used by default. It allows `psql` (the PostgreSQL command line SQL interpreter) to remember each command you type, and allows you to use arrow keys to recall and edit previous commands. This is very helpful and is strongly recommended. If you don't want to use it then you must specify the `--without-readline` option to `configure`. As an alternative, you can often use the BSD-licensed `libedit` library, originally developed on NetBSD. The `libedit` library is GNU Readline-compatible and is used if `libreadline` is not found, or if `--with-libedit-preferred` is used as an option to `configure`. If you are using a package-based Linux distribution, be aware that you need both the `readline` and `readline-devel` packages, if those are separate in your distribution.

- The zlib compression library is used by default. If you don't want to use it then you must specify the `--without-zlib` option to `configure`. Using this option disables support for compressed archives in `pg_dump` and `pg_restore`.

The following packages are optional. They are not required in the default configuration, but they are needed when certain build options are enabled, as explained below:

- To build the server programming language PL/Perl you need a full Perl installation, including the `libperl` library and the header files. The minimum required version is Perl 5.8.3. Since PL/Perl will be a shared library, the `libperl` library must be a shared library also on most platforms. This appears to be the default in recent Perl versions, but it was not in earlier versions, and in any case it is the choice of whomever installed Perl at your site. `configure` will fail if building PL/Perl is selected but it cannot find a shared `libperl`. In that case, you will have to rebuild and install Perl manually to be able to build PL/Perl. During the configuration process for Perl, request a shared library.

If you intend to make more than incidental use of PL/Perl, you should ensure that the Perl installation was built with the `usemultiplicity` option enabled (`perl -V` will show whether this is the case).

- To build the PL/Python server programming language, you need a Python installation with the header files and the `distutils` module. The minimum required version is Python 2.4. Python 3 is supported if it's version 3.1 or later; but see Section 45.1 when using Python 3.

Since PL/Python will be a shared library, the `libpython` library must be a shared library also on most platforms. This is not the case in a default Python installation built from source, but a shared library is available in many operating system distributions. `configure` will fail if building PL/Python is selected but it cannot find a shared `libpython`. That might mean that you either have to install additional packages or rebuild (part of) your Python installation to provide this shared library. When building from source, run Python's `configure` with the `--enable-shared` flag.

- To build the PL/Tcl procedural language, you of course need a Tcl installation. The minimum required version is Tcl 8.4.
- To enable Native Language Support (NLS), that is, the ability to display a program's messages in a language other than English, you need an implementation of the Gettext API. Some operating systems have this built-in (e.g., Linux, NetBSD, Solaris), for other systems you can download an add-on package from <http://www.gnu.org/software/gettext/>. If you are using the Gettext implementation in the GNU C library then you will additionally need the GNU Gettext package for some utility programs. For any of the other implementations you will not need it.
- You need OpenSSL, if you want to support encrypted client connections. OpenSSL is also required for random number generation on platforms that do not have `/dev/urandom` (except Windows). The minimum version required is 0.9.8.
- You need Kerberos, OpenLDAP, and/or PAM, if you want to support authentication using those services.
- To build the PostgreSQL documentation, there is a separate set of requirements; see Section J.2.

If you are building from a Git tree instead of using a released source package, or if you want to do server development, you also need the following packages:

- Flex and Bison are needed to build from a Git checkout, or if you changed the actual scanner and parser definition files. If you need them, be sure to get Flex 2.5.31 or later and Bison 1.875 or later. Other lex and yacc programs cannot be used.
- Perl 5.8.3 or later is needed to build from a Git checkout, or if you changed the input files for any of the build steps that use Perl scripts. If building on Windows you will need Perl in any case. Perl is also required to run some test suites.

If you need to get a GNU package, you can find it at your local GNU mirror site (see <https://www.gnu.org/prep/ftp> for a list) or at <ftp://ftp.gnu.org/gnu/>.

Also check that you have sufficient disk space. You will need about 100 MB for the source tree during compilation and about 20 MB for the installation directory. An empty database cluster takes about 35 MB; databases take about five times the amount of space that a flat text file with the same data would take. If you are going to run the regression tests you will temporarily need up to an extra 150 MB. Use the `df` command to check free disk space.

16.3. Getting the Source

The PostgreSQL 12.1 sources can be obtained from the download section of our website: <https://www.postgresql.org/download/>. You should get a file named `postgresql-12.1.tar.gz` or `postgresql-12.1.tar.bz2`. After you have obtained the file, unpack it:

```
gunzip postgresql-12.1.tar.gz
tar xf postgresql-12.1.tar
```

(Use `bunzip2` instead of `gunzip` if you have the `.bz2` file.) This will create a directory `postgresql-12.1` under the current directory with the PostgreSQL sources. Change into that directory for the rest of the installation procedure.

You can also get the source directly from the version control repository, see Appendix I.

16.4. Installation Procedure

1. Configuration

The first step of the installation procedure is to configure the source tree for your system and choose the options you would like. This is done by running the `configure` script. For a default installation simply enter:

```
./configure
```

This script will run a number of tests to determine values for various system dependent variables and detect any quirks of your operating system, and finally will create several files in the build tree to record what it found. You can also run `configure` in a directory outside the source tree, if you want to keep the build directory separate. This procedure is also called a *VPATH* build. Here's how:

```
mkdir build_dir
cd build_dir
/path/to/source/tree/configure [options go here]
make
```

The default configuration will build the server and utilities, as well as all client applications and interfaces that require only a C compiler. All files will be installed under `/usr/local/pgsql` by default.

You can customize the build and installation process by supplying one or more of the following command line options to `configure`:

```
--prefix=PREFIX
```

Install all files under the directory `PREFIX` instead of `/usr/local/pgsql`. The actual files will be installed into various subdirectories; no files will ever be installed directly into the `PREFIX` directory.

If you have special needs, you can also customize the individual subdirectories with the following options. However, if you leave these with their defaults, the installation will be relocatable, meaning you can move the directory after installation. (The `man` and `doc` locations are not affected by this.)

For relocatable installs, you might want to use `configure`'s `--disable-rpath` option. Also, you will need to tell the operating system how to find the shared libraries.

`--exec-prefix=EXEC-PREFIX`

You can install architecture-dependent files under a different prefix, `EXEC-PREFIX`, than what `PREFIX` was set to. This can be useful to share architecture-independent files between hosts. If you omit this, then `EXEC-PREFIX` is set equal to `PREFIX` and both architecture-dependent and independent files will be installed under the same tree, which is probably what you want.

`--bindir=DIRECTORY`

Specifies the directory for executable programs. The default is `EXEC-PREFIX/bin`, which normally means `/usr/local/pgsql/bin`.

`--sysconfdir=DIRECTORY`

Sets the directory for various configuration files, `PREFIX/etc` by default.

`--libdir=DIRECTORY`

Sets the location to install libraries and dynamically loadable modules. The default is `EXEC-PREFIX/lib`.

`--includedir=DIRECTORY`

Sets the directory for installing C and C++ header files. The default is `PREFIX/include`.

`--datarootdir=DIRECTORY`

Sets the root directory for various types of read-only data files. This only sets the default for some of the following options. The default is `PREFIX/share`.

`--datadir=DIRECTORY`

Sets the directory for read-only data files used by the installed programs. The default is `DATAROOTDIR`. Note that this has nothing to do with where your database files will be placed.

`--localedir=DIRECTORY`

Sets the directory for installing locale data, in particular message translation catalog files. The default is `DATAROOTDIR/locale`.

`--mandir=DIRECTORY`

The man pages that come with PostgreSQL will be installed under this directory, in their respective `manx` subdirectories. The default is `DATAROOTDIR/man`.

`--docdir=DIRECTORY`

Sets the root directory for installing documentation files, except “man” pages. This only sets the default for the following options. The default value for this option is `DATAROOTDIR/doc/postgresql`.

`--htmldir=DIRECTORY`

The HTML-formatted documentation for PostgreSQL will be installed under this directory. The default is `DATAROOTDIR`.

Note

Care has been taken to make it possible to install PostgreSQL into shared installation locations (such as `/usr/local/include`) without interfering with the namespace of the rest of the system. First, the string `"/postgresql"` is automatically appended to `datadir`, `sysconfdir`, and `docdir`, unless the fully expanded directory name already contains the string `"postgres"` or `"pgsql"`. For example, if you choose `/usr/local` as prefix, the documentation will be installed in `/usr/local/doc/postgresql`, but if the prefix is `/opt/postgres`, then it will be in `/opt/postgres/doc`. The public C header files of the client interfaces are installed into `includedir` and are namespace-clean. The internal header files and the server header files are installed into private directories under `includedir`. See the documentation of each interface for information about how to access its header files. Finally, a private subdirectory will also be created, if appropriate, under `libdir` for dynamically loadable modules.

`--with-extra-version=STRING`

Append `STRING` to the PostgreSQL version number. You can use this, for example, to mark binaries built from unreleased Git snapshots or containing custom patches with an extra version string such as a `git describe` identifier or a distribution package release number.

`--with-includes=DIRECTORIES`

`DIRECTORIES` is a colon-separated list of directories that will be added to the list the compiler searches for header files. If you have optional packages (such as GNU Readline) installed in a non-standard location, you have to use this option and probably also the corresponding `--with-libraries` option.

Example: `--with-includes=/opt/gnu/include:/usr/sup/include`.

`--with-libraries=DIRECTORIES`

`DIRECTORIES` is a colon-separated list of directories to search for libraries. You will probably have to use this option (and the corresponding `--with-includes` option) if you have packages installed in non-standard locations.

Example: `--with-libraries=/opt/gnu/lib:/usr/sup/lib`.

`--enable-nls [=LANGUAGES]`

Enables Native Language Support (NLS), that is, the ability to display a program's messages in a language other than English. `LANGUAGES` is an optional space-separated list of codes of the languages that you want supported, for example `--enable-nls='de fr'`. (The intersection between your list and the set of actually provided translations will be computed automatically.) If you do not specify a list, then all available translations are installed.

To use this option, you will need an implementation of the Gettext API; see above.

`--with-pgport=NUMBER`

Set *NUMBER* as the default port number for server and clients. The default is 5432. The port can always be changed later on, but if you specify it here then both server and clients will have the same default compiled in, which can be very convenient. Usually the only good reason to select a non-default value is if you intend to run multiple PostgreSQL servers on the same machine.

`--with-perl`

Build the PL/Perl server-side language.

`--with-python`

Build the PL/Python server-side language.

`--with-tcl`

Build the PL/Tcl server-side language.

`--with-tclconfig=DIRECTORY`

Tcl installs the file `tclConfig.sh`, which contains configuration information needed to build modules interfacing to Tcl. This file is normally found automatically at a well-known location, but if you want to use a different version of Tcl you can specify the directory in which to look for it.

`--with-gssapi`

Build with support for GSSAPI authentication. On many systems, the GSSAPI (usually a part of the Kerberos installation) system is not installed in a location that is searched by default (e.g., `/usr/include`, `/usr/lib`), so you must use the options `--with-includes` and `--with-libraries` in addition to this option. `configure` will check for the required header files and libraries to make sure that your GSSAPI installation is sufficient before proceeding.

`--with-krb-srvnam=NAME`

The default name of the Kerberos service principal used by GSSAPI. `postgres` is the default. There's usually no reason to change this unless you have a Windows environment, in which case it must be set to upper case `POSTGRES`.

`--with-llvm`

Build with support for LLVM based JIT compilation (see Chapter 31). This requires the LLVM library to be installed. The minimum required version of LLVM is currently 3.9.

`llvm-config` will be used to find the required compilation options. `llvm-config`, and then `llvm-config-$major-$minor` for all supported versions, will be searched on `PATH`. If that would not yield the correct binary, use `LLVM_CONFIG` to specify a path to the correct `llvm-config`. For example

```
./configure ... --with-llvm LLVM_CONFIG='/path/to/llvm/bin/
llvm-config'
```

LLVM support requires a compatible `clang` compiler (specified, if necessary, using the `CLANG` environment variable), and a working C++ compiler (specified, if necessary, using the `CXX` environment variable).

`--with-icu`

Build with support for the ICU library. This requires the ICU4C package to be installed. The minimum required version of ICU4C is currently 4.2.

By default, `pkg-config` will be used to find the required compilation options. This is supported for ICU4C version 4.6 and later. For older versions, or if `pkg-config` is not available, the variables `ICU_CFLAGS` and `ICU_LIBS` can be specified to `configure`, like in this example:

```
./configure ... --with-icu ICU_CFLAGS='-I/some/where/
include' ICU_LIBS='-L/some/where/lib -licui18n -licuuc -
licudata'
```

(If ICU4C is in the default search path for the compiler, then you still need to specify a nonempty string in order to avoid use of `pkg-config`, for example, `ICU_CFLAGS=' '`.)

`--with-openssl`

Build with support for SSL (encrypted) connections. This requires the OpenSSL package to be installed. `configure` will check for the required header files and libraries to make sure that your OpenSSL installation is sufficient before proceeding.

`--with-pam`

Build with PAM (Pluggable Authentication Modules) support.

`--with-bsd-auth`

Build with BSD Authentication support. (The BSD Authentication framework is currently only available on OpenBSD.)

`--with-ldap`

Build with LDAP support for authentication and connection parameter lookup (see Section 33.17 and Section 20.10 for more information). On Unix, this requires the OpenLDAP package to be installed. On Windows, the default WinLDAP library is used. `configure` will check for the required header files and libraries to make sure that your OpenLDAP installation is sufficient before proceeding.

`--with-systemd`

Build with support for `systemd` service notifications. This improves integration if the server binary is started under `systemd` but has no impact otherwise; see Section 18.3 for more information. `libsystemd` and the associated header files need to be installed to be able to use this option.

`--without-readline`

Prevents use of the Readline library (and `libedit` as well). This option disables command-line editing and history in `psql`, so it is not recommended.

`--with-libedit-preferred`

Favors the use of the BSD-licensed `libedit` library rather than GPL-licensed Readline. This option is significant only if you have both libraries installed; the default in that case is to use Readline.

`--with-bonjour`

Build with Bonjour support. This requires Bonjour support in your operating system. Recommended on macOS.

`--with-uuid=LIBRARY`

Build the `uuid-oss` module (which provides functions to generate UUIDs), using the specified UUID library. `LIBRARY` must be one of:

- `bsd` to use the UUID functions found in FreeBSD, NetBSD, and some other BSD-derived systems
- `e2fs` to use the UUID library created by the `e2fsprogs` project; this library is present in most Linux systems and in macOS, and can be obtained for other platforms as well
- `oss` to use the OSSP UUID library¹

`--with-oss-uuid`

Obsolete equivalent of `--with-uuid=oss`.

`--with-libxml`

Build with `libxml` (enables SQL/XML support). `Libxml` version 2.6.23 or later is required for this feature.

`Libxml` installs a program `xml2-config` that can be used to detect the required compiler and linker options. PostgreSQL will use it automatically if found. To specify a `libxml` installation at an unusual location, you can either set the environment variable `XML2_CONFIG` to point to the `xml2-config` program belonging to the installation, or use the options `--with-includes` and `--with-libraries`.

`--with-libxslt`

Use `libxslt` when building the `xml2` module. `xml2` relies on this library to perform XSL transformations of XML.

`--disable-float4-byval`

Disable passing `float4` values “by value”, causing them to be passed “by reference” instead. This option costs performance, but may be needed for compatibility with old user-defined functions that are written in C and use the “version 0” calling convention. A better long-term solution is to update any such functions to use the “version 1” calling convention.

`--disable-float8-byval`

Disable passing `float8` values “by value”, causing them to be passed “by reference” instead. This option costs performance, but may be needed for compatibility with old user-defined functions that are written in C and use the “version 0” calling convention. A better long-term solution is to update any such functions to use the “version 1” calling convention. Note that this option affects not only `float8`, but also `int8` and some related types such as `timestamp`. On 32-bit platforms, `--disable-float8-byval` is the default and it is not allowed to select `--enable-float8-byval`.

¹ <http://www.oss.org/pkg/lib/uuid/>

`--with-segsize=SEGSIZE`

Set the *segment size*, in gigabytes. Large tables are divided into multiple operating-system files, each of size equal to the segment size. This avoids problems with file size limits that exist on many platforms. The default segment size, 1 gigabyte, is safe on all supported platforms. If your operating system has “largefile” support (which most do, nowadays), you can use a larger segment size. This can be helpful to reduce the number of file descriptors consumed when working with very large tables. But be careful not to select a value larger than is supported by your platform and the file systems you intend to use. Other tools you might wish to use, such as tar, could also set limits on the usable file size. It is recommended, though not absolutely required, that this value be a power of 2. Note that changing this value requires an `initdb`.

`--with-blocksize=BLOCKSIZE`

Set the *block size*, in kilobytes. This is the unit of storage and I/O within tables. The default, 8 kilobytes, is suitable for most situations; but other values may be useful in special cases. The value must be a power of 2 between 1 and 32 (kilobytes). Note that changing this value requires an `initdb`.

`--with-wal-blocksize=BLOCKSIZE`

Set the *WAL block size*, in kilobytes. This is the unit of storage and I/O within the WAL log. The default, 8 kilobytes, is suitable for most situations; but other values may be useful in special cases. The value must be a power of 2 between 1 and 64 (kilobytes). Note that changing this value requires an `initdb`.

`--disable-spinlocks`

Allow the build to succeed even if PostgreSQL has no CPU spinlock support for the platform. The lack of spinlock support will result in poor performance; therefore, this option should only be used if the build aborts and informs you that the platform lacks spinlock support. If this option is required to build PostgreSQL on your platform, please report the problem to the PostgreSQL developers.

`--disable-thread-safety`

Disable the thread-safety of client libraries. This prevents concurrent threads in `libpq` and ECPG programs from safely controlling their private connection handles.

`--with-system-tzdata=DIRECTORY`

PostgreSQL includes its own time zone database, which it requires for date and time operations. This time zone database is in fact compatible with the IANA time zone database provided by many operating systems such as FreeBSD, Linux, and Solaris, so it would be redundant to install it again. When this option is used, the system-supplied time zone database in `DIRECTORY` is used instead of the one included in the PostgreSQL source distribution. `DIRECTORY` must be specified as an absolute path. `/usr/share/zoneinfo` is a likely directory on some operating systems. Note that the installation routine will not detect mismatching or erroneous time zone data. If you use this option, you are advised to run the regression tests to verify that the time zone data you have pointed to works correctly with PostgreSQL.

This option is mainly aimed at binary package distributors who know their target operating system well. The main advantage of using this option is that the PostgreSQL package won't need to be upgraded whenever any of the many local daylight-saving time rules change. Another advantage is that PostgreSQL can be cross-compiled more straightforwardly if the time zone database files do not need to be built during the installation.

`--without-zlib`

Prevents use of the Zlib library. This disables support for compressed archives in `pg_dump` and `pg_restore`. This option is only intended for those rare systems where this library is not available.

`--enable-debug`

Compiles all programs and libraries with debugging symbols. This means that you can run the programs in a debugger to analyze problems. This enlarges the size of the installed executables considerably, and on non-GCC compilers it usually also disables compiler optimization, causing slowdowns. However, having the symbols available is extremely helpful for dealing with any problems that might arise. Currently, this option is recommended for production installations only if you use GCC. But you should always have it on if you are doing development work or running a beta version.

`--enable-coverage`

If using GCC, all programs and libraries are compiled with code coverage testing instrumentation. When run, they generate files in the build directory with code coverage metrics. See Section 32.5 for more information. This option is for use only with GCC and when doing development work.

`--enable-profiling`

If using GCC, all programs and libraries are compiled so they can be profiled. On backend exit, a subdirectory will be created that contains the `gmon.out` file for use in profiling. This option is for use only with GCC and when doing development work.

`--enable-cassert`

Enables *assertion* checks in the server, which test for many “cannot happen” conditions. This is invaluable for code development purposes, but the tests can slow down the server significantly. Also, having the tests turned on won't necessarily enhance the stability of your server! The assertion checks are not categorized for severity, and so what might be a relatively harmless bug will still lead to server restarts if it triggers an assertion failure. This option is not recommended for production use, but you should have it on for development work or when running a beta version.

`--enable-depend`

Enables automatic dependency tracking. With this option, the makefiles are set up so that all affected object files will be rebuilt when any header file is changed. This is useful if you are doing development work, but is just wasted overhead if you intend only to compile once and install. At present, this option only works with GCC.

`--enable-dtrace`

Compiles PostgreSQL with support for the dynamic tracing tool DTrace. See Section 27.5 for more information.

To point to the `dtrace` program, the environment variable `DTRACE` can be set. This will often be necessary because `dtrace` is typically installed under `/usr/sbin`, which might not be in the path.

Extra command-line options for the `dtrace` program can be specified in the environment variable `DTRACEFLAGS`. On Solaris, to include DTrace support in a 64-bit binary, you must specify `DTRACEFLAGS=" -64 "` to configure. For example, using the GCC compiler:

```
./configure CC='gcc -m64' --enable-dtrace
DTRACEFLAGS='-64' ...
```

Using Sun's compiler:

```
./configure CC='/opt/SUNWspro/bin/cc -xtarget=native64' --
enable-dtrace DTRACEFLAGS='-64' ...
```

`--enable-tap-tests`

Enable tests using the Perl TAP tools. This requires a Perl installation and the Perl module `IPC::Run`. See Section 32.4 for more information.

If you prefer a C compiler different from the one `configure` picks, you can set the environment variable `CC` to the program of your choice. By default, `configure` will pick `gcc` if available, else the platform's default (usually `cc`). Similarly, you can override the default compiler flags if needed with the `CFLAGS` variable.

You can specify environment variables on the `configure` command line, for example:

```
./configure CC=/opt/bin/gcc CFLAGS='-O2 -pipe'
```

Here is a list of the significant variables that can be set in this manner:

BISON

Bison program

CC

C compiler

CFLAGS

options to pass to the C compiler

CLANG

path to `clang` program used to process source code for inlining when compiling with `--with-llvm`

CPP

C preprocessor

CPPFLAGS

options to pass to the C preprocessor

CXX

C++ compiler

CXXFLAGS

options to pass to the C++ compiler

DTRACE

location of the `dtrace` program

DTRACEFLAGS

options to pass to the `dtrace` program

FLEX

Flex program

LDFLAGS

options to use when linking either executables or shared libraries

LDFLAGS_EX

additional options for linking executables only

LDFLAGS_SL

additional options for linking shared libraries only

LLVM_CONFIG

`llvm-config` program used to locate the LLVM installation.

MSGFMT

`msgfmt` program for native language support

PERL

Perl interpreter program. This will be used to determine the dependencies for building PL/Perl. The default is `perl`.

PYTHON

Python interpreter program. This will be used to determine the dependencies for building PL/Python. Also, whether Python 2 or 3 is specified here (or otherwise implicitly chosen) determines which variant of the PL/Python language becomes available. See Section 45.1 for more information. If this is not set, the following are probed in this order: `python` `python3` `python2`.

TCLSH

Tcl interpreter program. This will be used to determine the dependencies for building PL/Tcl, and it will be substituted into Tcl scripts.

XML2_CONFIG

`xml2-config` program used to locate the libxml installation.

Sometimes it is useful to add compiler flags after-the-fact to the set that were chosen by `configure`. An important example is that `gcc's -Werror` option cannot be included in the `CFLAGS` passed to `configure`, because it will break many of `configure's` built-in tests. To add such flags, include them in the `COPT` environment variable while running `make`. The contents of `COPT` are added to both the `CFLAGS` and `LDFLAGS` options set up by `configure`. For example, you could do

```
make COPT='-Werror'
```

or

```
export COPT='-Werror'  
make
```

Note

When developing code inside the server, it is recommended to use the configure options `--enable-cassert` (which turns on many run-time error checks) and `--enable-debug` (which improves the usefulness of debugging tools).

If using GCC, it is best to build with an optimization level of at least `-O1`, because using no optimization (`-O0`) disables some important compiler warnings (such as the use of uninitialized variables). However, non-zero optimization levels can complicate debugging because stepping through compiled code will usually not match up one-to-one with source code lines. If you get confused while trying to debug optimized code, recompile the specific files of interest with `-O0`. An easy way to do this is by passing an option to make: `make PROFILE=-O0 file.o`.

The `COPT` and `PROFILE` environment variables are actually handled identically by the PostgreSQL makefiles. Which to use is a matter of preference, but a common habit among developers is to use `PROFILE` for one-time flag adjustments, while `COPT` might be kept set all the time.

2. Build

To start the build, type either of:

```
make  
make all
```

(Remember to use GNU make.) The build will take a few minutes depending on your hardware. The last line displayed should be:

```
All of PostgreSQL successfully made. Ready to install.
```

If you want to build everything that can be built, including the documentation (HTML and man pages), and the additional modules (`contrib`), type instead:

```
make world
```

The last line displayed should be:

```
PostgreSQL, contrib, and documentation successfully made. Ready  
to install.
```

If you want to invoke the build from another makefile rather than manually, you must unset `MAKELEVEL` or set it to zero, for instance like this:

```
build-postgresql:
    $(MAKE) -C postgresql MAKELEVEL=0 all
```

Failure to do that can lead to strange error messages, typically about missing header files.

3. Regression Tests

If you want to test the newly built server before you install it, you can run the regression tests at this point. The regression tests are a test suite to verify that PostgreSQL runs on your machine in the way the developers expected it to. Type:

make check

(This won't work as root; do it as an unprivileged user.) See Chapter 32 for detailed information about interpreting the test results. You can repeat this test at any later time by issuing the same command.

4. Installing the Files

Note

If you are upgrading an existing system be sure to read Section 18.6, which has instructions about upgrading a cluster.

To install PostgreSQL enter:

make install

This will install files into the directories that were specified in Step 1. Make sure that you have appropriate permissions to write into that area. Normally you need to do this step as root. Alternatively, you can create the target directories in advance and arrange for appropriate permissions to be granted.

To install the documentation (HTML and man pages), enter:

make install-docs

If you built the world above, type instead:

make install-world

This also installs the documentation.

You can use `make install-strip` instead of `make install` to strip the executable files and libraries as they are installed. This will save some space. If you built with debugging support, stripping will effectively remove the debugging support, so it should only be done if debugging is no longer needed. `install-strip` tries to do a reasonable job saving space, but it does not have perfect knowledge of how to strip every unneeded byte from an executable file, so if you want to save all the disk space you possibly can, you will have to do manual work.

The standard installation provides all the header files needed for client application development as well as for server-side program development, such as custom functions or data types written

in C. (Prior to PostgreSQL 8.0, a separate `make install-all-headers` command was needed for the latter, but this step has been folded into the standard install.)

Client-only installation: If you want to install only the client applications and interface libraries, then you can use these commands:

```
make -C src/bin install
make -C src/include install
make -C src/interfaces install
make -C doc install
```

`src/bin` has a few binaries for server-only use, but they are small.

Uninstallation: To undo the installation use the command `make uninstall`. However, this will not remove any created directories.

Cleaning: After the installation you can free disk space by removing the built files from the source tree with the command `make clean`. This will preserve the files made by the `configure` program, so that you can rebuild everything with `make` later on. To reset the source tree to the state in which it was distributed, use `make distclean`. If you are going to build for several platforms within the same source tree you must do this and re-configure for each platform. (Alternatively, use a separate build tree for each platform, so that the source tree remains unmodified.)

If you perform a build and then discover that your `configure` options were wrong, or if you change anything that `configure` investigates (for example, software upgrades), then it's a good idea to do `make distclean` before reconfiguring and rebuilding. Without this, your changes in configuration choices might not propagate everywhere they need to.

16.5. Post-Installation Setup

16.5.1. Shared Libraries

On some systems with shared libraries you need to tell the system how to find the newly installed shared libraries. The systems on which this is *not* necessary include FreeBSD, HP-UX, Linux, NetBSD, OpenBSD, and Solaris.

The method to set the shared library search path varies between platforms, but the most widely-used method is to set the environment variable `LD_LIBRARY_PATH` like so: In Bourne shells (`sh`, `ksh`, `bash`, `zsh`):

```
LD_LIBRARY_PATH=/usr/local/pgsql/lib
export LD_LIBRARY_PATH
```

or in `csh` or `tcsh`:

```
setenv LD_LIBRARY_PATH /usr/local/pgsql/lib
```

Replace `/usr/local/pgsql/lib` with whatever you set `--libdir` to in Step 1. You should put these commands into a shell start-up file such as `/etc/profile` or `~/.bash_profile`. Some good information about the caveats associated with this method can be found at http://xahlee.info/UnixResource_dir/_ldpath.html.

On some systems it might be preferable to set the environment variable `LD_RUN_PATH` *before* building.

On Cygwin, put the library directory in the `PATH` or move the `.dll` files into the `bin` directory.

If in doubt, refer to the manual pages of your system (perhaps `ld.so` or `rld`). If you later get a message like:

```
psql: error in loading shared libraries
libpq.so.2.1: cannot open shared object file: No such file or
directory
```

then this step was necessary. Simply take care of it then.

If you are on Linux and you have root access, you can run:

```
/sbin/ldconfig /usr/local/pgsql/lib
```

(or equivalent directory) after installation to enable the run-time linker to find the shared libraries faster. Refer to the manual page of `ldconfig` for more information. On FreeBSD, NetBSD, and OpenBSD the command is:

```
/sbin/ldconfig -m /usr/local/pgsql/lib
```

instead. Other systems are not known to have an equivalent command.

16.5.2. Environment Variables

If you installed into `/usr/local/pgsql` or some other location that is not searched for programs by default, you should add `/usr/local/pgsql/bin` (or whatever you set `--bindir` to in Step 1) into your `PATH`. Strictly speaking, this is not necessary, but it will make the use of PostgreSQL much more convenient.

To do this, add the following to your shell start-up file, such as `~/.bash_profile` (or `/etc/profile`, if you want it to affect all users):

```
PATH=/usr/local/pgsql/bin:$PATH
export PATH
```

If you are using `csh` or `tcsh`, then use this command:

```
set path = ( /usr/local/pgsql/bin $path )
```

To enable your system to find the man documentation, you need to add lines like the following to a shell start-up file unless you installed into a location that is searched by default:

```
MANPATH=/usr/local/pgsql/share/man:$MANPATH
export MANPATH
```

The environment variables `PGHOST` and `PGPORT` specify to client applications the host and port of the database server, overriding the compiled-in defaults. If you are going to run client applications remotely then it is convenient if every user that plans to use the database sets `PGHOST`. This is not required, however; the settings can be communicated via command line options to most client programs.

16.6. Supported Platforms

A platform (that is, a CPU architecture and operating system combination) is considered supported by the PostgreSQL development community if the code contains provisions to work on that platform and it has recently been verified to build and pass its regression tests on that platform. Currently, most testing of platform compatibility is done automatically by test machines in the PostgreSQL Build

Farm². If you are interested in using PostgreSQL on a platform that is not represented in the build farm, but on which the code works or can be made to work, you are strongly encouraged to set up a build farm member machine so that continued compatibility can be assured.

In general, PostgreSQL can be expected to work on these CPU architectures: x86, x86_64, IA64, PowerPC, PowerPC 64, S/390, S/390x, Sparc, Sparc 64, ARM, MIPS, MIPSEL, and PA-RISC. Code support exists for M68K, M32R, and VAX, but these architectures are not known to have been tested recently. It is often possible to build on an unsupported CPU type by configuring with `--disable-spinlocks`, but performance will be poor.

PostgreSQL can be expected to work on these operating systems: Linux (all recent distributions), Windows (Win2000 SP4 and later), FreeBSD, OpenBSD, NetBSD, macOS, AIX, HP/UX, and Solaris. Other Unix-like systems may also work but are not currently being tested. In most cases, all CPU architectures supported by a given operating system will work. Look in Section 16.7 below to see if there is information specific to your operating system, particularly if using an older system.

If you have installation problems on a platform that is known to be supported according to recent build farm results, please report it to `<pgsql-bugs@lists.postgresql.org>`. If you are interested in porting PostgreSQL to a new platform, `<pgsql-hackers@lists.postgresql.org>` is the appropriate place to discuss that.

16.7. Platform-Specific Notes

This section documents additional platform-specific issues regarding the installation and setup of PostgreSQL. Be sure to read the installation instructions, and in particular Section 16.2 as well. Also, check Chapter 32 regarding the interpretation of regression test results.

Platforms that are not covered here have no known platform-specific installation issues.

16.7.1. AIX

PostgreSQL works on AIX, but AIX versions before about 6.1 have various issues and are not recommended. You can use GCC or the native IBM compiler `xlc`.

16.7.1.1. Memory Management

AIX can be somewhat peculiar with regards to the way it does memory management. You can have a server with many multiples of gigabytes of RAM free, but still get out of memory or address space errors when running applications. One example is loading of extensions failing with unusual errors. For example, running as the owner of the PostgreSQL installation:

```
=# CREATE EXTENSION plperl;  
ERROR: could not load library "/opt/dbs/pgsql/lib/plperl.so": A  
memory address is not in the address space for the process.
```

Running as a non-owner in the group possessing the PostgreSQL installation:

```
=# CREATE EXTENSION plperl;  
ERROR: could not load library "/opt/dbs/pgsql/lib/plperl.so": Bad  
address
```

Another example is out of memory errors in the PostgreSQL server logs, with every memory allocation near or greater than 256 MB failing.

The overall cause of all these problems is the default bittedness and memory model used by the server process. By default, all binaries built on AIX are 32-bit. This does not depend upon hardware type or

² <https://buildfarm.postgresql.org/>

kernel in use. These 32-bit processes are limited to 4 GB of memory laid out in 256 MB segments using one of a few models. The default allows for less than 256 MB in the heap as it shares a single segment with the stack.

In the case of the `plperl` example, above, check your `umask` and the permissions of the binaries in your PostgreSQL installation. The binaries involved in that example were 32-bit and installed as mode 750 instead of 755. Due to the permissions being set in this fashion, only the owner or a member of the possessing group can load the library. Since it isn't world-readable, the loader places the object into the process' heap instead of the shared library segments where it would otherwise be placed.

The “ideal” solution for this is to use a 64-bit build of PostgreSQL, but that is not always practical, because systems with 32-bit processors can build, but not run, 64-bit binaries.

If a 32-bit binary is desired, set `LDR_CNTRL` to `MAXDATA=0xn0000000`, where $1 \leq n \leq 8$, before starting the PostgreSQL server, and try different values and `postgresql.conf` settings to find a configuration that works satisfactorily. This use of `LDR_CNTRL` tells AIX that you want the server to have `MAXDATA` bytes set aside for the heap, allocated in 256 MB segments. When you find a workable configuration, `ldedit` can be used to modify the binaries so that they default to using the desired heap size. PostgreSQL can also be rebuilt, passing `configure LDFLAGS="-Wl, -bmaxdata:0xn0000000"` to achieve the same effect.

For a 64-bit build, set `OBJECT_MODE` to 64 and pass `CC="gcc -maix64"` and `LDFLAGS="-Wl, -bbigtoc"` to `configure`. (Options for `xlc` might differ.) If you omit the export of `OBJECT_MODE`, your build may fail with linker errors. When `OBJECT_MODE` is set, it tells AIX's build utilities such as `ar`, `as`, and `ld` what type of objects to default to handling.

By default, overcommit of paging space can happen. While we have not seen this occur, AIX will kill processes when it runs out of memory and the overcommit is accessed. The closest to this that we have seen is fork failing because the system decided that there was not enough memory for another process. Like many other parts of AIX, the paging space allocation method and out-of-memory kill is configurable on a system- or process-wide basis if this becomes a problem.

References and Resources

“Large Program Support¹”. *AIX Documentation: General Programming Concepts: Writing and Debugging Programs*.

“Program Address Space Overview²”. *AIX Documentation: General Programming Concepts: Writing and Debugging Programs*.

“Performance Overview of the Virtual Memory Manager (VMM)³”. *AIX Documentation: Performance Management Guide*.

“Page Space Allocation⁴”. *AIX Documentation: Performance Management Guide*.

“Paging-space thresholds tuning⁵”. *AIX Documentation: Performance Management Guide*.

*Developing and Porting C and C++ Applications on AIX*⁶. IBM Redbook.

16.7.2. Cygwin

PostgreSQL can be built using Cygwin, a Linux-like environment for Windows, but that method is inferior to the native Windows build (see Chapter 17) and running a server under Cygwin is no longer recommended.

¹ http://publib.boulder.ibm.com/infocenter/pseries/topic/com.ibm.aix.doc/aixprgdd/genprogc/lrg_prg_support.htm

² http://publib.boulder.ibm.com/infocenter/pseries/topic/com.ibm.aix.doc/aixprgdd/genprogc/address_space.htm

³ <http://publib.boulder.ibm.com/infocenter/pseries/v5r3/topic/com.ibm.aix.doc/aixbman/prftungd/resmgmt2.htm>

⁴ <http://publib.boulder.ibm.com/infocenter/pseries/v5r3/topic/com.ibm.aix.doc/aixbman/prftungd/memperf7.htm>

⁵ <http://publib.boulder.ibm.com/infocenter/pseries/v5r3/topic/com.ibm.aix.doc/aixbman/prftungd/memperf6.htm>

⁶ <http://www.redbooks.ibm.com/abstracts/sg245674.html?Open>

When building from source, proceed according to the Unix-style installation procedure (i.e., `./configure; make; etc.`), noting the following Cygwin-specific differences:

- Set your path to use the Cygwin bin directory before the Windows utilities. This will help prevent problems with compilation.
- The `adduser` command is not supported; use the appropriate user management application on Windows NT, 2000, or XP. Otherwise, skip this step.
- The `su` command is not supported; use `ssh` to simulate `su` on Windows NT, 2000, or XP. Otherwise, skip this step.
- OpenSSL is not supported.
- Start `cygserver` for shared memory support. To do this, enter the command `/usr/sbin/cygserver &`. This program needs to be running anytime you start the PostgreSQL server or initialize a database cluster (`initdb`). The default `cygserver` configuration may need to be changed (e.g., increase `SEMMNS`) to prevent PostgreSQL from failing due to a lack of system resources.
- Building might fail on some systems where a locale other than `C` is in use. To fix this, set the locale to `C` by doing `export LANG=C.utf8` before building, and then setting it back to the previous setting after you have installed PostgreSQL.
- The parallel regression tests (`make check`) can generate spurious regression test failures due to overflowing the `listen()` backlog queue which causes connection refused errors or hangs. You can limit the number of connections using the make variable `MAX_CONNECTIONS` thus:

```
make MAX_CONNECTIONS=5 check
```

(On some systems you can have up to about 10 simultaneous connections.)

It is possible to install `cygserver` and the PostgreSQL server as Windows NT services. For information on how to do this, please refer to the `README` document included with the PostgreSQL binary package on Cygwin. It is installed in the directory `/usr/share/doc/Cygwin`.

16.7.3. macOS

On recent macOS releases, it's necessary to embed the “sysroot” path in the include switches used to find some system header files. This results in the outputs of the `configure` script varying depending on which SDK version was used during `configure`. That shouldn't pose any problem in simple scenarios, but if you are trying to do something like building an extension on a different machine than the server code was built on, you may need to force use of a different sysroot path. To do that, set `PG_SYSROOT`, for example

```
make PG_SYSROOT=/desired/path all
```

To find out the appropriate path on your machine, run

```
xcodebuild -version -sdk macosx Path
```

Note that building an extension using a different sysroot version than was used to build the core server is not really recommended; in the worst case it could result in hard-to-debug ABI inconsistencies.

You can also select a non-default sysroot path when configuring, by specifying `PG_SYSROOT` to `configure`:

```
./configure ... PG_SYSROOT=/desired/path
```

macOS's "System Integrity Protection" (SIP) feature breaks `make check`, because it prevents passing the needed setting of `DYLD_LIBRARY_PATH` down to the executables being tested. You can work around that by doing `make install` before `make check`. Most PostgreSQL developers just turn off SIP, though.

16.7.4. MinGW/Native Windows

PostgreSQL for Windows can be built using MinGW, a Unix-like build environment for Microsoft operating systems, or using Microsoft's Visual C++ compiler suite. The MinGW build procedure uses the normal build system described in this chapter; the Visual C++ build works completely differently and is described in Chapter 17.

The native Windows port requires a 32 or 64-bit version of Windows 2000 or later. Earlier operating systems do not have sufficient infrastructure (but Cygwin may be used on those). MinGW, the Unix-like build tools, and MSYS, a collection of Unix tools required to run shell scripts like `configure`, can be downloaded from <http://www.mingw.org/>. Neither is required to run the resulting binaries; they are needed only for creating the binaries.

To build 64 bit binaries using MinGW, install the 64 bit tool set from <https://mingw-w64.org/>, put its bin directory in the `PATH`, and run `configure` with the `--host=x86_64-w64-mingw32` option.

After you have everything installed, it is suggested that you run `psql` under `CMD . EXE`, as the MSYS console has buffering issues.

16.7.4.1. Collecting Crash Dumps on Windows

If PostgreSQL on Windows crashes, it has the ability to generate minidumps that can be used to track down the cause for the crash, similar to core dumps on Unix. These dumps can be read using the Windows Debugger Tools or using Visual Studio. To enable the generation of dumps on Windows, create a subdirectory named `crashdumps` inside the cluster data directory. The dumps will then be written into this directory with a unique name based on the identifier of the crashing process and the current time of the crash.

16.7.5. Solaris

PostgreSQL is well-supported on Solaris. The more up to date your operating system, the fewer issues you will experience.

16.7.5.1. Required Tools

You can build with either GCC or Sun's compiler suite. For better code optimization, Sun's compiler is strongly recommended on the SPARC architecture. If you are using Sun's compiler, be careful not to select `/usr/ucb/cc`; use `/opt/SUNWsprow/bin/cc`.

You can download Sun Studio from <https://www.oracle.com/technetwork/server-storage/solarisstudio/downloads/>. Many GNU tools are integrated into Solaris 10, or they are present on the Solaris companion CD. If you need packages for older versions of Solaris, you can find these tools at <http://www.sunfreeware.com>. If you prefer sources, look at <https://www.gnu.org/prep/ftp>.

16.7.5.2. configure Complains About a Failed Test Program

If `configure` complains about a failed test program, this is probably a case of the run-time linker being unable to find some library, probably `libz`, `libreadline` or some other non-standard library such as `libssl`. To point it to the right location, set the `LD_FLAGS` environment variable on the `configure` command line, e.g.,

```
configure ... LDFLAGS="-R /usr/sfw/lib:/opt/sfw/lib:/usr/local/lib"
```

See the `ld` man page for more information.

16.7.5.3. Compiling for Optimal Performance

On the SPARC architecture, Sun Studio is strongly recommended for compilation. Try using the `-xO5` optimization flag to generate significantly faster binaries. Do not use any flags that modify behavior of floating-point operations and `errno` processing (e.g., `-fast`).

If you do not have a reason to use 64-bit binaries on SPARC, prefer the 32-bit version. The 64-bit operations are slower and 64-bit binaries are slower than the 32-bit variants. On the other hand, 32-bit code on the AMD64 CPU family is not native, so 32-bit code is significantly slower on that CPU family.

16.7.5.4. Using DTrace for Tracing PostgreSQL

Yes, using DTrace is possible. See Section 27.5 for further information.

If you see the linking of the `postgres` executable abort with an error message like:

```
Undefined                          first referenced
 symbol                              in file
AbortTransaction                    utils/probes.o
CommitTransaction                    utils/probes.o
ld: fatal: Symbol referencing errors. No output written to postgres
collect2: ld returned 1 exit status
make: *** [postgres] Error 1
```

your DTrace installation is too old to handle probes in static functions. You need Solaris 10u4 or newer to use DTrace.

Chapter 17. Installation from Source Code on Windows

It is recommended that most users download the binary distribution for Windows, available as a graphical installer package from the PostgreSQL website. Building from source is only intended for people developing PostgreSQL or extensions.

There are several different ways of building PostgreSQL on Windows. The simplest way to build with Microsoft tools is to install Visual Studio 2019 and use the included compiler. It is also possible to build with the full Microsoft Visual C++ 2013 to 2019. In some cases that requires the installation of the Windows SDK in addition to the compiler.

It is also possible to build PostgreSQL using the GNU compiler tools provided by MinGW, or using Cygwin for older versions of Windows.

Building using MinGW or Cygwin uses the normal build system, see Chapter 16 and the specific notes in Section 16.7.4 and Section 16.7.2. To produce native 64 bit binaries in these environments, use the tools from MinGW-w64. These tools can also be used to cross-compile for 32 bit and 64 bit Windows targets on other hosts, such as Linux and macOS. Cygwin is not recommended for running a production server, and it should only be used for running on older versions of Windows where the native build does not work, such as Windows 98. The official binaries are built using Visual Studio.

Native builds of `psql` don't support command line editing. The Cygwin build does support command line editing, so it should be used where `psql` is needed for interactive use on Windows.

17.1. Building with Visual C++ or the Microsoft Windows SDK

PostgreSQL can be built using the Visual C++ compiler suite from Microsoft. These compilers can be either from Visual Studio, Visual Studio Express or some versions of the Microsoft Windows SDK. If you do not already have a Visual Studio environment set up, the easiest ways are to use the compilers from Visual Studio 2019 or those in the Windows SDK 10, which are both free downloads from Microsoft.

Both 32-bit and 64-bit builds are possible with the Microsoft Compiler suite. 32-bit PostgreSQL builds are possible with Visual Studio 2013 to Visual Studio 2019, as well as standalone Windows SDK releases 8.1a to 10. 64-bit PostgreSQL builds are supported with Microsoft Windows SDK version 8.1a to 10 or Visual Studio 2013 and above. Compilation is supported down to Windows 7 and Windows Server 2008 R2 SP1 when building with Visual Studio 2013 to Visual Studio 2019.

The tools for building using Visual C++ or Platform SDK are in the `src/tools/msvc` directory. When building, make sure there are no tools from MinGW or Cygwin present in your system PATH. Also, make sure you have all the required Visual C++ tools available in the PATH. In Visual Studio, start the Visual Studio Command Prompt. If you wish to build a 64-bit version, you must use the 64-bit version of the command, and vice versa. In the Microsoft Windows SDK, start the CMD shell listed under the SDK on the Start Menu. In recent SDK versions you can change the targeted CPU architecture, build type, and target OS by using the `setenv` command, e.g. `setenv /x86 /release /xp` to target Windows XP or later with a 32-bit release build. See `/?` for other options to `setenv`. All commands should be run from the `src\tools\msvc` directory.

Before you build, you may need to edit the file `config.pl` to reflect any configuration options you want to change, or the paths to any third party libraries to use. The complete configuration is determined by first reading and parsing the file `config_default.pl`, and then apply any changes from `config.pl`. For example, to specify the location of your Python installation, put the following in `config.pl`:

```
$config->{python} = 'c:\python26';
```

You only need to specify those parameters that are different from what's in `config_default.pl`.

If you need to set any other environment variables, create a file called `buildenv.pl` and put the required commands there. For example, to add the path for bison when it's not in the `PATH`, create a file containing:

```
$ENV{PATH}=$ENV{PATH} . 'c:\some\where\bison\bin';
```

To pass additional command line arguments to the Visual Studio build command (`msbuild` or `vcbuild`):

```
$ENV{MSBFLAGS}="/m";
```

17.1.1. Requirements

The following additional products are required to build PostgreSQL. Use the `config.pl` file to specify which directories the libraries are available in.

Microsoft Windows SDK

If your build environment doesn't ship with a supported version of the Microsoft Windows SDK it is recommended that you upgrade to the latest version (currently version 10), available for download from <https://www.microsoft.com/download>.

You must always include the Windows Headers and Libraries part of the SDK. If you install a Windows SDK including the Visual C++ Compilers, you don't need Visual Studio to build. Note that as of Version 8.0a the Windows SDK no longer ships with a complete command-line build environment.

ActiveState Perl

ActiveState Perl is required to run the build generation scripts. MinGW or Cygwin Perl will not work. It must also be present in the `PATH`. Binaries can be downloaded from <https://www.activestate.com> (Note: version 5.8.3 or later is required, the free Standard Distribution is sufficient).

The following additional products are not required to get started, but are required to build the complete package. Use the `config.pl` file to specify which directories the libraries are available in.

ActiveState TCL

Required for building PL/Tcl (Note: version 8.4 is required, the free Standard Distribution is sufficient).

Bison and Flex

Bison and Flex are required to build from Git, but not required when building from a release file. Only Bison 1.875 or versions 2.2 and later will work. Flex must be version 2.5.31 or later.

Both Bison and Flex are included in the msys tool suite, available from <http://www.mingw.org/wiki/MSYS> as part of the MinGW compiler suite.

You will need to add the directory containing `flex.exe` and `bison.exe` to the `PATH` environment variable in `buildenv.pl` unless they are already in `PATH`. In the case of MinGW, the directory is the `\msys\1.0\bin` subdirectory of your MinGW installation directory.

Note

The Bison distribution from GnuWin32 appears to have a bug that causes Bison to malfunction when installed in a directory with spaces in the name, such as the default location on English installations C:\Program Files\GnuWin32. Consider installing into C:\GnuWin32 or use the NTFS short name path to GnuWin32 in your PATH environment setting (e.g. C:\PROGRA~1\GnuWin32).

Note

The obsolete `winflex` binaries distributed on the PostgreSQL FTP site and referenced in older documentation will fail with “flex: fatal internal error, exec failed” on 64-bit Windows hosts. Use Flex from MSYS instead.

Diff

Diff is required to run the regression tests, and can be downloaded from <http://gnuwin32.sourceforge.net>.

Gettext

Gettext is required to build with NLS support, and can be downloaded from <http://gnuwin32.sourceforge.net>. Note that binaries, dependencies and developer files are all needed.

MIT Kerberos

Required for GSSAPI authentication support. MIT Kerberos can be downloaded from <http://web.mit.edu/Kerberos/dist/index.html>.

libxml2 and libxslt

Required for XML support. Binaries can be downloaded from <http://zlatkovic.com/pub/libxml> or source from <http://xmlsoft.org>. Note that libxml2 requires iconv, which is available from the same download location.

OpenSSL

Required for SSL support. Binaries can be downloaded from <https://slproweb.com/products/Win32OpenSSL.html> or source from <https://www.openssl.org>.

ossp-uuid

Required for UUID-OSSP support (contrib only). Source can be downloaded from <http://www.ossp.org/pkg/lib/uuid/>.

Python

Required for building PL/Python. Binaries can be downloaded from <https://www.python.org>.

zlib

Required for compression support in `pg_dump` and `pg_restore`. Binaries can be downloaded from <http://www.zlib.net>.

17.1.2. Special Considerations for 64-Bit Windows

PostgreSQL will only build for the x64 architecture on 64-bit Windows, there is no support for Itanium processors.

Mixing 32- and 64-bit versions in the same build tree is not supported. The build system will automatically detect if it's running in a 32- or 64-bit environment, and build PostgreSQL accordingly. For this reason, it is important to start the correct command prompt before building.

To use a server-side third party library such as python or OpenSSL, this library *must* also be 64-bit. There is no support for loading a 32-bit library in a 64-bit server. Several of the third party libraries that PostgreSQL supports may only be available in 32-bit versions, in which case they cannot be used with 64-bit PostgreSQL.

17.1.3. Building

To build all of PostgreSQL in release configuration (the default), run the command:

```
build
```

To build all of PostgreSQL in debug configuration, run the command:

```
build DEBUG
```

To build just a single project, for example psql, run the commands:

```
build psql  
build DEBUG psql
```

To change the default build configuration to debug, put the following in the `builddenv.pl` file:

```
$ENV{CONFIG}="Debug" ;
```

It is also possible to build from inside the Visual Studio GUI. In this case, you need to run:

```
perl mkvcbuild.pl
```

from the command prompt, and then open the generated `pgsql.sln` (in the root directory of the source tree) in Visual Studio.

17.1.4. Cleaning and Installing

Most of the time, the automatic dependency tracking in Visual Studio will handle changed files. But if there have been large changes, you may need to clean the installation. To do this, simply run the `clean.bat` command, which will automatically clean out all generated files. You can also run it with the `dist` parameter, in which case it will behave like `make distclean` and remove the flex/bison output files as well.

By default, all files are written into a subdirectory of the `debug` or `release` directories. To install these files using the standard layout, and also generate the files required to initialize and use the database, run the command:

```
install c:\destination\directory
```

If you want to install only the client applications and interface libraries, then you can use these commands:

```
install c:\destination\directory client
```

17.1.5. Running the Regression Tests

To run the regression tests, make sure you have completed the build of all required parts first. Also, make sure that the DLLs required to load all parts of the system (such as the Perl and Python DLLs for the procedural languages) are present in the system path. If they are not, set it through the `buildenv.pl` file. To run the tests, run one of the following commands from the `src\tools\msvc` directory:

```
vcregress check  
vcregress installcheck  
vcregress plcheck  
vcregress contribcheck  
vcregress modulescheck  
vcregress ecpgcheck  
vcregress isolationcheck  
vcregress bincheck  
vcregress recoverycheck  
vcregress upgradecheck
```

To change the schedule used (default is parallel), append it to the command line like:

```
vcregress check serial
```

For more information about the regression tests, see Chapter 32.

Running the regression tests on client programs, with `vcregress bincheck`, or on recovery tests, with `vcregress recoverycheck`, requires an additional Perl module to be installed:

IPC::Run

As of this writing, `IPC::Run` is not included in the ActiveState Perl installation, nor in the ActiveState Perl Package Manager (PPM) library. To install, download the `IPC-Run-<version>.tar.gz` source archive from CPAN, at <https://metacpan.org/release/IPC-Run>, and uncompress. Edit the `buildenv.pl` file, and add a `PERL5LIB` variable to point to the `lib` subdirectory from the extracted archive. For example:

```
$ENV{PERL5LIB}=$ENV{PERL5LIB} . ' ;c:\IPC-Run-0.94\lib' ;
```

Chapter 18. Server Setup and Operation

This chapter discusses how to set up and run the database server and its interactions with the operating system.

18.1. The PostgreSQL User Account

As with any server daemon that is accessible to the outside world, it is advisable to run PostgreSQL under a separate user account. This user account should only own the data that is managed by the server, and should not be shared with other daemons. (For example, using the user `nobody` is a bad idea.) It is not advisable to install executables owned by this user because compromised systems could then modify their own binaries.

To add a Unix user account to your system, look for a command `useradd` or `adduser`. The user name `postgres` is often used, and is assumed throughout this book, but you can use another name if you like.

18.2. Creating a Database Cluster

Before you can do anything, you must initialize a database storage area on disk. We call this a *database cluster*. (The SQL standard uses the term *catalog cluster*.) A database cluster is a collection of databases that is managed by a single instance of a running database server. After initialization, a database cluster will contain a database named `postgres`, which is meant as a default database for use by utilities, users and third party applications. The database server itself does not require the `postgres` database to exist, but many external utility programs assume it exists. Another database created within each cluster during initialization is called `template1`. As the name suggests, this will be used as a template for subsequently created databases; it should not be used for actual work. (See Chapter 22 for information about creating new databases within a cluster.)

In file system terms, a database cluster is a single directory under which all data will be stored. We call this the *data directory* or *data area*. It is completely up to you where you choose to store your data. There is no default, although locations such as `/usr/local/pgsql/data` or `/var/lib/pgsql/data` are popular. To initialize a database cluster, use the command `initdb`, which is installed with PostgreSQL. The desired file system location of your database cluster is indicated by the `-D` option, for example:

```
$ initdb -D /usr/local/pgsql/data
```

Note that you must execute this command while logged into the PostgreSQL user account, which is described in the previous section.

Tip

As an alternative to the `-D` option, you can set the environment variable `PGDATA`.

Alternatively, you can run `initdb` via the `pg_ctl` program like so:

```
$ pg_ctl -D /usr/local/pgsql/data initdb
```

This may be more intuitive if you are using `pg_ctl` for starting and stopping the server (see Section 18.3), so that `pg_ctl` would be the sole command you use for managing the database server instance.

`initdb` will attempt to create the directory you specify if it does not already exist. Of course, this will fail if `initdb` does not have permissions to write in the parent directory. It's generally recommendable that the PostgreSQL user own not just the data directory but its parent directory as well, so that this should not be a problem. If the desired parent directory doesn't exist either, you will need to create it first, using root privileges if the grandparent directory isn't writable. So the process might look like this:

```
root# mkdir /usr/local/pgsql
root# chown postgres /usr/local/pgsql
root# su postgres
postgres$ initdb -D /usr/local/pgsql/data
```

`initdb` will refuse to run if the data directory exists and already contains files; this is to prevent accidentally overwriting an existing installation.

Because the data directory contains all the data stored in the database, it is essential that it be secured from unauthorized access. `initdb` therefore revokes access permissions from everyone but the PostgreSQL user, and optionally, group. Group access, when enabled, is read-only. This allows an unprivileged user in the same group as the cluster owner to take a backup of the cluster data or perform other operations that only require read access.

Note that enabling or disabling group access on an existing cluster requires the cluster to be shut down and the appropriate mode to be set on all directories and files before restarting PostgreSQL. Otherwise, a mix of modes might exist in the data directory. For clusters that allow access only by the owner, the appropriate modes are 0700 for directories and 0600 for files. For clusters that also allow reads by the group, the appropriate modes are 0750 for directories and 0640 for files.

However, while the directory contents are secure, the default client authentication setup allows any local user to connect to the database and even become the database superuser. If you do not trust other local users, we recommend you use one of `initdb`'s `-W`, `--pwprompt` or `--pwfile` options to assign a password to the database superuser. Also, specify `-A md5` or `-A password` so that the default `trust` authentication mode is not used; or modify the generated `pg_hba.conf` file after running `initdb`, but *before* you start the server for the first time. (Other reasonable approaches include using `peer` authentication or file system permissions to restrict connections. See Chapter 20 for more information.)

`initdb` also initializes the default locale for the database cluster. Normally, it will just take the locale settings in the environment and apply them to the initialized database. It is possible to specify a different locale for the database; more information about that can be found in Section 23.1. The default sort order used within the particular database cluster is set by `initdb`, and while you can create new databases using different sort order, the order used in the template databases that `initdb` creates cannot be changed without dropping and recreating them. There is also a performance impact for using locales other than C or POSIX. Therefore, it is important to make this choice correctly the first time.

`initdb` also sets the default character set encoding for the database cluster. Normally this should be chosen to match the locale setting. For details see Section 23.3.

Non-C and non-POSIX locales rely on the operating system's collation library for character set ordering. This controls the ordering of keys stored in indexes. For this reason, a cluster cannot switch to an incompatible collation library version, either through snapshot restore, binary streaming replication, a different operating system, or an operating system upgrade.

18.2.1. Use of Secondary File Systems

Many installations create their database clusters on file systems (volumes) other than the machine's "root" volume. If you choose to do this, it is not advisable to try to use the secondary volume's topmost

directory (mount point) as the data directory. Best practice is to create a directory within the mount-point directory that is owned by the PostgreSQL user, and then create the data directory within that. This avoids permissions problems, particularly for operations such as `pg_upgrade`, and it also ensures clean failures if the secondary volume is taken offline.

18.2.2. File Systems

Generally, any file system with POSIX semantics can be used for PostgreSQL. Users prefer different file systems for a variety of reasons, including vendor support, performance, and familiarity. Experience suggests that, all other things being equal, one should not expect major performance or behavior changes merely from switching file systems or making minor file system configuration changes.

18.2.2.1. NFS

It is possible to use an NFS file system for storing the PostgreSQL data directory. PostgreSQL does nothing special for NFS file systems, meaning it assumes NFS behaves exactly like locally-connected drives. PostgreSQL does not use any functionality that is known to have nonstandard behavior on NFS, such as file locking.

The only firm requirement for using NFS with PostgreSQL is that the file system is mounted using the `hard` option. With the `hard` option, processes can “hang” indefinitely if there are network problems, so this configuration will require a careful monitoring setup. The `soft` option will interrupt system calls in case of network problems, but PostgreSQL will not repeat system calls interrupted in this way, so any such interruption will result in an I/O error being reported.

It is not necessary to use the `sync` mount option. The behavior of the `async` option is sufficient, since PostgreSQL issues `fsync` calls at appropriate times to flush the write caches. (This is analogous to how it works on a local file system.) However, it is strongly recommended to use the `sync` export option on the NFS *server* on systems where it exists (mainly Linux). Otherwise, an `fsync` or equivalent on the NFS client is not actually guaranteed to reach permanent storage on the server, which could cause corruption similar to running with the parameter `fsync` off. The defaults of these mount and export options differ between vendors and versions, so it is recommended to check and perhaps specify them explicitly in any case to avoid any ambiguity.

In some cases, an external storage product can be accessed either via NFS or a lower-level protocol such as iSCSI. In the latter case, the storage appears as a block device and any available file system can be created on it. That approach might relieve the DBA from having to deal with some of the idiosyncrasies of NFS, but of course the complexity of managing remote storage then happens at other levels.

18.3. Starting the Database Server

Before anyone can access the database, you must start the database server. The database server program is called `postgres`. The `postgres` program must know where to find the data it is supposed to use. This is done with the `-D` option. Thus, the simplest way to start the server is:

```
$ postgres -D /usr/local/pgsql/data
```

which will leave the server running in the foreground. This must be done while logged into the PostgreSQL user account. Without `-D`, the server will try to use the data directory named by the environment variable `PGDATA`. If that variable is not provided either, it will fail.

Normally it is better to start `postgres` in the background. For this, use the usual Unix shell syntax:

```
$ postgres -D /usr/local/pgsql/data >logfile 2>&1 &
```

It is important to store the server's stdout and stderr output somewhere, as shown above. It will help for auditing purposes and to diagnose problems. (See Section 24.3 for a more thorough discussion of log file handling.)

The `postgres` program also takes a number of other command-line options. For more information, see the `postgres` reference page and Chapter 19 below.

This shell syntax can get tedious quickly. Therefore the wrapper program `pg_ctl` is provided to simplify some tasks. For example:

```
pg_ctl start -l logfile
```

will start the server in the background and put the output into the named log file. The `-D` option has the same meaning here as for `postgres`. `pg_ctl` is also capable of stopping the server.

Normally, you will want to start the database server when the computer boots. Autostart scripts are operating-system-specific. There are a few distributed with PostgreSQL in the `contrib/start-scripts` directory. Installing one will require root privileges.

Different systems have different conventions for starting up daemons at boot time. Many systems have a file `/etc/rc.local` or `/etc/rc.d/rc.local`. Others use `init.d` or `rc.d` directories. Whatever you do, the server must be run by the PostgreSQL user account *and not by root* or any other user. Therefore you probably should form your commands using `su postgres -c '...'`. For example:

```
su postgres -c 'pg_ctl start -D /usr/local/pgsql/data -l serverlog'
```

Here are a few more operating-system-specific suggestions. (In each case be sure to use the proper installation directory and user name where we show generic values.)

- For FreeBSD, look at the file `contrib/start-scripts/freebsd` in the PostgreSQL source distribution.
- On OpenBSD, add the following lines to the file `/etc/rc.local`:

```
if [ -x /usr/local/pgsql/bin/pg_ctl -a -x /usr/local/pgsql/bin/
postgres ]; then
    su -l postgres -c '/usr/local/pgsql/bin/pg_ctl start -s -l /
var/postgresql/log -D /usr/local/pgsql/data'
    echo -n ' postgresql'
fi
```

- On Linux systems either add

```
/usr/local/pgsql/bin/pg_ctl start -l logfile -D /usr/local/pgsql/
data
```

to `/etc/rc.d/rc.local` or `/etc/rc.local` or look at the file `contrib/start-scripts/linux` in the PostgreSQL source distribution.

When using `systemd`, you can use the following service unit file (e.g., at `/etc/systemd/system/postgresql.service`):

```
[Unit]
Description=PostgreSQL database server
```

```
Documentation=man:postgres(1)
```

```
[Service]
```

```
Type=notify
```

```
User=postgres
```

```
ExecStart=/usr/local/pgsql/bin/postgres -D /usr/local/pgsql/data
```

```
ExecReload=/bin/kill -HUP $MAINPID
```

```
KillMode=mixed
```

```
KillSignal=SIGINT
```

```
TimeoutSec=0
```

```
[Install]
```

```
WantedBy=multi-user.target
```

Using `Type=notify` requires that the server binary was built with `configure --with-systemd`.

Consider carefully the timeout setting. `systemd` has a default timeout of 90 seconds as of this writing and will kill a process that does not notify readiness within that time. But a PostgreSQL server that might have to perform crash recovery at startup could take much longer to become ready. The suggested value of 0 disables the timeout logic.

- On NetBSD, use either the FreeBSD or Linux start scripts, depending on preference.
- On Solaris, create a file called `/etc/init.d/postgresql` that contains the following line:

```
su - postgres -c "/usr/local/pgsql/bin/pg_ctl start -l logfile -D /usr/local/pgsql/data"
```

Then, create a symbolic link to it in `/etc/rc3.d` as `S99postgresql`.

While the server is running, its PID is stored in the file `postmaster.pid` in the data directory. This is used to prevent multiple server instances from running in the same data directory and can also be used for shutting down the server.

18.3.1. Server Start-up Failures

There are several common reasons the server might fail to start. Check the server's log file, or start it by hand (without redirecting standard output or standard error) and see what error messages appear. Below we explain some of the most common error messages in more detail.

```
LOG:  could not bind IPv4 address "127.0.0.1": Address already in
      use
HINT:  Is another postmaster already running on port 5432? If not,
      wait a few seconds and retry.
FATAL:  could not create any TCP/IP sockets
```

This usually means just what it suggests: you tried to start another server on the same port where one is already running. However, if the kernel error message is not `Address already in use` or some variant of that, there might be a different problem. For example, trying to start a server on a reserved port number might draw something like:

```
$ postgres -p 666
LOG:  could not bind IPv4 address "127.0.0.1": Permission denied
HINT:  Is another postmaster already running on port 666? If not,
      wait a few seconds and retry.
```

```
FATAL: could not create any TCP/IP sockets
```

A message like:

```
FATAL: could not create shared memory segment: Invalid argument
DETAIL: Failed system call was shmget(key=5440001,
      size=4011376640, 03600).
```

probably means your kernel's limit on the size of shared memory is smaller than the work area PostgreSQL is trying to create (4011376640 bytes in this example). Or it could mean that you do not have System-V-style shared memory support configured into your kernel at all. As a temporary workaround, you can try starting the server with a smaller-than-normal number of buffers (`shared_buffers`). You will eventually want to reconfigure your kernel to increase the allowed shared memory size. You might also see this message when trying to start multiple servers on the same machine, if their total space requested exceeds the kernel limit.

An error like:

```
FATAL: could not create semaphores: No space left on device
DETAIL: Failed system call was semget(5440126, 17, 03600).
```

does *not* mean you've run out of disk space. It means your kernel's limit on the number of System V semaphores is smaller than the number PostgreSQL wants to create. As above, you might be able to work around the problem by starting the server with a reduced number of allowed connections (`max_connections`), but you'll eventually want to increase the kernel limit.

If you get an “illegal system call” error, it is likely that shared memory or semaphores are not supported in your kernel at all. In that case your only option is to reconfigure the kernel to enable these features.

Details about configuring System V IPC facilities are given in Section 18.4.1.

18.3.2. Client Connection Problems

Although the error conditions possible on the client side are quite varied and application-dependent, a few of them might be directly related to how the server was started. Conditions other than those shown below should be documented with the respective client application.

```
psql: could not connect to server: Connection refused
        Is the server running on host "server.joe.com" and
        accepting
        TCP/IP connections on port 5432?
```

This is the generic “I couldn't find a server to talk to” failure. It looks like the above when TCP/IP communication is attempted. A common mistake is to forget to configure the server to allow TCP/IP connections.

Alternatively, you'll get this when attempting Unix-domain socket communication to a local server:

```
psql: could not connect to server: No such file or directory
        Is the server running locally and accepting
        connections on Unix domain socket "/tmp/.s.PGSQL.5432"?
```

The last line is useful in verifying that the client is trying to connect to the right place. If there is in fact no server running there, the kernel error message will typically be either `Connection refused` or `No such file or directory`, as illustrated. (It is important to realize that `Connection refused` in this context does *not* mean that the server got your connection request and rejected it.

That case will produce a different message, as shown in Section 20.15.) Other error messages such as `Connection timed out` might indicate more fundamental problems, like lack of network connectivity.

18.4. Managing Kernel Resources

PostgreSQL can sometimes exhaust various operating system resource limits, especially when multiple copies of the server are running on the same system, or in very large installations. This section explains the kernel resources used by PostgreSQL and the steps you can take to resolve problems related to kernel resource consumption.

18.4.1. Shared Memory and Semaphores

PostgreSQL requires the operating system to provide inter-process communication (IPC) features, specifically shared memory and semaphores. Unix-derived systems typically provide “System V” IPC, “POSIX” IPC, or both. Windows has its own implementation of these features and is not discussed here.

The complete lack of these facilities is usually manifested by an “Illegal system call” error upon server start. In that case there is no alternative but to reconfigure your kernel. PostgreSQL won't work without them. This situation is rare, however, among modern operating systems.

By default, PostgreSQL allocates a very small amount of System V shared memory, as well as a much larger amount of anonymous `mmap` shared memory. Alternatively, a single large System V shared memory region can be used (see `shared_memory_type`). In addition a significant number of semaphores, which can be either System V or POSIX style, are created at server startup. Currently, POSIX semaphores are used on Linux and FreeBSD systems while other platforms use System V semaphores.

Note

Prior to PostgreSQL 9.3, only System V shared memory was used, so the amount of System V shared memory required to start the server was much larger. If you are running an older version of the server, please consult the documentation for your server version.

System V IPC features are typically constrained by system-wide allocation limits. When PostgreSQL exceeds one of these limits, the server will refuse to start and should leave an instructive error message describing the problem and what to do about it. (See also Section 18.3.1.) The relevant kernel parameters are named consistently across different systems; Table 18.1 gives an overview. The methods to set them, however, vary. Suggestions for some platforms are given below.

Table 18.1. System V IPC Parameters

Name	Description	Values needed to run one PostgreSQL instance
SHMMAX	Maximum size of shared memory segment (bytes)	at least 1kB, but the default is usually much higher
SHMMIN	Minimum size of shared memory segment (bytes)	1
SHMALL	Total amount of shared memory available (bytes or pages)	same as SHMMAX if bytes, or <code>ceil(SHMMAX/PAGE_SIZE)</code> if pages, plus room for other applications

Name	Description	Values needed to run one PostgreSQL instance
SHMSEG	Maximum number of shared memory segments per process	only 1 segment is needed, but the default is much higher
SHMMNI	Maximum number of shared memory segments system-wide	like SHMSEG plus room for other applications
SEMMNI	Maximum number of semaphore identifiers (i.e., sets)	at least $\text{ceil}((\text{max_connections} + \text{autovacuum_max_workers} + \text{max_wal_senders} + \text{max_worker_processes} + 5) / 16)$ plus room for other applications
SEMMNS	Maximum number of semaphores system-wide	$\text{ceil}((\text{max_connections} + \text{autovacuum_max_workers} + \text{max_wal_senders} + \text{max_worker_processes} + 5) / 16) * 17$ plus room for other applications
SEMSL	Maximum number of semaphores per set	at least 17
SEMMAP	Number of entries in semaphore map	see text
SEVMX	Maximum value of semaphore	at least 1000 (The default is often 32767; do not change unless necessary)

PostgreSQL requires a few bytes of System V shared memory (typically 48 bytes, on 64-bit platforms) for each copy of the server. On most modern operating systems, this amount can easily be allocated. However, if you are running many copies of the server or you explicitly configure the server to use large amounts of System V shared memory (see `shared_memory_type` and `dynamic_shared_memory_type`), it may be necessary to increase `SHMALL`, which is the total amount of System V shared memory system-wide. Note that `SHMALL` is measured in pages rather than bytes on many systems.

Less likely to cause problems is the minimum size for shared memory segments (`SHMMIN`), which should be at most approximately 32 bytes for PostgreSQL (it is usually just 1). The maximum number of segments system-wide (`SHMMNI`) or per-process (`SHMSEG`) are unlikely to cause a problem unless your system has them set to zero.

When using System V semaphores, PostgreSQL uses one semaphore per allowed connection (`max_connections`), allowed autovacuum worker process (`autovacuum_max_workers`) and allowed background process (`max_worker_processes`), in sets of 16. Each such set will also contain a 17th semaphore which contains a “magic number”, to detect collision with semaphore sets used by other applications. The maximum number of semaphores in the system is set by `SEMMNS`, which consequently must be at least as high as `max_connections` plus `autovacuum_max_workers` plus `max_wal_senders`, plus `max_worker_processes`, plus one extra for each 16 allowed connections plus workers (see the formula in Table 18.1). The parameter `SEMMNI` determines the limit on the number of semaphore sets that can exist on the system at one time. Hence this parameter must be at least $\text{ceil}((\text{max_connections} + \text{autovacuum_max_workers} + \text{max_wal_senders} + \text{max_worker_processes} + 5) / 16)$. Lowering the number of allowed connections is a temporary workaround for failures, which are usually confusingly worded “No space left on device”, from the function `semget`.

In some cases it might also be necessary to increase `SEMMAP` to be at least on the order of `SEMMNS`. If the system has this parameter (many do not), it defines the size of the semaphore resource map, in

which each contiguous block of available semaphores needs an entry. When a semaphore set is freed it is either added to an existing entry that is adjacent to the freed block or it is registered under a new map entry. If the map is full, the freed semaphores get lost (until reboot). Fragmentation of the semaphore space could over time lead to fewer available semaphores than there should be.

Various other settings related to “semaphore undo”, such as `SEMMNU` and `SEMUME`, do not affect PostgreSQL.

When using POSIX semaphores, the number of semaphores needed is the same as for System V, that is one semaphore per allowed connection (`max_connections`), allowed autovacuum worker process (`autovacuum_max_workers`) and allowed background process (`max_worker_processes`). On the platforms where this option is preferred, there is no specific kernel limit on the number of POSIX semaphores.

AIX

At least as of version 5.1, it should not be necessary to do any special configuration for such parameters as `SHMMAX`, as it appears this is configured to allow all memory to be used as shared memory. That is the sort of configuration commonly used for other databases such as DB/2.

It might, however, be necessary to modify the global `ulimit` information in `/etc/security/limits`, as the default hard limits for file sizes (`fsize`) and numbers of files (`nofiles`) might be too low.

FreeBSD

The default IPC settings can be changed using the `sysctl` or `loader` interfaces. The following parameters can be set using `sysctl`:

```
# sysctl kern.ipc.shmall=32768
# sysctl kern.ipc.shmmax=134217728
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

These semaphore-related settings are read-only as far as `sysctl` is concerned, but can be set in `/boot/loader.conf`:

```
kern.ipc.semmani=256
kern.ipc.semms=512
```

After modifying that file, a reboot is required for the new settings to take effect.

You might also want to configure your kernel to lock System V shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

If running in FreeBSD jails by enabling `sysctl's security.jail.sysvipc_allowed`, postmasters running in different jails should be run by different operating system users. This improves security because it prevents non-root users from interfering with shared memory or semaphores in different jails, and it allows the PostgreSQL IPC cleanup code to function properly. (In FreeBSD 6.0 and later the IPC cleanup code does not properly detect processes in other jails, preventing the running of postmasters on the same port in different jails.)

FreeBSD versions before 4.0 work like old OpenBSD (see below).

NetBSD

In NetBSD 5.0 and later, IPC parameters can be adjusted using `sysctl`, for example:

```
# sysctl -w kern.ipc.semnmni=100
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

You will usually want to increase `kern.ipc.semnmni` and `kern.ipc.semnmns`, as NetBSD's default settings for these are uncomfortably small.

You might also want to configure your kernel to lock System V shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

NetBSD versions before 5.0 work like old OpenBSD (see below), except that kernel parameters should be set with the keyword `options` not `option`.

OpenBSD

In OpenBSD 3.3 and later, IPC parameters can be adjusted using `sysctl`, for example:

```
# sysctl kern.seminfo.semnmni=100
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

You will usually want to increase `kern.seminfo.semnmni` and `kern.seminfo.semnmns`, as OpenBSD's default settings for these are uncomfortably small.

In older OpenBSD versions, you will need to build a custom kernel to change the IPC parameters. Make sure that the options `SYSVSHM` and `SYSVSEM` are enabled, too. (They are by default.) The following shows an example of how to set the various parameters in the kernel configuration file:

```
option      SYSVSHM
option      SHMMAXPGS=4096
option      SHMSEG=256

option      SYSVSEM
option      SEMMNI=256
option      SEMMNS=512
option      SEMMNU=256
```

HP-UX

The default settings tend to suffice for normal installations. On HP-UX 10, the factory default for `SEMMNS` is 128, which might be too low for larger database sites.

IPC parameters can be set in the System Administration Manager (SAM) under Kernel Configuration → Configurable Parameters. Choose Create A New Kernel when you're done.

Linux

The default maximum segment size is 32 MB, and the default maximum total size is 2097152 pages. A page is almost always 4096 bytes except in unusual kernel configurations with “huge pages” (use `getconf PAGE_SIZE` to verify).

The shared memory size settings can be changed via the `sysctl` interface. For example, to allow 16 GB:

```
$ sysctl -w kernel.shmmax=17179869184
```

```
$ sysctl -w kernel.shmall=4194304
```

In addition these settings can be preserved between reboots in the file `/etc/sysctl.conf`. Doing that is highly recommended.

Ancient distributions might not have the `sysctl` program, but equivalent changes can be made by manipulating the `/proc` file system:

```
$ echo 17179869184 >/proc/sys/kernel/shmmax
$ echo 4194304 >/proc/sys/kernel/shmall
```

The remaining defaults are quite generously sized, and usually do not require changes.

macOS

The recommended method for configuring shared memory in macOS is to create a file named `/etc/sysctl.conf`, containing variable assignments such as:

```
kern.sysv.shmmax=4194304
kern.sysv.shmmin=1
kern.sysv.shmmni=32
kern.sysv.shmseg=8
kern.sysv.shmall=1024
```

Note that in some macOS versions, *all five* shared-memory parameters must be set in `/etc/sysctl.conf`, else the values will be ignored.

Beware that recent releases of macOS ignore attempts to set `SHMMAX` to a value that isn't an exact multiple of 4096.

`SHMALL` is measured in 4 kB pages on this platform.

In older macOS versions, you will need to reboot to have changes in the shared memory parameters take effect. As of 10.5 it is possible to change all but `SHMMNI` on the fly, using `sysctl`. But it's still best to set up your preferred values via `/etc/sysctl.conf`, so that the values will be kept across reboots.

The file `/etc/sysctl.conf` is only honored in macOS 10.3.9 and later. If you are running a previous 10.3.x release, you must edit the file `/etc/rc` and change the values in the following commands:

```
sysctl -w kern.sysv.shmmax
sysctl -w kern.sysv.shmmin
sysctl -w kern.sysv.shmmni
sysctl -w kern.sysv.shmseg
sysctl -w kern.sysv.shmall
```

Note that `/etc/rc` is usually overwritten by macOS system updates, so you should expect to have to redo these edits after each update.

In macOS 10.2 and earlier, instead edit these commands in the file `/System/Library/StartupItems/SystemTuning/SystemTuning`.

Solaris 2.6 to 2.9 (Solaris 6 to Solaris 9)

The relevant settings can be changed in `/etc/system`, for example:

```
set shmsys:shminfo_shmmax=0x2000000
set shmsys:shminfo_shmmin=1
set shmsys:shminfo_shmmni=256
set shmsys:shminfo_shmseg=256

set semsys:seminfo_semmap=256
set semsys:seminfo_semmni=512
set semsys:seminfo_semmns=512
set semsys:seminfo_semmsl=32
```

You need to reboot for the changes to take effect. See also <http://sunsite.uakom.sk/sunworldonline/swol-09-1997/swol-09-insidesolaris.html> for information on shared memory under older versions of Solaris.

Solaris 2.10 (Solaris 10) and later OpenSolaris

In Solaris 10 and later, and OpenSolaris, the default shared memory and semaphore settings are good enough for most PostgreSQL applications. Solaris now defaults to a SHMMAX of one-quarter of system RAM. To further adjust this setting, use a project setting associated with the `postgres` user. For example, run the following as `root`:

```
projadd -c "PostgreSQL DB User" -K "project.max-shm-
memory=(privileged,8GB,deny)" -U postgres -G postgres
user.postgres
```

This command adds the `user.postgres` project and sets the shared memory maximum for the `postgres` user to 8GB, and takes effect the next time that user logs in, or when you restart PostgreSQL (not reload). The above assumes that PostgreSQL is run by the `postgres` user in the `postgres` group. No server reboot is required.

Other recommended kernel setting changes for database servers which will have a large number of connections are:

```
project.max-shm-ids=(priv,32768,deny)
project.max-sem-ids=(priv,4096,deny)
project.max-msg-ids=(priv,4096,deny)
```

Additionally, if you are running PostgreSQL inside a zone, you may need to raise the zone resource usage limits as well. See "Chapter2: Projects and Tasks" in the *System Administrator's Guide* for more information on projects and `prectl`.

18.4.2. systemd RemoveIPC

If `systemd` is in use, some care must be taken that IPC resources (shared memory and semaphores) are not prematurely removed by the operating system. This is especially of concern when installing PostgreSQL from source. Users of distribution packages of PostgreSQL are less likely to be affected, as the `postgres` user is then normally created as a system user.

The setting `RemoveIPC` in `logind.conf` controls whether IPC objects are removed when a user fully logs out. System users are exempt. This setting defaults to `on` in stock `systemd`, but some operating system distributions default it to `off`.

A typical observed effect when this setting is `on` is that the semaphore objects used by a PostgreSQL server are removed at apparently random times, leading to the server crashing with log messages like

```
LOG: semctl(1234567890, 0, IPC_RMID, ...) failed: Invalid argument
```

Different types of IPC objects (shared memory vs. semaphores, System V vs. POSIX) are treated slightly differently by `systemd`, so one might observe that some IPC resources are not removed in the same way as others. But it is not advisable to rely on these subtle differences.

A “user logging out” might happen as part of a maintenance job or manually when an administrator logs in as the `postgres` user or something similar, so it is hard to prevent in general.

What is a “system user” is determined at `systemd` compile time from the `SYS_UID_MAX` setting in `/etc/login.defs`.

Packaging and deployment scripts should be careful to create the `postgres` user as a system user by using `useradd -r, adduser --system`, or equivalent.

Alternatively, if the user account was created incorrectly or cannot be changed, it is recommended to set

```
RemoveIPC=no
```

in `/etc/systemd/logind.conf` or another appropriate configuration file.

Caution

At least one of these two things has to be ensured, or the PostgreSQL server will be very unreliable.

18.4.3. Resource Limits

Unix-like operating systems enforce various kinds of resource limits that might interfere with the operation of your PostgreSQL server. Of particular importance are limits on the number of processes per user, the number of open files per process, and the amount of memory available to each process. Each of these have a “hard” and a “soft” limit. The soft limit is what actually counts but it can be changed by the user up to the hard limit. The hard limit can only be changed by the root user. The system call `setrlimit` is responsible for setting these parameters. The shell’s built-in command `ulimit` (Bourne shells) or `limit` (csh) is used to control the resource limits from the command line. On BSD-derived systems the file `/etc/login.conf` controls the various resource limits set during login. See the operating system documentation for details. The relevant parameters are `maxproc`, `openfiles`, and `datasize`. For example:

```
default:\
...
      :datasize-cur=256M:\
      :maxproc-cur=256:\
      :openfiles-cur=256:\
...
```

(`-cur` is the soft limit. Append `-max` to set the hard limit.)

Kernels can also have system-wide limits on some resources.

- On Linux `/proc/sys/fs/file-max` determines the maximum number of open files that the kernel will support. It can be changed by writing a different number into the file or by adding an assignment in `/etc/sysctl.conf`. The maximum limit of files per process is fixed at the time the kernel is compiled; see `/usr/src/linux/Documentation/proc.txt` for more information.

The PostgreSQL server uses one process per connection so you should provide for at least as many processes as allowed connections, in addition to what you need for the rest of your system. This is usually not a problem but if you run several servers on one machine things might get tight.

The factory default limit on open files is often set to “socially friendly” values that allow many users to coexist on a machine without using an inappropriate fraction of the system resources. If you run many servers on a machine this is perhaps what you want, but on dedicated servers you might want to raise this limit.

On the other side of the coin, some systems allow individual processes to open large numbers of files; if more than a few processes do so then the system-wide limit can easily be exceeded. If you find this happening, and you do not want to alter the system-wide limit, you can set PostgreSQL's `max_files_per_process` configuration parameter to limit the consumption of open files.

18.4.4. Linux Memory Overcommit

In Linux 2.4 and later, the default virtual memory behavior is not optimal for PostgreSQL. Because of the way that the kernel implements memory overcommit, the kernel might terminate the PostgreSQL postmaster (the master server process) if the memory demands of either PostgreSQL or another process cause the system to run out of virtual memory.

If this happens, you will see a kernel message that looks like this (consult your system documentation and configuration on where to look for such a message):

```
Out of Memory: Killed process 12345 (postgres).
```

This indicates that the `postgres` process has been terminated due to memory pressure. Although existing database connections will continue to function normally, no new connections will be accepted. To recover, PostgreSQL will need to be restarted.

One way to avoid this problem is to run PostgreSQL on a machine where you can be sure that other processes will not run the machine out of memory. If memory is tight, increasing the swap space of the operating system can help avoid the problem, because the out-of-memory (OOM) killer is invoked only when physical memory and swap space are exhausted.

If PostgreSQL itself is the cause of the system running out of memory, you can avoid the problem by changing your configuration. In some cases, it may help to lower memory-related configuration parameters, particularly `shared_buffers` and `work_mem`. In other cases, the problem may be caused by allowing too many connections to the database server itself. In many cases, it may be better to reduce `max_connections` and instead make use of external connection-pooling software.

On Linux 2.6 and later, it is possible to modify the kernel's behavior so that it will not “overcommit” memory. Although this setting will not prevent the OOM killer¹ from being invoked altogether, it will lower the chances significantly and will therefore lead to more robust system behavior. This is done by selecting strict overcommit mode via `sysctl`:

```
sysctl -w vm.overcommit_memory=2
```

or placing an equivalent entry in `/etc/sysctl.conf`. You might also wish to modify the related setting `vm.overcommit_ratio`. For details see the kernel documentation file <https://www.kernel.org/doc/Documentation/vm/overcommit-accounting>.

Another approach, which can be used with or without altering `vm.overcommit_memory`, is to set the process-specific *OOM score adjustment* value for the postmaster process to `-1000`, thereby guaranteeing it will not be targeted by the OOM killer. The simplest way to do this is to execute

¹ <https://lwn.net/Articles/104179/>

```
echo -1000 > /proc/self/oom_score_adj
```

in the postmaster's startup script just before invoking the postmaster. Note that this action must be done as root, or it will have no effect; so a root-owned startup script is the easiest place to do it. If you do this, you should also set these environment variables in the startup script before invoking the postmaster:

```
export PG_OOM_ADJUST_FILE=/proc/self/oom_score_adj
export PG_OOM_ADJUST_VALUE=0
```

These settings will cause postmaster child processes to run with the normal OOM score adjustment of zero, so that the OOM killer can still target them at need. You could use some other value for `PG_OOM_ADJUST_VALUE` if you want the child processes to run with some other OOM score adjustment. (`PG_OOM_ADJUST_VALUE` can also be omitted, in which case it defaults to zero.) If you do not set `PG_OOM_ADJUST_FILE`, the child processes will run with the same OOM score adjustment as the postmaster, which is unwise since the whole point is to ensure that the postmaster has a preferential setting.

Older Linux kernels do not offer `/proc/self/oom_score_adj`, but may have a previous version of the same functionality called `/proc/self/oom_adj`. This works the same except the disable value is `-17` not `-1000`.

Note

Some vendors' Linux 2.4 kernels are reported to have early versions of the 2.6 `overcommit_sysctl` parameter. However, setting `vm.overcommit_memory` to 2 on a 2.4 kernel that does not have the relevant code will make things worse, not better. It is recommended that you inspect the actual kernel source code (see the function `vm_enough_memory` in the file `mm/mmap.c`) to verify what is supported in your kernel before you try this in a 2.4 installation. The presence of the `overcommit-accounting` documentation file should *not* be taken as evidence that the feature is there. If in any doubt, consult a kernel expert or your kernel vendor.

18.4.5. Linux Huge Pages

Using huge pages reduces overhead when using large contiguous chunks of memory, as PostgreSQL does, particularly when using large values of `shared_buffers`. To use this feature in PostgreSQL you need a kernel with `CONFIG_HUGETLBFS=y` and `CONFIG_HUGETLB_PAGE=y`. You will also have to adjust the kernel setting `vm.nr_hugepages`. To estimate the number of huge pages needed, start PostgreSQL without huge pages enabled and check the postmaster's anonymous shared memory segment size, as well as the system's huge page size, using the `/proc` file system. This might look like:

```
$ head -1 $PGDATA/postmaster.pid
4170
$ pmap 4170 | awk '/rw-s/ && /zero/ {print $2}'
6490428K
$ grep ^Hugepagesize /proc/meminfo
Hugepagesize:      2048 kB
```

`6490428 / 2048` gives approximately `3169.154`, so in this example we need at least 3170 huge pages, which we can set with:

```
$ sysctl -w vm.nr_hugepages=3170
```

A larger setting would be appropriate if other programs on the machine also need huge pages. Don't forget to add this setting to `/etc/sysctl.conf` so that it will be reapplied after reboots.

Sometimes the kernel is not able to allocate the desired number of huge pages immediately, so it might be necessary to repeat the command or to reboot. (Immediately after a reboot, most of the machine's memory should be available to convert into huge pages.) To verify the huge page allocation situation, use:

```
$ grep Huge /proc/meminfo
```

It may also be necessary to give the database server's operating system user permission to use huge pages by setting `vm.hugetlb_shm_group` via `sysctl`, and/or give permission to lock memory with `ulimit -l`.

The default behavior for huge pages in PostgreSQL is to use them when possible and to fall back to normal pages when failing. To enforce the use of huge pages, you can set `huge_pages` to `on` in `postgresql.conf`. Note that with this setting PostgreSQL will fail to start if not enough huge pages are available.

For a detailed description of the Linux huge pages feature have a look at <https://www.kernel.org/doc/Documentation/vm/hugetlbpage.txt>.

18.5. Shutting Down the Server

There are several ways to shut down the database server. You control the type of shutdown by sending different signals to the master `postgres` process.

SIGTERM

This is the *Smart Shutdown* mode. After receiving SIGTERM, the server disallows new connections, but lets existing sessions end their work normally. It shuts down only after all of the sessions terminate. If the server is in online backup mode, it additionally waits until online backup mode is no longer active. While backup mode is active, new connections will still be allowed, but only to superusers (this exception allows a superuser to connect to terminate online backup mode). If the server is in recovery when a smart shutdown is requested, recovery and streaming replication will be stopped only after all regular sessions have terminated.

SIGINT

This is the *Fast Shutdown* mode. The server disallows new connections and sends all existing server processes SIGTERM, which will cause them to abort their current transactions and exit promptly. It then waits for all server processes to exit and finally shuts down. If the server is in online backup mode, backup mode will be terminated, rendering the backup useless.

SIGQUIT

This is the *Immediate Shutdown* mode. The server will send SIGQUIT to all child processes and wait for them to terminate. If any do not terminate within 5 seconds, they will be sent SIGKILL. The master server process exits as soon as all child processes have exited, without doing normal database shutdown processing. This will lead to recovery (by replaying the WAL log) upon next start-up. This is recommended only in emergencies.

The `pg_ctl` program provides a convenient interface for sending these signals to shut down the server. Alternatively, you can send the signal directly using `kill` on non-Windows systems. The PID of the `postgres` process can be found using the `ps` program, or from the file `postmaster.pid` in the data directory. For example, to do a fast shutdown:

```
$ kill -INT `head -1 /usr/local/pgsql/data/postmaster.pid`
```

Important

It is best not to use SIGKILL to shut down the server. Doing so will prevent the server from releasing shared memory and semaphores. Furthermore, SIGKILL kills the `postgres` process without letting it relay the signal to its subprocesses, so it might be necessary to kill the individual subprocesses by hand as well.

To terminate an individual session while allowing other sessions to continue, use `pg_terminate_backend()` (see Table 9.83) or send a SIGTERM signal to the child process associated with the session.

18.6. Upgrading a PostgreSQL Cluster

This section discusses how to upgrade your database data from one PostgreSQL release to a newer one.

Current PostgreSQL version numbers consist of a major and a minor version number. For example, in the version number 10.1, the 10 is the major version number and the 1 is the minor version number, meaning this would be the first minor release of the major release 10. For releases before PostgreSQL version 10.0, version numbers consist of three numbers, for example, 9.5.3. In those cases, the major version consists of the first two digit groups of the version number, e.g., 9.5, and the minor version is the third number, e.g., 3, meaning this would be the third minor release of the major release 9.5.

Minor releases never change the internal storage format and are always compatible with earlier and later minor releases of the same major version number. For example, version 10.1 is compatible with version 10.0 and version 10.6. Similarly, for example, 9.5.3 is compatible with 9.5.0, 9.5.1, and 9.5.6. To update between compatible versions, you simply replace the executables while the server is down and restart the server. The data directory remains unchanged — minor upgrades are that simple.

For *major* releases of PostgreSQL, the internal data storage format is subject to change, thus complicating upgrades. The traditional method for moving data to a new major version is to dump and reload the database, though this can be slow. A faster method is `pg_upgrade`. Replication methods are also available, as discussed below.

New major versions also typically introduce some user-visible incompatibilities, so application programming changes might be required. All user-visible changes are listed in the release notes (Appendix E); pay particular attention to the section labeled "Migration". If you are upgrading across several major versions, be sure to read the release notes for each intervening version.

Cautious users will want to test their client applications on the new version before switching over fully; therefore, it's often a good idea to set up concurrent installations of old and new versions. When testing a PostgreSQL major upgrade, consider the following categories of possible changes:

Administration

The capabilities available for administrators to monitor and control the server often change and improve in each major release.

SQL

Typically this includes new SQL command capabilities and not changes in behavior, unless specifically mentioned in the release notes.

Library API

Typically libraries like `libpq` only add new functionality, again unless mentioned in the release notes.

System Catalogs

System catalog changes usually only affect database management tools.

Server C-language API

This involves changes in the backend function API, which is written in the C programming language. Such changes affect code that references backend functions deep inside the server.

18.6.1. Upgrading Data via `pg_dumpall`

One upgrade method is to dump data from one major version of PostgreSQL and reload it in another — to do this, you must use a *logical* backup tool like `pg_dumpall`; file system level backup methods will not work. (There are checks in place that prevent you from using a data directory with an incompatible version of PostgreSQL, so no great harm can be done by trying to start the wrong server version on a data directory.)

It is recommended that you use the `pg_dump` and `pg_dumpall` programs from the *newer* version of PostgreSQL, to take advantage of enhancements that might have been made in these programs. Current releases of the dump programs can read data from any server version back to 7.0.

These instructions assume that your existing installation is under the `/usr/local/pgsql` directory, and that the data area is in `/usr/local/pgsql/data`. Substitute your paths appropriately.

1. If making a backup, make sure that your database is not being updated. This does not affect the integrity of the backup, but the changed data would of course not be included. If necessary, edit the permissions in the file `/usr/local/pgsql/data/pg_hba.conf` (or equivalent) to disallow access from everyone except you. See Chapter 20 for additional information on access control.

To back up your database installation, type:

```
pg_dumpall > outputfile
```

To make the backup, you can use the `pg_dumpall` command from the version you are currently running; see Section 25.1.2 for more details. For best results, however, try to use the `pg_dumpall` command from PostgreSQL 12.1, since this version contains bug fixes and improvements over older versions. While this advice might seem idiosyncratic since you haven't installed the new version yet, it is advisable to follow it if you plan to install the new version in parallel with the old version. In that case you can complete the installation normally and transfer the data later. This will also decrease the downtime.

2. Shut down the old server:

```
pg_ctl stop
```

On systems that have PostgreSQL started at boot time, there is probably a start-up file that will accomplish the same thing. For example, on a Red Hat Linux system one might find that this works:

```
/etc/rc.d/init.d/postgresql stop
```

See Chapter 18 for details about starting and stopping the server.

3. If restoring from backup, rename or delete the old installation directory if it is not version-specific. It is a good idea to rename the directory, rather than delete it, in case you have trouble and need to revert to it. Keep in mind the directory might consume significant disk space. To rename the directory, use a command like this:

```
mv /usr/local/pgsql /usr/local/pgsql.old
```

(Be sure to move the directory as a single unit so relative paths remain unchanged.)

4. Install the new version of PostgreSQL as outlined in Section 16.4.
5. Create a new database cluster if needed. Remember that you must execute these commands while logged in to the special database user account (which you already have if you are upgrading).

```
/usr/local/pgsql/bin/initdb -D /usr/local/pgsql/data
```

6. Restore your previous `pg_hba.conf` and any `postgresql.conf` modifications.
7. Start the database server, again using the special database user account:

```
/usr/local/pgsql/bin/postgres -D /usr/local/pgsql/data
```

8. Finally, restore your data from backup with:

```
/usr/local/pgsql/bin/psql -d postgres -f outputfile
```

using the *new* psql.

The least downtime can be achieved by installing the new server in a different directory and running both the old and the new servers in parallel, on different ports. Then you can use something like:

```
pg_dumpall -p 5432 | psql -d postgres -p 5433
```

to transfer your data.

18.6.2. Upgrading Data via `pg_upgrade`

The `pg_upgrade` module allows an installation to be migrated in-place from one major PostgreSQL version to another. Upgrades can be performed in minutes, particularly with `--link` mode. It requires steps similar to `pg_dumpall` above, e.g. starting/stopping the server, running `initdb`. The `pg_upgrade` documentation outlines the necessary steps.

18.6.3. Upgrading Data via Replication

It is also possible to use logical replication methods to create a standby server with the updated version of PostgreSQL. This is possible because logical replication supports replication between different major versions of PostgreSQL. The standby can be on the same computer or a different computer. Once it has synced up with the master server (running the older version of PostgreSQL), you can switch masters and make the standby the master and shut down the older database instance. Such a switch-over results in only several seconds of downtime for an upgrade.

This method of upgrading can be performed using the built-in logical replication facilities as well as using external logical replication systems such as `pglogical`, `Slony`, `Londiste`, and `Bucardo`.

18.7. Preventing Server Spoofing

While the server is running, it is not possible for a malicious user to take the place of the normal database server. However, when the server is down, it is possible for a local user to spoof the normal

server by starting their own server. The spoof server could read passwords and queries sent by clients, but could not return any data because the `PGDATA` directory would still be secure because of directory permissions. Spoofing is possible because any user can start a database server; a client cannot identify an invalid server unless it is specially configured.

One way to prevent spoofing of `local` connections is to use a Unix domain socket directory (`unix_socket_directories`) that has write permission only for a trusted local user. This prevents a malicious user from creating their own socket file in that directory. If you are concerned that some applications might still reference `/tmp` for the socket file and hence be vulnerable to spoofing, during operating system startup create a symbolic link `/tmp/.s.PGSQL.5432` that points to the relocated socket file. You also might need to modify your `/tmp` cleanup script to prevent removal of the symbolic link.

Another option for `local` connections is for clients to use `requirepeer` to specify the required owner of the server process connected to the socket.

To prevent spoofing on TCP connections, either use SSL certificates and make sure that clients check the server's certificate, or use GSSAPI encryption (or both, if they're on separate connections).

To prevent spoofing with SSL, the server must be configured to accept only `hostssl` connections (Section 20.1) and have SSL key and certificate files (Section 18.9). The TCP client must connect using `sslmode=verify-ca` or `verify-full` and have the appropriate root certificate file installed (Section 33.18.1).

To prevent spoofing with GSSAPI, the server must be configured to accept only `hostgssenc` connections (Section 20.1) and use `gss` authentication with them. The TCP client must connect using `gssencmode=require`.

18.8. Encryption Options

PostgreSQL offers encryption at several levels, and provides flexibility in protecting data from disclosure due to database server theft, unscrupulous administrators, and insecure networks. Encryption might also be required to secure sensitive data such as medical records or financial transactions.

Password Encryption

Database user passwords are stored as hashes (determined by the setting `password_encryption`), so the administrator cannot determine the actual password assigned to the user. If `SCRAM` or `MD5` encryption is used for client authentication, the unencrypted password is never even temporarily present on the server because the client encrypts it before being sent across the network. `SCRAM` is preferred, because it is an Internet standard and is more secure than the PostgreSQL-specific `MD5` authentication protocol.

Encryption For Specific Columns

The `pgcrypto` module allows certain fields to be stored encrypted. This is useful if only some of the data is sensitive. The client supplies the decryption key and the data is decrypted on the server and then sent to the client.

The decrypted data and the decryption key are present on the server for a brief time while it is being decrypted and communicated between the client and server. This presents a brief moment where the data and keys can be intercepted by someone with complete access to the database server, such as the system administrator.

Data Partition Encryption

Storage encryption can be performed at the file system level or the block level. Linux file system encryption options include `eCryptfs` and `EncFS`, while FreeBSD uses `PEFS`. Block level or full disk encryption options include `dm-crypt` + `LUKS` on Linux and `GEOM` modules `geli` and `gbde` on FreeBSD. Many other operating systems support this functionality, including Windows.

This mechanism prevents unencrypted data from being read from the drives if the drives or the entire computer is stolen. This does not protect against attacks while the file system is mounted, because when mounted, the operating system provides an unencrypted view of the data. However, to mount the file system, you need some way for the encryption key to be passed to the operating system, and sometimes the key is stored somewhere on the host that mounts the disk.

Encrypting Data Across A Network

SSL connections encrypt all data sent across the network: the password, the queries, and the data returned. The `pg_hba.conf` file allows administrators to specify which hosts can use non-encrypted connections (`host`) and which require SSL-encrypted connections (`hostssl`). Also, clients can specify that they connect to servers only via SSL.

GSSAPI-encrypted connections encrypt all data sent across the network, including queries and data returned. (No password is sent across the network.) The `pg_hba.conf` file allows administrators to specify which hosts can use non-encrypted connections (`host`) and which require GSSAPI-encrypted connections (`hostgssenc`). Also, clients can specify that they connect to servers only on GSSAPI-encrypted connections (`gssencmode=require`).

Stunnel or SSH can also be used to encrypt transmissions.

SSL Host Authentication

It is possible for both the client and server to provide SSL certificates to each other. It takes some extra configuration on each side, but this provides stronger verification of identity than the mere use of passwords. It prevents a computer from pretending to be the server just long enough to read the password sent by the client. It also helps prevent “man in the middle” attacks where a computer between the client and server pretends to be the server and reads and passes all data between the client and server.

Client-Side Encryption

If the system administrator for the server's machine cannot be trusted, it is necessary for the client to encrypt the data; this way, unencrypted data never appears on the database server. Data is encrypted on the client before being sent to the server, and database results have to be decrypted on the client before being used.

18.9. Secure TCP/IP Connections with SSL

PostgreSQL has native support for using SSL connections to encrypt client/server communications for increased security. This requires that OpenSSL is installed on both client and server systems and that support in PostgreSQL is enabled at build time (see Chapter 16).

18.9.1. Basic Setup

With SSL support compiled in, the PostgreSQL server can be started with SSL enabled by setting the parameter `ssl` to `on` in `postgresql.conf`. The server will listen for both normal and SSL connections on the same TCP port, and will negotiate with any connecting client on whether to use SSL. By default, this is at the client's option; see Section 20.1 about how to set up the server to require use of SSL for some or all connections.

To start in SSL mode, files containing the server certificate and private key must exist. By default, these files are expected to be named `server.crt` and `server.key`, respectively, in the server's data directory, but other names and locations can be specified using the configuration parameters `ssl_cert_file` and `ssl_key_file`.

On Unix systems, the permissions on `server.key` must disallow any access to world or group; achieve this by the command `chmod 0600 server.key`. Alternatively, the file can be owned by

root and have group read access (that is, 0640 permissions). That setup is intended for installations where certificate and key files are managed by the operating system. The user under which the PostgreSQL server runs should then be made a member of the group that has access to those certificate and key files.

If the data directory allows group read access then certificate files may need to be located outside of the data directory in order to conform to the security requirements outlined above. Generally, group access is enabled to allow an unprivileged user to backup the database, and in that case the backup software will not be able to read the certificate files and will likely error.

If the private key is protected with a passphrase, the server will prompt for the passphrase and will not start until it has been entered. Using a passphrase by default disables the ability to change the server's SSL configuration without a server restart, but see `ssl_passphrase_command_supports_reload`. Furthermore, passphrase-protected private keys cannot be used at all on Windows.

The first certificate in `server.crt` must be the server's certificate because it must match the server's private key. The certificates of "intermediate" certificate authorities can also be appended to the file. Doing this avoids the necessity of storing intermediate certificates on clients, assuming the root and intermediate certificates were created with `v3_ca` extensions. This allows easier expiration of intermediate certificates.

It is not necessary to add the root certificate to `server.crt`. Instead, clients must have the root certificate of the server's certificate chain.

18.9.2. OpenSSL Configuration

PostgreSQL reads the system-wide OpenSSL configuration file. By default, this file is named `openssl.cnf` and is located in the directory reported by `openssl version -d`. This default can be overridden by setting environment variable `OPENSSL_CONF` to the name of the desired configuration file.

OpenSSL supports a wide range of ciphers and authentication algorithms, of varying strength. While a list of ciphers can be specified in the OpenSSL configuration file, you can specify ciphers specifically for use by the database server by modifying `ssl_ciphers` in `postgresql.conf`.

Note

It is possible to have authentication without encryption overhead by using `NULL-SHA` or `NULL-MD5` ciphers. However, a man-in-the-middle could read and pass communications between client and server. Also, encryption overhead is minimal compared to the overhead of authentication. For these reasons `NULL` ciphers are not recommended.

18.9.3. Using Client Certificates

To require the client to supply a trusted certificate, place certificates of the root certificate authorities (CAs) you trust in a file in the data directory, set the parameter `ssl_ca_file` in `postgresql.conf` to the new file name, and add the authentication option `clientcert=verify-ca` or `clientcert=verify-full` to the appropriate `hostssl` line(s) in `pg_hba.conf`. A certificate will then be requested from the client during SSL connection startup. (See Section 33.18 for a description of how to set up certificates on the client.)

For a `hostssl` entry with `clientcert=verify-ca`, the server will verify that the client's certificate is signed by one of the trusted certificate authorities. If `clientcert=verify-full` is specified, the server will not only verify the certificate chain, but it will also check whether the username or its mapping matches the `cn` (Common Name) of the provided certificate. Note that certificate chain validation is always ensured when the `cert` authentication method is used (see Section 20.12).

Intermediate certificates that chain up to existing root certificates can also appear in the `ssl_ca_file` file if you wish to avoid storing them on clients (assuming the root and intermediate certificates were created with `v3_ca` extensions). Certificate Revocation List (CRL) entries are also checked if the parameter `ssl_crl_file` is set. (See http://h41379.www4.hp.com/doc/83final/ba554_90007/ch04s02.html for diagrams showing SSL certificate usage.)

The `clientcert` authentication option is available for all authentication methods, but only in `pg_hba.conf` lines specified as `hostssl`. When `clientcert` is not specified or is set to `no-verify`, the server will still verify any presented client certificates against its CA file, if one is configured — but it will not insist that a client certificate be presented.

There are two approaches to enforce that users provide a certificate during login.

The first approach makes use of the `cert` authentication method for `hostssl` entries in `pg_hba.conf`, such that the certificate itself is used for authentication while also providing `ssl` connection security. See Section 20.12 for details. (It is not necessary to specify any `clientcert` options explicitly when using the `cert` authentication method.) In this case, the `cn` (Common Name) provided in the certificate is checked against the user name or an applicable mapping.

The second approach combines any authentication method for `hostssl` entries with the verification of client certificates by setting the `clientcert` authentication option to `verify-ca` or `verify-full`. The former option only enforces that the certificate is valid, while the latter also ensures that the `cn` (Common Name) in the certificate matches the user name or an applicable mapping.

18.9.4. SSL Server File Usage

Table 18.2 summarizes the files that are relevant to the SSL setup on the server. (The shown file names are default names. The locally configured names could be different.)

Table 18.2. SSL Server File Usage

File	Contents	Effect
<code>ssl_cert_file</code> (\$PGDATA/ <code>server.crt</code>)	server certificate	sent to client to indicate server's identity
<code>ssl_key_file</code> (\$PGDATA/ <code>server.key</code>)	server private key	proves server certificate was sent by the owner; does not indicate certificate owner is trustworthy
<code>ssl_ca_file</code>	trusted certificate authorities	checks that client certificate is signed by a trusted certificate authority
<code>ssl_crl_file</code>	certificates revoked by certificate authorities	client certificate must not be on this list

The server reads these files at server start and whenever the server configuration is reloaded. On Windows systems, they are also re-read whenever a new backend process is spawned for a new client connection.

If an error in these files is detected at server start, the server will refuse to start. But if an error is detected during a configuration reload, the files are ignored and the old SSL configuration continues to be used. On Windows systems, if an error in these files is detected at backend start, that backend will be unable to establish an SSL connection. In all these cases, the error condition is reported in the server log.

18.9.5. Creating Certificates

To create a simple self-signed certificate for the server, valid for 365 days, use the following OpenSSL command, replacing `dbhost.yourdomain.com` with the server's host name:

```
openssl req -new -x509 -days 365 -nodes -text -out server.crt \  
-keyout server.key -subj "/CN=dbhost.yourdomain.com"
```

Then do:

```
chmod og-rwx server.key
```

because the server will reject the file if its permissions are more liberal than this. For more details on how to create your server private key and certificate, refer to the OpenSSL documentation.

While a self-signed certificate can be used for testing, a certificate signed by a certificate authority (CA) (usually an enterprise-wide root CA) should be used in production.

To create a server certificate whose identity can be validated by clients, first create a certificate signing request (CSR) and a public/private key file:

```
openssl req -new -nodes -text -out root.csr \  
-keyout root.key -subj "/CN=root.yourdomain.com"  
chmod og-rwx root.key
```

Then, sign the request with the key to create a root certificate authority (using the default OpenSSL configuration file location on Linux):

```
openssl x509 -req -in root.csr -text -days 3650 \  
-extfile /etc/ssl/openssl.cnf -extensions v3_ca \  
-signkey root.key -out root.crt
```

Finally, create a server certificate signed by the new root certificate authority:

```
openssl req -new -nodes -text -out server.csr \  
-keyout server.key -subj "/CN=dbhost.yourdomain.com"  
chmod og-rwx server.key  
  
openssl x509 -req -in server.csr -text -days 365 \  
-CA root.crt -CAkey root.key -CAcreateserial \  
-out server.crt
```

`server.crt` and `server.key` should be stored on the server, and `root.crt` should be stored on the client so the client can verify that the server's leaf certificate was signed by its trusted root certificate. `root.key` should be stored offline for use in creating future certificates.

It is also possible to create a chain of trust that includes intermediate certificates:

```
# root  
openssl req -new -nodes -text -out root.csr \  
-keyout root.key -subj "/CN=root.yourdomain.com"  
chmod og-rwx root.key  
openssl x509 -req -in root.csr -text -days 3650 \  
-extfile /etc/ssl/openssl.cnf -extensions v3_ca \  
-signkey root.key -out root.crt  
  
# intermediate  
openssl req -new -nodes -text -out intermediate.csr \  
-keyout intermediate.key -subj "/CN=intermediate.yourdomain.com"  
chmod og-rwx intermediate.key
```

```
openssl x509 -req -in intermediate.csr -text -days 1825 \  
  -extfile /etc/ssl/openssl.cnf -extensions v3_ca \  
  -CA root.crt -CAkey root.key -CAcreateserial \  
  -out intermediate.crt  
  
# leaf  
openssl req -new -nodes -text -out server.csr \  
  -keyout server.key -subj "/CN=dbhost.yourdomain.com"  
chmod og-rwx server.key  
openssl x509 -req -in server.csr -text -days 365 \  
  -CA intermediate.crt -CAkey intermediate.key -CAcreateserial \  
  -out server.crt
```

`server.crt` and `intermediate.crt` should be concatenated into a certificate file bundle and stored on the server. `server.key` should also be stored on the server. `root.crt` should be stored on the client so the client can verify that the server's leaf certificate was signed by a chain of certificates linked to its trusted root certificate. `root.key` and `intermediate.key` should be stored offline for use in creating future certificates.

18.10. Secure TCP/IP Connections with GSSAPI Encryption

PostgreSQL also has native support for using GSSAPI to encrypt client/server communications for increased security. Support requires that a GSSAPI implementation (such as MIT krb5) is installed on both client and server systems, and that support in PostgreSQL is enabled at build time (see Chapter 16).

18.10.1. Basic Setup

The PostgreSQL server will listen for both normal and GSSAPI-encrypted connections on the same TCP port, and will negotiate with any connecting client on whether to use GSSAPI for encryption (and for authentication). By default, this decision is up to the client (which means it can be downgraded by an attacker); see Section 20.1 about setting up the server to require the use of GSSAPI for some or all connections.

Other than configuration of the negotiation behavior, GSSAPI encryption requires no setup beyond that which is necessary for GSSAPI authentication. (For more information on configuring that, see Section 20.6.)

18.11. Secure TCP/IP Connections with SSH Tunnels

It is possible to use SSH to encrypt the network connection between clients and a PostgreSQL server. Done properly, this provides an adequately secure network connection, even for non-SSL-capable clients.

First make sure that an SSH server is running properly on the same machine as the PostgreSQL server and that you can log in using `ssh` as some user. Then you can establish a secure tunnel with a command like this from the client machine:

```
ssh -L 63333:localhost:5432 joe@foo.com
```

The first number in the `-L` argument, 63333, is the port number of your end of the tunnel; it can be any unused port. (IANA reserves ports 49152 through 65535 for private use.) The second number, 5432,

is the remote end of the tunnel: the port number your server is using. The name or IP address between the port numbers is the host with the database server you are going to connect to, as seen from the host you are logging in to, which is `foo.com` in this example. In order to connect to the database server using this tunnel, you connect to port 63333 on the local machine:

```
psql -h localhost -p 63333 postgres
```

To the database server it will then look as though you are really user `joe` on host `foo.com` connecting to `localhost` in that context, and it will use whatever authentication procedure was configured for connections from this user and host. Note that the server will not think the connection is SSL-encrypted, since in fact it is not encrypted between the SSH server and the PostgreSQL server. This should not pose any extra security risk as long as they are on the same machine.

In order for the tunnel setup to succeed you must be allowed to connect via `ssh` as `joe@foo.com`, just as if you had attempted to use `ssh` to create a terminal session.

You could also have set up the port forwarding as

```
ssh -L 63333:foo.com:5432 joe@foo.com
```

but then the database server will see the connection as coming in on its `foo.com` interface, which is not opened by the default setting `listen_addresses = 'localhost'`. This is usually not what you want.

If you have to “hop” to the database server via some login host, one possible setup could look like this:

```
ssh -L 63333:db.foo.com:5432 joe@shell.foo.com
```

Note that this way the connection from `shell.foo.com` to `db.foo.com` will not be encrypted by the SSH tunnel. SSH offers quite a few configuration possibilities when the network is restricted in various ways. Please refer to the SSH documentation for details.

Tip

Several other applications exist that can provide secure tunnels using a procedure similar in concept to the one just described.

18.12. Registering Event Log on Windows

To register a Windows event log library with the operating system, issue this command:

```
regsvr32 pgsql_library_directory/pgevent.dll
```

This creates registry entries used by the event viewer, under the default event source named `PostgreSQL`.

To specify a different event source name (see `event_source`), use the `/n` and `/i` options:

```
regsvr32 /n /i:event_source_name pgsql_library_directory/pgevent.dll
```

To unregister the event log library from the operating system, issue this command:

```
regsvr32 /u [/i:event_source_name] pgsql_library_directory/  
pgevent.dll
```

Note

To enable event logging in the database server, modify `log_destination` to include `eventlog` in `postgresql.conf`.

Chapter 19. Server Configuration

There are many configuration parameters that affect the behavior of the database system. In the first section of this chapter we describe how to interact with configuration parameters. The subsequent sections discuss each parameter in detail.

19.1. Setting Parameters

19.1.1. Parameter Names and Values

All parameter names are case-insensitive. Every parameter takes a value of one of five types: boolean, string, integer, floating point, or enumerated (enum). The type determines the syntax for setting the parameter:

- *Boolean*: Values can be written as `on`, `off`, `true`, `false`, `yes`, `no`, `1`, `0` (all case-insensitive) or any unambiguous prefix of one of these.
- *String*: In general, enclose the value in single quotes, doubling any single quotes within the value. Quotes can usually be omitted if the value is a simple number or identifier, however. (Values that match a SQL keyword require quoting in some contexts.)
- *Numeric (integer and floating point)*: Numeric parameters can be specified in the customary integer and floating-point formats; fractional values are rounded to the nearest integer if the parameter is of integer type. Integer parameters additionally accept hexadecimal input (beginning with `0x`) and octal input (beginning with `0`), but these formats cannot have a fraction. Do not use thousands separators. Quotes are not required, except for hexadecimal input.
- *Numeric with Unit*: Some numeric parameters have an implicit unit, because they describe quantities of memory or time. The unit might be bytes, kilobytes, blocks (typically eight kilobytes), milliseconds, seconds, or minutes. An unadorned numeric value for one of these settings will use the setting's default unit, which can be learned from `pg_settings.unit`. For convenience, settings can be given with a unit specified explicitly, for example `'120 ms'` for a time value, and they will be converted to whatever the parameter's actual unit is. Note that the value must be written as a string (with quotes) to use this feature. The unit name is case-sensitive, and there can be whitespace between the numeric value and the unit.
 - Valid memory units are B (bytes), kB (kilobytes), MB (megabytes), GB (gigabytes), and TB (terabytes). The multiplier for memory units is 1024, not 1000.
 - Valid time units are `us` (microseconds), `ms` (milliseconds), `s` (seconds), `min` (minutes), `h` (hours), and `d` (days).

If a fractional value is specified with a unit, it will be rounded to a multiple of the next smaller unit if there is one. For example, `30.1 GB` will be converted to `30822 MB` not `32319628902 B`. If the parameter is of integer type, a final rounding to integer occurs after any units conversion.
- *Enumerated*: Enumerated-type parameters are written in the same way as string parameters, but are restricted to have one of a limited set of values. The values allowable for such a parameter can be found from `pg_settings.enumvals`. Enum parameter values are case-insensitive.

19.1.2. Parameter Interaction via the Configuration File

The most fundamental way to set these parameters is to edit the file `postgresql.conf`, which is normally kept in the data directory. A default copy is installed when the database cluster directory is initialized. An example of what this file might look like is:

```
# This is a comment
```

```
log_connections = yes
log_destination = 'syslog'
search_path = '$user', public'
shared_buffers = 128MB
```

One parameter is specified per line. The equal sign between name and value is optional. Whitespace is insignificant (except within a quoted parameter value) and blank lines are ignored. Hash marks (#) designate the remainder of the line as a comment. Parameter values that are not simple identifiers or numbers must be single-quoted. To embed a single quote in a parameter value, write either two quotes (preferred) or backslash-quote. If the file contains multiple entries for the same parameter, all but the last one are ignored.

Parameters set in this way provide default values for the cluster. The settings seen by active sessions will be these values unless they are overridden. The following sections describe ways in which the administrator or user can override these defaults.

The configuration file is reread whenever the main server process receives a SIGHUP signal; this signal is most easily sent by running `pg_ctl reload` from the command line or by calling the SQL function `pg_reload_conf()`. The main server process also propagates this signal to all currently running server processes, so that existing sessions also adopt the new values (this will happen after they complete any currently-executing client command). Alternatively, you can send the signal to a single server process directly. Some parameters can only be set at server start; any changes to their entries in the configuration file will be ignored until the server is restarted. Invalid parameter settings in the configuration file are likewise ignored (but logged) during SIGHUP processing.

In addition to `postgresql.conf`, a PostgreSQL data directory contains a file `postgresql.auto.conf`, which has the same format as `postgresql.conf` but is intended to be edited automatically, not manually. This file holds settings provided through the `ALTER SYSTEM` command. This file is read whenever `postgresql.conf` is, and its settings take effect in the same way. Settings in `postgresql.auto.conf` override those in `postgresql.conf`.

External tools may also modify `postgresql.auto.conf`. It is not recommended to do this while the server is running, since a concurrent `ALTER SYSTEM` command could overwrite such changes. Such tools might simply append new settings to the end, or they might choose to remove duplicate settings and/or comments (as `ALTER SYSTEM` will).

The system view `pg_file_settings` can be helpful for pre-testing changes to the configuration files, or for diagnosing problems if a SIGHUP signal did not have the desired effects.

19.1.3. Parameter Interaction via SQL

PostgreSQL provides three SQL commands to establish configuration defaults. The already-mentioned `ALTER SYSTEM` command provides a SQL-accessible means of changing global defaults; it is functionally equivalent to editing `postgresql.conf`. In addition, there are two commands that allow setting of defaults on a per-database or per-role basis:

- The `ALTER DATABASE` command allows global settings to be overridden on a per-database basis.
- The `ALTER ROLE` command allows both global and per-database settings to be overridden with user-specific values.

Values set with `ALTER DATABASE` and `ALTER ROLE` are applied only when starting a fresh database session. They override values obtained from the configuration files or server command line, and constitute defaults for the rest of the session. Note that some settings cannot be changed after server start, and so cannot be set with these commands (or the ones listed below).

Once a client is connected to the database, PostgreSQL provides two additional SQL commands (and equivalent functions) to interact with session-local configuration settings:

- The `SHOW` command allows inspection of the current value of all parameters. The corresponding function is `current_setting(setting_name text)`.

- The SET command allows modification of the current value of those parameters that can be set locally to a session; it has no effect on other sessions. The corresponding function is `set_config(setting_name, new_value, is_local)`.

In addition, the system view `pg_settings` can be used to view and change session-local values:

- Querying this view is similar to using `SHOW ALL` but provides more detail. It is also more flexible, since it's possible to specify filter conditions or join against other relations.
- Using `UPDATE` on this view, specifically updating the `setting` column, is the equivalent of issuing SET commands. For example, the equivalent of

```
SET configuration_parameter TO DEFAULT;
```

is:

```
UPDATE pg_settings SET setting = reset_val WHERE name =  
'configuration_parameter';
```

19.1.4. Parameter Interaction via the Shell

In addition to setting global defaults or attaching overrides at the database or role level, you can pass settings to PostgreSQL via shell facilities. Both the server and libpq client library accept parameter values via the shell.

- During server startup, parameter settings can be passed to the `postgres` command via the `-c` command-line parameter. For example,

```
postgres -c log_connections=yes -c log_destination='syslog'
```

Settings provided in this way override those set via `postgresql.conf` or `ALTER SYSTEM`, so they cannot be changed globally without restarting the server.

- When starting a client session via libpq, parameter settings can be specified using the `PGOPTIONS` environment variable. Settings established in this way constitute defaults for the life of the session, but do not affect other sessions. For historical reasons, the format of `PGOPTIONS` is similar to that used when launching the `postgres` command; specifically, the `-c` flag must be specified. For example,

```
env PGOPTIONS="-c geqo=off -c statement_timeout=5min" psql
```

Other clients and libraries might provide their own mechanisms, via the shell or otherwise, that allow the user to alter session settings without direct use of SQL commands.

19.1.5. Managing Configuration File Contents

PostgreSQL provides several features for breaking down complex `postgresql.conf` files into sub-files. These features are especially useful when managing multiple servers with related, but not identical, configurations.

In addition to individual parameter settings, the `postgresql.conf` file can contain *include directives*, which specify another file to read and process as if it were inserted into the configuration file at this point. This feature allows a configuration file to be divided into physically separate parts. Include directives simply look like:

```
include 'filename'
```

If the file name is not an absolute path, it is taken as relative to the directory containing the referencing configuration file. Inclusions can be nested.

There is also an `include_if_exists` directive, which acts the same as the `include` directive, except when the referenced file does not exist or cannot be read. A regular `include` will consider this an error condition, but `include_if_exists` merely logs a message and continues processing the referencing configuration file.

The `postgresql.conf` file can also contain `include_dir` directives, which specify an entire directory of configuration files to include. These look like

```
include_dir 'directory'
```

Non-absolute directory names are taken as relative to the directory containing the referencing configuration file. Within the specified directory, only non-directory files whose names end with the suffix `.conf` will be included. File names that start with the `.` character are also ignored, to prevent mistakes since such files are hidden on some platforms. Multiple files within an include directory are processed in file name order (according to C locale rules, i.e. numbers before letters, and uppercase letters before lowercase ones).

Include files or directories can be used to logically separate portions of the database configuration, rather than having a single large `postgresql.conf` file. Consider a company that has two database servers, each with a different amount of memory. There are likely elements of the configuration both will share, for things such as logging. But memory-related parameters on the server will vary between the two. And there might be server specific customizations, too. One way to manage this situation is to break the custom configuration changes for your site into three files. You could add this to the end of your `postgresql.conf` file to include them:

```
include 'shared.conf'  
include 'memory.conf'  
include 'server.conf'
```

All systems would have the same `shared.conf`. Each server with a particular amount of memory could share the same `memory.conf`; you might have one for all servers with 8GB of RAM, another for those having 16GB. And finally `server.conf` could have truly server-specific configuration information in it.

Another possibility is to create a configuration file directory and put this information into files there. For example, a `conf.d` directory could be referenced at the end of `postgresql.conf`:

```
include_dir 'conf.d'
```

Then you could name the files in the `conf.d` directory like this:

```
00shared.conf  
01memory.conf  
02server.conf
```

This naming convention establishes a clear order in which these files will be loaded. This is important because only the last setting encountered for a particular parameter while the server is reading configuration files will be used. In this example, something set in `conf.d/02server.conf` would override a value set in `conf.d/01memory.conf`.

You might instead use this approach to naming the files descriptively:

```
00shared.conf
01memory-8GB.conf
02server-foo.conf
```

This sort of arrangement gives a unique name for each configuration file variation. This can help eliminate ambiguity when several servers have their configurations all stored in one place, such as in a version control repository. (Storing database configuration files under version control is another good practice to consider.)

19.2. File Locations

In addition to the `postgresql.conf` file already mentioned, PostgreSQL uses two other manually-edited configuration files, which control client authentication (their use is discussed in Chapter 20). By default, all three configuration files are stored in the database cluster's data directory. The parameters described in this section allow the configuration files to be placed elsewhere. (Doing so can ease administration. In particular it is often easier to ensure that the configuration files are properly backed-up when they are kept separate.)

`data_directory (string)`

Specifies the directory to use for data storage. This parameter can only be set at server start.

`config_file (string)`

Specifies the main server configuration file (customarily called `postgresql.conf`). This parameter can only be set on the `postgres` command line.

`hba_file (string)`

Specifies the configuration file for host-based authentication (customarily called `pg_hba.conf`). This parameter can only be set at server start.

`ident_file (string)`

Specifies the configuration file for user name mapping (customarily called `pg_ident.conf`). This parameter can only be set at server start. See also Section 20.2.

`external_pid_file (string)`

Specifies the name of an additional process-ID (PID) file that the server should create for use by server administration programs. This parameter can only be set at server start.

In a default installation, none of the above parameters are set explicitly. Instead, the data directory is specified by the `-D` command-line option or the `PGDATA` environment variable, and the configuration files are all found within the data directory.

If you wish to keep the configuration files elsewhere than the data directory, the `postgres -D` command-line option or `PGDATA` environment variable must point to the directory containing the configuration files, and the `data_directory` parameter must be set in `postgresql.conf` (or on the command line) to show where the data directory is actually located. Notice that `data_directory` overrides `-D` and `PGDATA` for the location of the data directory, but not for the location of the configuration files.

If you wish, you can specify the configuration file names and locations individually using the parameters `config_file`, `hba_file` and/or `ident_file`. `config_file` can only be specified on the `postgres` command line, but the others can be set within the main configuration file. If all three parameters plus `data_directory` are explicitly set, then it is not necessary to specify `-D` or `PGDATA`.

When setting any of these parameters, a relative path will be interpreted with respect to the directory in which `postgres` is started.

19.3. Connections and Authentication

19.3.1. Connection Settings

`listen_addresses` (string)

Specifies the TCP/IP address(es) on which the server is to listen for connections from client applications. The value takes the form of a comma-separated list of host names and/or numeric IP addresses. The special entry `*` corresponds to all available IP interfaces. The entry `0.0.0.0` allows listening for all IPv4 addresses and `::` allows listening for all IPv6 addresses. If the list is empty, the server does not listen on any IP interface at all, in which case only Unix-domain sockets can be used to connect to it. The default value is `localhost`, which allows only local TCP/IP “loopback” connections to be made. While client authentication (Chapter 20) allows fine-grained control over who can access the server, `listen_addresses` controls which interfaces accept connection attempts, which can help prevent repeated malicious connection requests on insecure network interfaces. This parameter can only be set at server start.

`port` (integer)

The TCP port the server listens on; 5432 by default. Note that the same port number is used for all IP addresses the server listens on. This parameter can only be set at server start.

`max_connections` (integer)

Determines the maximum number of concurrent connections to the database server. The default is typically 100 connections, but might be less if your kernel settings will not support it (as determined during `initdb`). This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`superuser_reserved_connections` (integer)

Determines the number of connection “slots” that are reserved for connections by PostgreSQL superusers. At most `max_connections` connections can ever be active simultaneously. Whenever the number of active concurrent connections is at least `max_connections` minus `superuser_reserved_connections`, new connections will be accepted only for superusers, and no new replication connections will be accepted.

The default value is three connections. The value must be less than `max_connections`. This parameter can only be set at server start.

`unix_socket_directories` (string)

Specifies the directory of the Unix-domain socket(s) on which the server is to listen for connections from client applications. Multiple sockets can be created by listing multiple directories separated by commas. Whitespace between entries is ignored; surround a directory name with double quotes if you need to include whitespace or commas in the name. An empty value specifies not listening on any Unix-domain sockets, in which case only TCP/IP sockets can be used to connect to the server. The default value is normally `/tmp`, but that can be changed at build time. This parameter can only be set at server start.

In addition to the socket file itself, which is named `.s.PGSQL.nnnn` where `nnnn` is the server's port number, an ordinary file named `.s.PGSQL.nnnn.lock` will be created in each of the `unix_socket_directories` directories. Neither file should ever be removed manually.

This parameter is irrelevant on Windows, which does not have Unix-domain sockets.

`unix_socket_group` (string)

Sets the owning group of the Unix-domain socket(s). (The owning user of the sockets is always the user that starts the server.) In combination with the parameter `unix_socket_permissions` this can be used as an additional access control mechanism for Unix-domain connections. By default this is the empty string, which uses the default group of the server user. This parameter can only be set at server start.

This parameter is irrelevant on Windows, which does not have Unix-domain sockets.

`unix_socket_permissions` (integer)

Sets the access permissions of the Unix-domain socket(s). Unix-domain sockets use the usual Unix file system permission set. The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls. (To use the customary octal format the number must start with a 0 (zero).)

The default permissions are 0777, meaning anyone can connect. Reasonable alternatives are 0770 (only user and group, see also `unix_socket_group`) and 0700 (only user). (Note that for a Unix-domain socket, only write permission matters, so there is no point in setting or revoking read or execute permissions.)

This access control mechanism is independent of the one described in Chapter 20.

This parameter can only be set at server start.

This parameter is irrelevant on systems, notably Solaris as of Solaris 10, that ignore socket permissions entirely. There, one can achieve a similar effect by pointing `unix_socket_directories` to a directory having search permission limited to the desired audience. This parameter is also irrelevant on Windows, which does not have Unix-domain sockets.

`bonjour` (boolean)

Enables advertising the server's existence via Bonjour. The default is off. This parameter can only be set at server start.

`bonjour_name` (string)

Specifies the Bonjour service name. The computer name is used if this parameter is set to the empty string '' (which is the default). This parameter is ignored if the server was not compiled with Bonjour support. This parameter can only be set at server start.

`tcp_keepalives_idle` (integer)

Specifies the amount of time with no network activity after which the operating system should send a TCP keepalive message to the client. If this value is specified without units, it is taken as seconds. A value of 0 (the default) selects the operating system's default. This parameter is supported only on systems that support `TCP_KEEPIDLE` or an equivalent socket option, and on Windows; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

Note

On Windows, setting a value of 0 will set this parameter to 2 hours, since Windows does not provide a way to read the system default value.

`tcp_keepalives_interval` (integer)

Specifies the amount of time after which a TCP keepalive message that has not been acknowledged by the client should be retransmitted. If this value is specified without units, it is taken as seconds. A value of 0 (the default) selects the operating system's default. This parameter is supported only on systems that support `TCP_KEEPINTVL` or an equivalent socket option, and on Windows; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

Note

On Windows, setting a value of 0 will set this parameter to 1 second, since Windows does not provide a way to read the system default value.

`tcp_keepalives_count` (integer)

Specifies the number of TCP keepalive messages that can be lost before the server's connection to the client is considered dead. A value of 0 (the default) selects the operating system's default. This parameter is supported only on systems that support `TCP_KEEPCNT` or an equivalent socket option; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

Note

This parameter is not supported on Windows, and must be zero.

`tcp_user_timeout` (integer)

Specifies the amount of time that transmitted data may remain unacknowledged before the TCP connection is forcibly closed. If this value is specified without units, it is taken as milliseconds. A value of 0 (the default) selects the operating system's default. This parameter is supported only on systems that support `TCP_USER_TIMEOUT`; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

Note

This parameter is not supported on Windows, and must be zero.

19.3.2. Authentication

`authentication_timeout` (integer)

Maximum amount of time allowed to complete client authentication. If a would-be client has not completed the authentication protocol in this much time, the server closes the connection. This prevents hung clients from occupying a connection indefinitely. If this value is specified without units, it is taken as seconds. The default is one minute (1m). This parameter can only be set in the `postgresql.conf` file or on the server command line.

`password_encryption` (enum)

When a password is specified in `CREATE ROLE` or `ALTER ROLE`, this parameter determines the algorithm to use to encrypt the password. The default value is `md5`, which stores the password as

an MD5 hash (on is also accepted, as alias for md5). Setting this parameter to `scram-sha-256` will encrypt the password with SCRAM-SHA-256.

Note that older clients might lack support for the SCRAM authentication mechanism, and hence not work with passwords encrypted with SCRAM-SHA-256. See Section 20.5 for more details.

`krb_server_keyfile` (string)

Sets the location of the Kerberos server key file. See Section 20.6 for details. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`krb_caseins_users` (boolean)

Sets whether GSSAPI user names should be treated case-insensitively. The default is `off` (case sensitive). This parameter can only be set in the `postgresql.conf` file or on the server command line.

`db_user_namespace` (boolean)

This parameter enables per-database user names. It is off by default. This parameter can only be set in the `postgresql.conf` file or on the server command line.

If this is on, you should create users as `username@dbname`. When `username` is passed by a connecting client, `@` and the database name are appended to the user name and that database-specific user name is looked up by the server. Note that when you create users with names containing `@` within the SQL environment, you will need to quote the user name.

With this parameter enabled, you can still create ordinary global users. Simply append `@` when specifying the user name in the client, e.g. `joe@`. The `@` will be stripped off before the user name is looked up by the server.

`db_user_namespace` causes the client's and server's user name representation to differ. Authentication checks are always done with the server's user name so authentication methods must be configured for the server's user name, not the client's. Because `md5` uses the user name as salt on both the client and server, `md5` cannot be used with `db_user_namespace`.

Note

This feature is intended as a temporary measure until a complete solution is found. At that time, this option will be removed.

19.3.3. SSL

See Section 18.9 for more information about setting up SSL.

`ssl` (boolean)

Enables SSL connections. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `off`.

`ssl_ca_file` (string)

Specifies the name of the file containing the SSL server certificate authority (CA). Relative paths are relative to the data directory. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is empty, meaning no CA file is loaded, and client certificate verification is not performed.

`ssl_cert_file` (string)

Specifies the name of the file containing the SSL server certificate. Relative paths are relative to the data directory. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `server.crt`.

`ssl_crl_file` (string)

Specifies the name of the file containing the SSL server certificate revocation list (CRL). Relative paths are relative to the data directory. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is empty, meaning no CRL file is loaded.

`ssl_key_file` (string)

Specifies the name of the file containing the SSL server private key. Relative paths are relative to the data directory. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `server.key`.

`ssl_ciphers` (string)

Specifies a list of SSL cipher suites that are allowed to be used on secure connections. See the ciphers manual page in the OpenSSL package for the syntax of this setting and a list of supported values. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default value is `HIGH:MEDIUM:+3DES:!aNULL`. The default is usually a reasonable choice unless you have specific security requirements.

Explanation of the default value:

HIGH

Cipher suites that use ciphers from HIGH group (e.g., AES, Camellia, 3DES)

MEDIUM

Cipher suites that use ciphers from MEDIUM group (e.g., RC4, SEED)

+3DES

The OpenSSL default order for HIGH is problematic because it orders 3DES higher than AES128. This is wrong because 3DES offers less security than AES128, and it is also much slower. +3DES reorders it after all other HIGH and MEDIUM ciphers.

!aNULL

Disables anonymous cipher suites that do no authentication. Such cipher suites are vulnerable to man-in-the-middle attacks and therefore should not be used.

Available cipher suite details will vary across OpenSSL versions. Use the command `openssl ciphers -v 'HIGH:MEDIUM:+3DES:!aNULL'` to see actual details for the currently installed OpenSSL version. Note that this list is filtered at run time based on the server key type.

`ssl_prefer_server_ciphers` (boolean)

Specifies whether to use the server's SSL cipher preferences, rather than the client's. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is on.

Older PostgreSQL versions do not have this setting and always use the client's preferences. This setting is mainly for backward compatibility with those versions. Using the server's preferences is usually better because it is more likely that the server is appropriately configured.

`ssl_ecdh_curve` (string)

Specifies the name of the curve to use in ECDH key exchange. It needs to be supported by all clients that connect. It does not need to be the same curve used by the server's Elliptic Curve key. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `prime256v1`.

OpenSSL names for the most common curves are: `prime256v1` (NIST P-256), `secp384r1` (NIST P-384), `secp521r1` (NIST P-521). The full list of available curves can be shown with the command `openssl ecparam -list_curves`. Not all of them are usable in TLS though.

`ssl_min_protocol_version` (enum)

Sets the minimum SSL/TLS protocol version to use. Valid values are currently: `TLSv1`, `TLSv1.1`, `TLSv1.2`, `TLSv1.3`. Older versions of the OpenSSL library do not support all values; an error will be raised if an unsupported setting is chosen. Protocol versions before TLS 1.0, namely SSL version 2 and 3, are always disabled.

The default is `TLSv1`, mainly to support older versions of the OpenSSL library. You might want to set this to a higher value if all software components can support the newer protocol versions.

`ssl_max_protocol_version` (enum)

Sets the maximum SSL/TLS protocol version to use. Valid values are as for `ssl_min_protocol_version`, with addition of an empty string, which allows any protocol version. The default is to allow any version. Setting the maximum protocol version is mainly useful for testing or if some component has issues working with a newer protocol.

`ssl_dh_params_file` (string)

Specifies the name of the file containing Diffie-Hellman parameters used for so-called ephemeral DH family of SSL ciphers. The default is empty, in which case compiled-in default DH parameters used. Using custom DH parameters reduces the exposure if an attacker manages to crack the well-known compiled-in DH parameters. You can create your own DH parameters file with the command `openssl dhparam -out dhparams.pem 2048`.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`ssl_passphrase_command` (string)

Sets an external command to be invoked when a passphrase for decrypting an SSL file such as a private key needs to be obtained. By default, this parameter is empty, which means the built-in prompting mechanism is used.

The command must print the passphrase to the standard output and exit with code 0. In the parameter value, `%p` is replaced by a prompt string. (Write `%%` for a literal `%`.) Note that the prompt string will probably contain whitespace, so be sure to quote adequately. A single newline is stripped from the end of the output if present.

The command does not actually have to prompt the user for a passphrase. It can read it from a file, obtain it from a keychain facility, or similar. It is up to the user to make sure the chosen mechanism is adequately secure.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`ssl_passphrase_command_supports_reload` (boolean)

This parameter determines whether the passphrase command set by `ssl_passphrase_command` will also be called during a configuration reload if a key file needs a passphrase. If this parameter is off (the default), then `ssl_passphrase_command` will be ignored during a reload and the SSL configuration will not be reloaded if a passphrase is needed. That setting is appro-

ropriate for a command that requires a TTY for prompting, which might not be available when the server is running. Setting this parameter to `on` might be appropriate if the passphrase is obtained from a file, for example.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.4. Resource Consumption

19.4.1. Memory

`shared_buffers` (integer)

Sets the amount of memory the database server uses for shared memory buffers. The default is typically 128 megabytes (128MB), but might be less if your kernel settings will not support it (as determined during `initdb`). This setting must be at least 128 kilobytes. However, settings significantly higher than the minimum are usually needed for good performance. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. (Non-default values of `BLCKSZ` change the minimum value.) This parameter can only be set at server start.

If you have a dedicated database server with 1GB or more of RAM, a reasonable starting value for `shared_buffers` is 25% of the memory in your system. There are some workloads where even larger settings for `shared_buffers` are effective, but because PostgreSQL also relies on the operating system cache, it is unlikely that an allocation of more than 40% of RAM to `shared_buffers` will work better than a smaller amount. Larger settings for `shared_buffers` usually require a corresponding increase in `max_wal_size`, in order to spread out the process of writing large quantities of new or changed data over a longer period of time.

On systems with less than 1GB of RAM, a smaller percentage of RAM is appropriate, so as to leave adequate space for the operating system.

`huge_pages` (enum)

Controls whether huge pages are requested for the main shared memory area. Valid values are `try` (the default), `on`, and `off`. With `huge_pages` set to `try`, the server will try to request huge pages, but fall back to the default if that fails. With `on`, failure to request huge pages will prevent the server from starting up. With `off`, huge pages will not be requested.

At present, this setting is supported only on Linux and Windows. The setting is ignored on other systems when set to `try`.

The use of huge pages results in smaller page tables and less CPU time spent on memory management, increasing performance. For more details about using huge pages on Linux, see Section 18.4.5.

Huge pages are known as large pages on Windows. To use them, you need to assign the user right Lock Pages in Memory to the Windows user account that runs PostgreSQL. You can use Windows Group Policy tool (`gpedit.msc`) to assign the user right Lock Pages in Memory. To start the database server on the command prompt as a standalone process, not as a Windows service, the command prompt must be run as an administrator or User Access Control (UAC) must be disabled. When the UAC is enabled, the normal command prompt revokes the user right Lock Pages in Memory when started.

Note that this setting only affects the main shared memory area. Operating systems such as Linux, FreeBSD, and Illumos can also use huge pages (also known as “super” pages or “large” pages) automatically for normal memory allocation, without an explicit request from PostgreSQL. On Linux, this is called “transparent huge pages” (THP). That feature has been known to cause performance degradation with PostgreSQL for some users on some Linux versions, so its use is currently discouraged (unlike explicit use of `huge_pages`).

`temp_buffers (integer)`

Sets the maximum amount of memory used for temporary buffers within each database session. These are session-local buffers used only for access to temporary tables. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The default is eight megabytes (8MB). (If `BLCKSZ` is not 8kB, the default value scales proportionally to it.) This setting can be changed within individual sessions, but only before the first use of temporary tables within the session; subsequent attempts to change the value will have no effect on that session.

A session will allocate temporary buffers as needed up to the limit given by `temp_buffers`. The cost of setting a large value in sessions that do not actually need many temporary buffers is only a buffer descriptor, or about 64 bytes, per increment in `temp_buffers`. However if a buffer is actually used an additional 8192 bytes will be consumed for it (or in general, `BLCKSZ` bytes).

`max_prepared_transactions (integer)`

Sets the maximum number of transactions that can be in the “prepared” state simultaneously (see `PREPARE TRANSACTION`). Setting this parameter to zero (which is the default) disables the prepared-transaction feature. This parameter can only be set at server start.

If you are not planning to use prepared transactions, this parameter should be set to zero to prevent accidental creation of prepared transactions. If you are using prepared transactions, you will probably want `max_prepared_transactions` to be at least as large as `max_connections`, so that every session can have a prepared transaction pending.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`work_mem (integer)`

Sets the maximum amount of memory to be used by a query operation (such as a sort or hash table) before writing to temporary disk files. If this value is specified without units, it is taken as kilobytes. The default value is four megabytes (4MB). Note that for a complex query, several sort or hash operations might be running in parallel; each operation will be allowed to use as much memory as this value specifies before it starts to write data into temporary files. Also, several running sessions could be doing such operations concurrently. Therefore, the total memory used could be many times the value of `work_mem`; it is necessary to keep this fact in mind when choosing the value. Sort operations are used for `ORDER BY`, `DISTINCT`, and merge joins. Hash tables are used in hash joins, hash-based aggregation, and hash-based processing of `IN` subqueries.

`maintenance_work_mem (integer)`

Specifies the maximum amount of memory to be used by maintenance operations, such as `VACUUM`, `CREATE INDEX`, and `ALTER TABLE ADD FOREIGN KEY`. If this value is specified without units, it is taken as kilobytes. It defaults to 64 megabytes (64MB). Since only one of these operations can be executed at a time by a database session, and an installation normally doesn't have many of them running concurrently, it's safe to set this value significantly larger than `work_mem`. Larger settings might improve performance for vacuuming and for restoring database dumps.

Note that when autovacuum runs, up to `autovacuum_max_workers` times this memory may be allocated, so be careful not to set the default value too high. It may be useful to control for this by separately setting `autovacuum_work_mem`.

`autovacuum_work_mem (integer)`

Specifies the maximum amount of memory to be used by each autovacuum worker process. If this value is specified without units, it is taken as kilobytes. It defaults to -1, indicating that the value of `maintenance_work_mem` should be used instead. The setting has no effect on the behavior of `VACUUM` when run in other contexts.

`max_stack_depth` (integer)

Specifies the maximum safe depth of the server's execution stack. The ideal setting for this parameter is the actual stack size limit enforced by the kernel (as set by `ulimit -s` or local equivalent), less a safety margin of a megabyte or so. The safety margin is needed because the stack depth is not checked in every routine in the server, but only in key potentially-recursive routines. If this value is specified without units, it is taken as kilobytes. The default setting is two megabytes (2MB), which is conservatively small and unlikely to risk crashes. However, it might be too small to allow execution of complex functions. Only superusers can change this setting.

Setting `max_stack_depth` higher than the actual kernel limit will mean that a runaway recursive function can crash an individual backend process. On platforms where PostgreSQL can determine the kernel limit, the server will not allow this variable to be set to an unsafe value. However, not all platforms provide the information, so caution is recommended in selecting a value.

`shared_memory_type` (enum)

Specifies the shared memory implementation that the server should use for the main shared memory region that holds PostgreSQL's shared buffers and other shared data. Possible values are `mmap` (for anonymous shared memory allocated using `mmap`), `sysv` (for System V shared memory allocated via `shmget`) and `windows` (for Windows shared memory). Not all values are supported on all platforms; the first supported option is the default for that platform. The use of the `sysv` option, which is not the default on any platform, is generally discouraged because it typically requires non-default kernel settings to allow for large allocations (see Section 18.4.1).

`dynamic_shared_memory_type` (enum)

Specifies the dynamic shared memory implementation that the server should use. Possible values are `posix` (for POSIX shared memory allocated using `shm_open`), `sysv` (for System V shared memory allocated via `shmget`), `windows` (for Windows shared memory), and `mmap` (to simulate shared memory using memory-mapped files stored in the data directory). Not all values are supported on all platforms; the first supported option is the default for that platform. The use of the `mmap` option, which is not the default on any platform, is generally discouraged because the operating system may write modified pages back to disk repeatedly, increasing system I/O load; however, it may be useful for debugging, when the `pg_dynshmem` directory is stored on a RAM disk, or when other shared memory facilities are not available.

19.4.2. Disk

`temp_file_limit` (integer)

Specifies the maximum amount of disk space that a process can use for temporary files, such as sort and hash temporary files, or the storage file for a held cursor. A transaction attempting to exceed this limit will be canceled. If this value is specified without units, it is taken as kilobytes. `-1` (the default) means no limit. Only superusers can change this setting.

This setting constrains the total space used at any instant by all temporary files used by a given PostgreSQL process. It should be noted that disk space used for explicit temporary tables, as opposed to temporary files used behind-the-scenes in query execution, does *not* count against this limit.

19.4.3. Kernel Resource Usage

`max_files_per_process` (integer)

Sets the maximum number of simultaneously open files allowed to each server subprocess. The default is one thousand files. If the kernel is enforcing a safe per-process limit, you don't need to worry about this setting. But on some platforms (notably, most BSD systems), the kernel will allow individual processes to open many more files than the system can actually support if many

processes all try to open that many files. If you find yourself seeing “Too many open files” failures, try reducing this setting. This parameter can only be set at server start.

19.4.4. Cost-based Vacuum Delay

During the execution of `VACUUM` and `ANALYZE` commands, the system maintains an internal counter that keeps track of the estimated cost of the various I/O operations that are performed. When the accumulated cost reaches a limit (specified by `vacuum_cost_limit`), the process performing the operation will sleep for a short period of time, as specified by `vacuum_cost_delay`. Then it will reset the counter and continue execution.

The intent of this feature is to allow administrators to reduce the I/O impact of these commands on concurrent database activity. There are many situations where it is not important that maintenance commands like `VACUUM` and `ANALYZE` finish quickly; however, it is usually very important that these commands do not significantly interfere with the ability of the system to perform other database operations. Cost-based vacuum delay provides a way for administrators to achieve this.

This feature is disabled by default for manually issued `VACUUM` commands. To enable it, set the `vacuum_cost_delay` variable to a nonzero value.

`vacuum_cost_delay` (floating point)

The amount of time that the process will sleep when the cost limit has been exceeded. If this value is specified without units, it is taken as milliseconds. The default value is zero, which disables the cost-based vacuum delay feature. Positive values enable cost-based vacuuming.

When using cost-based vacuuming, appropriate values for `vacuum_cost_delay` are usually quite small, perhaps less than 1 millisecond. While `vacuum_cost_delay` can be set to fractional-millisecond values, such delays may not be measured accurately on older platforms. On such platforms, increasing `VACUUM`'s throttled resource consumption above what you get at 1ms will require changing the other vacuum cost parameters. You should, nonetheless, keep `vacuum_cost_delay` as small as your platform will consistently measure; large delays are not helpful.

`vacuum_cost_page_hit` (integer)

The estimated cost for vacuuming a buffer found in the shared buffer cache. It represents the cost to lock the buffer pool, lookup the shared hash table and scan the content of the page. The default value is one.

`vacuum_cost_page_miss` (integer)

The estimated cost for vacuuming a buffer that has to be read from disk. This represents the effort to lock the buffer pool, lookup the shared hash table, read the desired block in from the disk and scan its content. The default value is 10.

`vacuum_cost_page_dirty` (integer)

The estimated cost charged when vacuum modifies a block that was previously clean. It represents the extra I/O required to flush the dirty block out to disk again. The default value is 20.

`vacuum_cost_limit` (integer)

The accumulated cost that will cause the vacuuming process to sleep. The default value is 200.

Note

There are certain operations that hold critical locks and should therefore complete as quickly as possible. Cost-based vacuum delays do not occur during such operations. Therefore it is possible that the cost accumulates far higher than the specified limit.

To avoid uselessly long delays in such cases, the actual delay is calculated as `vacuum_cost_delay * accumulated_balance / vacuum_cost_limit` with a maximum of `vacuum_cost_delay * 4`.

19.4.5. Background Writer

There is a separate server process called the *background writer*, whose function is to issue writes of “dirty” (new or modified) shared buffers. It writes shared buffers so server processes handling user queries seldom or never need to wait for a write to occur. However, the background writer does cause a net overall increase in I/O load, because while a repeatedly-dirtied page might otherwise be written only once per checkpoint interval, the background writer might write it several times as it is dirtied in the same interval. The parameters discussed in this subsection can be used to tune the behavior for local needs.

`bgwriter_delay` (integer)

Specifies the delay between activity rounds for the background writer. In each round the writer issues writes for some number of dirty buffers (controllable by the following parameters). It then sleeps for the length of `bgwriter_delay`, and repeats. When there are no dirty buffers in the buffer pool, though, it goes into a longer sleep regardless of `bgwriter_delay`. If this value is specified without units, it is taken as milliseconds. The default value is 200 milliseconds (200ms). Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting `bgwriter_delay` to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`bgwriter_lru_maxpages` (integer)

In each round, no more than this many buffers will be written by the background writer. Setting this to zero disables background writing. (Note that checkpoints, which are managed by a separate, dedicated auxiliary process, are unaffected.) The default value is 100 buffers. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`bgwriter_lru_multiplier` (floating point)

The number of dirty buffers written in each round is based on the number of new buffers that have been needed by server processes during recent rounds. The average recent need is multiplied by `bgwriter_lru_multiplier` to arrive at an estimate of the number of buffers that will be needed during the next round. Dirty buffers are written until there are that many clean, reusable buffers available. (However, no more than `bgwriter_lru_maxpages` buffers will be written per round.) Thus, a setting of 1.0 represents a “just in time” policy of writing exactly the number of buffers predicted to be needed. Larger values provide some cushion against spikes in demand, while smaller values intentionally leave writes to be done by server processes. The default is 2.0. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`bgwriter_flush_after` (integer)

Whenever more than this amount of data has been written by the background writer, attempt to force the OS to issue these writes to the underlying storage. Doing so will limit the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of a checkpoint, or when the OS writes data back in larger batches in the background. Often that will result in greatly reduced transaction latency, but there also are some cases, especially with workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache, where performance might degrade. This setting may have no effect on some platforms. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The valid range is between 0, which disables forced writeback, and 2MB. The default is 512kB on Linux, 0 elsewhere. (If `BLCKSZ` is not 8kB, the default and maximum values scale proportionally to it.) This parameter can only be set in the `postgresql.conf` file or on the server command line.

Smaller values of `bgwriter_lru_maxpages` and `bgwriter_lru_multiplier` reduce the extra I/O load caused by the background writer, but make it more likely that server processes will have to issue writes for themselves, delaying interactive queries.

19.4.6. Asynchronous Behavior

`effective_io_concurrency` (integer)

Sets the number of concurrent disk I/O operations that PostgreSQL expects can be executed simultaneously. Raising this value will increase the number of I/O operations that any individual PostgreSQL session attempts to initiate in parallel. The allowed range is 1 to 1000, or zero to disable issuance of asynchronous I/O requests. Currently, this setting only affects bitmap heap scans.

For magnetic drives, a good starting point for this setting is the number of separate drives comprising a RAID 0 stripe or RAID 1 mirror being used for the database. (For RAID 5 the parity drive should not be counted.) However, if the database is often busy with multiple queries issued in concurrent sessions, lower values may be sufficient to keep the disk array busy. A value higher than needed to keep the disks busy will only result in extra CPU overhead. SSDs and other memory-based storage can often process many concurrent requests, so the best value might be in the hundreds.

Asynchronous I/O depends on an effective `posix_fadvise` function, which some operating systems lack. If the function is not present then setting this parameter to anything but zero will result in an error. On some operating systems (e.g., Solaris), the function is present but does not actually do anything.

The default is 1 on supported systems, otherwise 0. This value can be overridden for tables in a particular tablespace by setting the `tablespace` parameter of the same name (see `ALTER TABLESPACE`).

`max_worker_processes` (integer)

Sets the maximum number of background processes that the system can support. This parameter can only be set at server start. The default is 8.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

When changing this value, consider also adjusting `max_parallel_workers`, `max_parallel_maintenance_workers`, and `max_parallel_workers_per_gather`.

`max_parallel_workers_per_gather` (integer)

Sets the maximum number of workers that can be started by a single `Gather` or `Gather Merge` node. Parallel workers are taken from the pool of processes established by `max_worker_processes`, limited by `max_parallel_workers`. Note that the requested number of workers may not actually be available at run time. If this occurs, the plan will run with fewer workers than expected, which may be inefficient. The default value is 2. Setting this value to 0 disables parallel query execution.

Note that parallel queries may consume very substantially more resources than non-parallel queries, because each worker process is a completely separate process which has roughly the same impact on the system as an additional user session. This should be taken into account when choosing a value for this setting, as well as when configuring other settings that control resource utilization, such as `work_mem`. Resource limits such as `work_mem` are applied individually to each worker, which means the total utilization may be much higher across all processes than it would normally be for any single process. For example, a parallel query using 4 workers may use up to 5 times as much CPU time, memory, I/O bandwidth, and so forth as a query which uses no workers at all.

For more information on parallel query, see Chapter 15.

`max_parallel_maintenance_workers` (integer)

Sets the maximum number of parallel workers that can be started by a single utility command. Currently, the only parallel utility command that supports the use of parallel workers is `CREATE INDEX`, and only when building a B-tree index. Parallel workers are taken from the pool of processes established by `max_worker_processes`, limited by `max_parallel_workers`. Note that the requested number of workers may not actually be available at run time. If this occurs, the utility operation will run with fewer workers than expected. The default value is 2. Setting this value to 0 disables the use of parallel workers by utility commands.

Note that parallel utility commands should not consume substantially more memory than equivalent non-parallel operations. This strategy differs from that of parallel query, where resource limits generally apply per worker process. Parallel utility commands treat the resource limit `maintenance_work_mem` as a limit to be applied to the entire utility command, regardless of the number of parallel worker processes. However, parallel utility commands may still consume substantially more CPU resources and I/O bandwidth.

`max_parallel_workers` (integer)

Sets the maximum number of workers that the system can support for parallel operations. The default value is 8. When increasing or decreasing this value, consider also adjusting `max_parallel_maintenance_workers` and `max_parallel_workers_per_gather`. Also, note that a setting for this value which is higher than `max_worker_processes` will have no effect, since parallel workers are taken from the pool of worker processes established by that setting.

`backend_flush_after` (integer)

Whenever more than this amount of data has been written by a single backend, attempt to force the OS to issue these writes to the underlying storage. Doing so will limit the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of a checkpoint, or when the OS writes data back in larger batches in the background. Often that will result in greatly reduced transaction latency, but there also are some cases, especially with workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache, where performance might degrade. This setting may have no effect on some platforms. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The valid range is between 0, which disables forced writeback, and 2MB. The default is 0, i.e., no forced writeback. (If `BLCKSZ` is not 8kB, the maximum value scales proportionally to it.)

`old_snapshot_threshold` (integer)

Sets the minimum amount of time that a query snapshot can be used without risk of a “snapshot too old” error occurring when using the snapshot. Data that has been dead for longer than this threshold is allowed to be vacuumed away. This can help prevent bloat in the face of snapshots which remain in use for a long time. To prevent incorrect results due to cleanup of data which would otherwise be visible to the snapshot, an error is generated when the snapshot is older than this threshold and the snapshot is used to read a page which has been modified since the snapshot was built.

If this value is specified without units, it is taken as minutes. A value of `-1` (the default) disables this feature, effectively setting the snapshot age limit to infinity. This parameter can only be set at server start.

Useful values for production work probably range from a small number of hours to a few days. Small values (such as `0` or `1min`) are only allowed because they may sometimes be useful for testing. While a setting as high as `60d` is allowed, please note that in many workloads extreme bloat or transaction ID wraparound may occur in much shorter time frames.

When this feature is enabled, freed space at the end of a relation cannot be released to the operating system, since that could remove information needed to detect the “snapshot too old” condition.

All space allocated to a relation remains associated with that relation for reuse only within that relation unless explicitly freed (for example, with `VACUUM FULL`).

This setting does not attempt to guarantee that an error will be generated under any particular circumstances. In fact, if the correct results can be generated from (for example) a cursor which has materialized a result set, no error will be generated even if the underlying rows in the referenced table have been vacuumed away. Some tables cannot safely be vacuumed early, and so will not be affected by this setting, such as system catalogs. For such tables this setting will neither reduce bloat nor create a possibility of a “snapshot too old” error on scanning.

19.5. Write Ahead Log

For additional information on tuning these settings, see Section 29.4.

19.5.1. Settings

`wal_level` (enum)

`wal_level` determines how much information is written to the WAL. The default value is `replica`, which writes enough data to support WAL archiving and replication, including running read-only queries on a standby server. `minimal` removes all logging except the information required to recover from a crash or immediate shutdown. Finally, `logical` adds information necessary to support logical decoding. Each level includes the information logged at all lower levels. This parameter can only be set at server start.

In `minimal` level, WAL-logging of some bulk operations can be safely skipped, which can make those operations much faster (see Section 14.4.7). Operations in which this optimization can be applied include:

```
CREATE TABLE AS
CREATE INDEX
CLUSTER
COPY into tables that were created or truncated in the same transaction
```

But `minimal` WAL does not contain enough information to reconstruct the data from a base backup and the WAL logs, so `replica` or higher must be used to enable WAL archiving (`archive_mode`) and streaming replication.

In `logical` level, the same information is logged as with `replica`, plus information needed to allow extracting logical change sets from the WAL. Using a level of `logical` will increase the WAL volume, particularly if many tables are configured for `REPLICA IDENTITY FULL` and many `UPDATE` and `DELETE` statements are executed.

In releases prior to 9.6, this parameter also allowed the values `archive` and `hot_standby`. These are still accepted but mapped to `replica`.

`fsync` (boolean)

If this parameter is on, the PostgreSQL server will try to make sure that updates are physically written to disk, by issuing `fsync()` system calls or various equivalent methods (see `wal_sync_method`). This ensures that the database cluster can recover to a consistent state after an operating system or hardware crash.

While turning off `fsync` is often a performance benefit, this can result in unrecoverable data corruption in the event of a power failure or system crash. Thus it is only advisable to turn off `fsync` if you can easily recreate your entire database from external data.

Examples of safe circumstances for turning off `fsync` include the initial loading of a new database cluster from a backup file, using a database cluster for processing a batch of data after which

the database will be thrown away and recreated, or for a read-only database clone which gets recreated frequently and is not used for failover. High quality hardware alone is not a sufficient justification for turning off `fsync`.

For reliable recovery when changing `fsync` off to on, it is necessary to force all modified buffers in the kernel to durable storage. This can be done while the cluster is shutdown or while `fsync` is on by running `initdb --sync-only`, running `sync`, unmounting the file system, or rebooting the server.

In many situations, turning off `synchronous_commit` for noncritical transactions can provide much of the potential performance benefit of turning off `fsync`, without the attendant risks of data corruption.

`fsync` can only be set in the `postgresql.conf` file or on the server command line. If you turn this parameter off, also consider turning off `full_page_writes`.

`synchronous_commit` (enum)

Specifies whether transaction commit will wait for WAL records to be written to disk before the command returns a “success” indication to the client. Valid values are `on`, `remote_apply`, `remote_write`, `local`, and `off`. The default, and safe, setting is `on`. When `off`, there can be a delay between when success is reported to the client and when the transaction is really guaranteed to be safe against a server crash. (The maximum delay is three times `wal_writer_delay`.) Unlike `fsync`, setting this parameter to `off` does not create any risk of database inconsistency: an operating system or database crash might result in some recent allegedly-committed transactions being lost, but the database state will be just the same as if those transactions had been aborted cleanly. So, turning `synchronous_commit` off can be a useful alternative when performance is more important than exact certainty about the durability of a transaction. For more discussion see Section 29.3.

If `synchronous_standby_names` is non-empty, this parameter also controls whether or not transaction commits will wait for their WAL records to be replicated to the standby server(s). When set to `on`, commits will wait until replies from the current synchronous standby(s) indicate they have received the commit record of the transaction and flushed it to disk. This ensures the transaction will not be lost unless both the primary and all synchronous standbys suffer corruption of their database storage. When set to `remote_apply`, commits will wait until replies from the current synchronous standby(s) indicate they have received the commit record of the transaction and applied it, so that it has become visible to queries on the standby(s). When set to `remote_write`, commits will wait until replies from the current synchronous standby(s) indicate they have received the commit record of the transaction and written it out to their operating system. This setting is sufficient to ensure data preservation even if a standby instance of PostgreSQL were to crash, but not if the standby suffers an operating-system-level crash, since the data has not necessarily reached stable storage on the standby. Finally, the setting `local` causes commits to wait for local flush to disk, but not for replication. This is not usually desirable when synchronous replication is in use, but is provided for completeness.

If `synchronous_standby_names` is empty, the settings `on`, `remote_apply`, `remote_write` and `local` all provide the same synchronization level: transaction commits only wait for local flush to disk.

This parameter can be changed at any time; the behavior for any one transaction is determined by the setting in effect when it commits. It is therefore possible, and useful, to have some transactions commit synchronously and others asynchronously. For example, to make a single multistatement transaction commit asynchronously when the default is the opposite, issue `SET LOCAL synchronous_commit TO OFF` within the transaction.

`wal_sync_method` (enum)

Method used for forcing WAL updates out to disk. If `fsync` is off then this setting is irrelevant, since WAL file updates will not be forced out at all. Possible values are:

- `open_datasync` (write WAL files with `open()` option `O_DSYNC`)
- `fdasync` (call `fdasync()` at each commit)
- `fsync` (call `fsync()` at each commit)
- `fsync_writethrough` (call `fsync()` at each commit, forcing write-through of any disk write cache)
- `open_sync` (write WAL files with `open()` option `O_SYNC`)

The `open_*` options also use `O_DIRECT` if available. Not all of these choices are available on all platforms. The default is the first method in the above list that is supported by the platform, except that `fdasync` is the default on Linux. The default is not necessarily ideal; it might be necessary to change this setting or other aspects of your system configuration in order to create a crash-safe configuration or achieve optimal performance. These aspects are discussed in Section 29.1. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`full_page_writes` (boolean)

When this parameter is on, the PostgreSQL server writes the entire content of each disk page to WAL during the first modification of that page after a checkpoint. This is needed because a page write that is in process during an operating system crash might be only partially completed, leading to an on-disk page that contains a mix of old and new data. The row-level change data normally stored in WAL will not be enough to completely restore such a page during post-crash recovery. Storing the full page image guarantees that the page can be correctly restored, but at the price of increasing the amount of data that must be written to WAL. (Because WAL replay always starts from a checkpoint, it is sufficient to do this during the first change of each page after a checkpoint. Therefore, one way to reduce the cost of full-page writes is to increase the checkpoint interval parameters.)

Turning this parameter off speeds normal operation, but might lead to either unrecoverable data corruption, or silent data corruption, after a system failure. The risks are similar to turning off `fsync`, though smaller, and it should be turned off only based on the same circumstances recommended for that parameter.

Turning off this parameter does not affect use of WAL archiving for point-in-time recovery (PITR) (see Section 25.3).

This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `on`.

`wal_log_hints` (boolean)

When this parameter is on, the PostgreSQL server writes the entire content of each disk page to WAL during the first modification of that page after a checkpoint, even for non-critical modifications of so-called hint bits.

If data checksums are enabled, hint bit updates are always WAL-logged and this setting is ignored. You can use this setting to test how much extra WAL-logging would occur if your database had data checksums enabled.

This parameter can only be set at server start. The default value is `off`.

`wal_compression` (boolean)

When this parameter is on, the PostgreSQL server compresses a full page image written to WAL when `full_page_writes` is on or during a base backup. A compressed page image will be decompressed during WAL replay. The default value is `off`. Only superusers can change this setting.

Turning this parameter on can reduce the WAL volume without increasing the risk of unrecoverable data corruption, but at the cost of some extra CPU spent on the compression during WAL logging and on the decompression during WAL replay.

`wal_buffers` (integer)

The amount of shared memory used for WAL data that has not yet been written to disk. The default setting of -1 selects a size equal to 1/32nd (about 3%) of `shared_buffers`, but not less than 64kB nor more than the size of one WAL segment, typically 16MB. This value can be set manually if the automatic choice is too large or too small, but any positive value less than 32kB will be treated as 32kB. If this value is specified without units, it is taken as WAL blocks, that is `XLOG_BLCKSZ` bytes, typically 8kB. This parameter can only be set at server start.

The contents of the WAL buffers are written out to disk at every transaction commit, so extremely large values are unlikely to provide a significant benefit. However, setting this value to at least a few megabytes can improve write performance on a busy server where many clients are committing at once. The auto-tuning selected by the default setting of -1 should give reasonable results in most cases.

`wal_writer_delay` (integer)

Specifies how often the WAL writer flushes WAL, in time terms. After flushing WAL the writer sleeps for the length of time given by `wal_writer_delay`, unless woken up sooner by an asynchronously committing transaction. If the last flush happened less than `wal_writer_delay` ago and less than `wal_writer_flush_after` worth of WAL has been produced since, then WAL is only written to the operating system, not flushed to disk. If this value is specified without units, it is taken as milliseconds. The default value is 200 milliseconds (200ms). Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting `wal_writer_delay` to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`wal_writer_flush_after` (integer)

Specifies how often the WAL writer flushes WAL, in volume terms. If the last flush happened less than `wal_writer_delay` ago and less than `wal_writer_flush_after` worth of WAL has been produced since, then WAL is only written to the operating system, not flushed to disk. If `wal_writer_flush_after` is set to 0 then WAL data is always flushed immediately. If this value is specified without units, it is taken as WAL blocks, that is `XLOG_BLCKSZ` bytes, typically 8kB. The default is 1MB. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`commit_delay` (integer)

Setting `commit_delay` adds a time delay before a WAL flush is initiated. This can improve group commit throughput by allowing a larger number of transactions to commit via a single WAL flush, if system load is high enough that additional transactions become ready to commit within the given interval. However, it also increases latency by up to the `commit_delay` for each WAL flush. Because the delay is just wasted if no other transactions become ready to commit, a delay is only performed if at least `commit_siblings` other transactions are active when a flush is about to be initiated. Also, no delays are performed if `fsync` is disabled. If this value is specified without units, it is taken as microseconds. The default `commit_delay` is zero (no delay). Only superusers can change this setting.

In PostgreSQL releases prior to 9.3, `commit_delay` behaved differently and was much less effective: it affected only commits, rather than all WAL flushes, and waited for the entire configured delay even if the WAL flush was completed sooner. Beginning in PostgreSQL 9.3, the first process that becomes ready to flush waits for the configured interval, while subsequent processes wait only until the leader completes the flush operation.

`commit_siblings` (integer)

Minimum number of concurrent open transactions to require before performing the `commit_delay` delay. A larger value makes it more probable that at least one other transaction will become ready to commit during the delay interval. The default is five transactions.

19.5.2. Checkpoints

`checkpoint_timeout` (integer)

Maximum time between automatic WAL checkpoints. If this value is specified without units, it is taken as seconds. The valid range is between 30 seconds and one day. The default is five minutes (5min). Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`checkpoint_completion_target` (floating point)

Specifies the target of checkpoint completion, as a fraction of total time between checkpoints. The default is 0.5. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`checkpoint_flush_after` (integer)

Whenever more than this amount of data has been written while performing a checkpoint, attempt to force the OS to issue these writes to the underlying storage. Doing so will limit the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of the checkpoint, or when the OS writes data back in larger batches in the background. Often that will result in greatly reduced transaction latency, but there also are some cases, especially with workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache, where performance might degrade. This setting may have no effect on some platforms. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The valid range is between 0, which disables forced writeback, and 2MB. The default is 256kB on Linux, 0 elsewhere. (If `BLCKSZ` is not 8kB, the default and maximum values scale proportionally to it.) This parameter can only be set in the `postgresql.conf` file or on the server command line.

`checkpoint_warning` (integer)

Write a message to the server log if checkpoints caused by the filling of WAL segment files happen closer together than this amount of time (which suggests that `max_wal_size` ought to be raised). If this value is specified without units, it is taken as seconds. The default is 30 seconds (30s). Zero disables the warning. No warnings will be generated if `checkpoint_timeout` is less than `checkpoint_warning`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`max_wal_size` (integer)

Maximum size to let the WAL grow to between automatic WAL checkpoints. This is a soft limit; WAL size can exceed `max_wal_size` under special circumstances, such as heavy load, a failing `archive_command`, or a high `wal_keep_segments` setting. If this value is specified without units, it is taken as megabytes. The default is 1 GB. Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`min_wal_size` (integer)

As long as WAL disk usage stays below this setting, old WAL files are always recycled for future use at a checkpoint, rather than removed. This can be used to ensure that enough WAL space is reserved to handle spikes in WAL usage, for example when running large batch jobs. If this value is specified without units, it is taken as megabytes. The default is 80 MB. This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.5.3. Archiving

`archive_mode` (enum)

When `archive_mode` is enabled, completed WAL segments are sent to archive storage by setting `archive_command`. In addition to `off`, to disable, there are two modes: `on`, and `always`. During normal operation, there is no difference between the two modes, but when set to `always` the WAL archiver is enabled also during archive recovery or standby mode. In `always` mode, all files restored from the archive or streamed with streaming replication will be archived (again). See Section 26.2.9 for details.

`archive_mode` and `archive_command` are separate variables so that `archive_command` can be changed without leaving archiving mode. This parameter can only be set at server start. `archive_mode` cannot be enabled when `wal_level` is set to `minimal`.

`archive_command` (string)

The local shell command to execute to archive a completed WAL file segment. Any `%p` in the string is replaced by the path name of the file to archive, and any `%f` is replaced by only the file name. (The path name is relative to the working directory of the server, i.e., the cluster's data directory.) Use `%%` to embed an actual `%` character in the command. It is important for the command to return a zero exit status only if it succeeds. For more information see Section 25.3.1.

This parameter can only be set in the `postgresql.conf` file or on the server command line. It is ignored unless `archive_mode` was enabled at server start. If `archive_command` is an empty string (the default) while `archive_mode` is enabled, WAL archiving is temporarily disabled, but the server continues to accumulate WAL segment files in the expectation that a command will soon be provided. Setting `archive_command` to a command that does nothing but return true, e.g. `/bin/true` (REM on Windows), effectively disables archiving, but also breaks the chain of WAL files needed for archive recovery, so it should only be used in unusual circumstances.

`archive_timeout` (integer)

The `archive_command` is only invoked for completed WAL segments. Hence, if your server generates little WAL traffic (or has slack periods where it does so), there could be a long delay between the completion of a transaction and its safe recording in archive storage. To limit how old unarchived data can be, you can set `archive_timeout` to force the server to switch to a new WAL segment file periodically. When this parameter is greater than zero, the server will switch to a new segment file whenever this amount of time has elapsed since the last segment file switch, and there has been any database activity, including a single checkpoint (checkpoints are skipped if there is no database activity). Note that archived files that are closed early due to a forced switch are still the same length as completely full files. Therefore, it is unwise to use a very short `archive_timeout` — it will bloat your archive storage. `archive_timeout` settings of a minute or so are usually reasonable. You should consider using streaming replication, instead of archiving, if you want data to be copied off the master server more quickly than that. If this value is specified without units, it is taken as seconds. This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.5.4. Archive Recovery

This section describes the settings that apply only for the duration of the recovery. They must be reset for any subsequent recovery you wish to perform.

“Recovery” covers using the server as a standby or for executing a targeted recovery. Typically, standby mode would be used to provide high availability and/or read scalability, whereas a targeted recovery is used to recover from data loss.

To start the server in standby mode, create a file called `standby.signal` in the data directory. The server will enter recovery and will not stop recovery when the end of archived WAL is reached,

but will keep trying to continue recovery by connecting to the sending server as specified by the `primary_conninfo` setting and/or by fetching new WAL segments using `restore_command`. For this mode, the parameters from this section and Section 19.6.3 are of interest. Parameters from Section 19.5.5 will also be applied but are typically not useful in this mode.

To start the server in targeted recovery mode, create a file called `recovery.signal` in the data directory. If both `standby.signal` and `recovery.signal` files are created, standby mode takes precedence. Targeted recovery mode ends when the archived WAL is fully replayed, or when `recovery_target` is reached. In this mode, the parameters from both this section and Section 19.5.5 will be used.

`restore_command` (string)

The local shell command to execute to retrieve an archived segment of the WAL file series. This parameter is required for archive recovery, but optional for streaming replication. Any `%f` in the string is replaced by the name of the file to retrieve from the archive, and any `%p` is replaced by the copy destination path name on the server. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Any `%r` is replaced by the name of the file containing the last valid restart point. That is the earliest file that must be kept to allow a restore to be restartable, so this information can be used to truncate the archive to just the minimum required to support restarting from the current restore. `%r` is typically only used by warm-standby configurations (see Section 26.2). Write `%%` to embed an actual `%` character.

It is important for the command to return a zero exit status only if it succeeds. The command *will* be asked for file names that are not present in the archive; it must return nonzero when so asked. Examples:

```
restore_command = 'cp /mnt/server/archivedir/%f "%p"'
restore_command = 'copy "C:\\server\\archivedir\\%f" "%p" ' #
Windows
```

An exception is that if the command was terminated by a signal (other than `SIGTERM`, which is used as part of a database server shutdown) or an error by the shell (such as command not found), then recovery will abort and the server will not start up.

This parameter can only be set at server start.

`archive_cleanup_command` (string)

This optional parameter specifies a shell command that will be executed at every restartpoint. The purpose of `archive_cleanup_command` is to provide a mechanism for cleaning up old archived WAL files that are no longer needed by the standby server. Any `%r` is replaced by the name of the file containing the last valid restart point. That is the earliest file that must be *kept* to allow a restore to be restartable, and so all files earlier than `%r` may be safely removed. This information can be used to truncate the archive to just the minimum required to support restart from the current restore. The `pg_archivecleanup` module is often used in `archive_cleanup_command` for single-standby configurations, for example:

```
archive_cleanup_command = 'pg_archivecleanup /mnt/server/
archivedir %r'
```

Note however that if multiple standby servers are restoring from the same archive directory, you will need to ensure that you do not delete WAL files until they are no longer needed by any of the servers. `archive_cleanup_command` would typically be used in a warm-standby configuration (see Section 26.2). Write `%%` to embed an actual `%` character in the command.

If the command returns a nonzero exit status then a warning log message will be written. An exception is that if the command was terminated by a signal or an error by the shell (such as command not found), a fatal error will be raised.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`recovery_end_command` (string)

This parameter specifies a shell command that will be executed once only at the end of recovery. This parameter is optional. The purpose of the `recovery_end_command` is to provide a mechanism for cleanup following replication or recovery. Any `%r` is replaced by the name of the file containing the last valid restart point, like in `archive_cleanup_command`.

If the command returns a nonzero exit status then a warning log message will be written and the database will proceed to start up anyway. An exception is that if the command was terminated by a signal or an error by the shell (such as command not found), the database will not proceed with startup.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.5.5. Recovery Target

By default, recovery will recover to the end of the WAL log. The following parameters can be used to specify an earlier stopping point. At most one of `recovery_target`, `recovery_target_lsn`, `recovery_target_name`, `recovery_target_time`, or `recovery_target_xid` can be used; if more than one of these is specified in the configuration file, an error will be raised. These parameters can only be set at server start.

`recovery_target = 'immediate'`

This parameter specifies that recovery should end as soon as a consistent state is reached, i.e. as early as possible. When restoring from an online backup, this means the point where taking the backup ended.

Technically, this is a string parameter, but `'immediate'` is currently the only allowed value.

`recovery_target_name` (string)

This parameter specifies the named restore point (created with `pg_create_restore_point()`) to which recovery will proceed.

`recovery_target_time` (timestamp)

This parameter specifies the time stamp up to which recovery will proceed. The precise stopping point is also influenced by `recovery_target_inclusive`.

`recovery_target_xid` (string)

This parameter specifies the transaction ID up to which recovery will proceed. Keep in mind that while transaction IDs are assigned sequentially at transaction start, transactions can complete in a different numeric order. The transactions that will be recovered are those that committed before (and optionally including) the specified one. The precise stopping point is also influenced by `recovery_target_inclusive`.

`recovery_target_lsn` (pg_lsn)

This parameter specifies the LSN of the write-ahead log location up to which recovery will proceed. The precise stopping point is also influenced by `recovery_target_inclusive`. This parameter is parsed using the system data type `pg_lsn`.

The following options further specify the recovery target, and affect what happens when the target is reached:

`recovery_target_inclusive` (boolean)

Specifies whether to stop just after the specified recovery target (`on`), or just before the recovery target (`off`). Applies when `recovery_target_lsn`, `recovery_target_time`, or `recovery_target_xid`

is specified. This setting controls whether transactions having exactly the target WAL location (LSN), commit time, or transaction ID, respectively, will be included in the recovery. Default is on.

`recovery_target_timeline` (string)

Specifies recovering into a particular timeline. The value can be a numeric timeline ID or a special value. The value `current` recovers along the same timeline that was current when the base backup was taken. The value `latest` recovers to the latest timeline found in the archive, which is useful in a standby server. `latest` is the default.

You usually only need to set this parameter in complex re-recovery situations, where you need to return to a state that itself was reached after a point-in-time recovery. See Section 25.3.5 for discussion.

`recovery_target_action` (enum)

Specifies what action the server should take once the recovery target is reached. The default is `pause`, which means recovery will be paused. `promote` means the recovery process will finish and the server will start to accept connections. Finally `shutdown` will stop the server after reaching the recovery target.

The intended use of the `pause` setting is to allow queries to be executed against the database to check if this recovery target is the most desirable point for recovery. The paused state can be resumed by using `pg_wal_replay_resume()` (see Table 9.86), which then causes recovery to end. If this recovery target is not the desired stopping point, then shut down the server, change the recovery target settings to a later target and restart to continue recovery.

The `shutdown` setting is useful to have the instance ready at the exact replay point desired. The instance will still be able to replay more WAL records (and in fact will have to replay WAL records since the last checkpoint next time it is started).

Note that because `recovery.signal` will not be removed when `recovery_target_action` is set to `shutdown`, any subsequent start will end with immediate shutdown unless the configuration is changed or the `recovery.signal` file is removed manually.

This setting has no effect if no recovery target is set. If `hot_standby` is not enabled, a setting of `pause` will act the same as `shutdown`.

19.6. Replication

These settings control the behavior of the built-in *streaming replication* feature (see Section 26.2.5). Servers will be either a master or a standby server. Masters can send data, while standbys are always receivers of replicated data. When cascading replication (see Section 26.2.7) is used, standby servers can also be senders, as well as receivers. Parameters are mainly for sending and standby servers, though some parameters have meaning only on the master server. Settings may vary across the cluster without problems if that is required.

19.6.1. Sending Servers

These parameters can be set on any server that is to send replication data to one or more standby servers. The master is always a sending server, so these parameters must always be set on the master. The role and meaning of these parameters does not change after a standby becomes the master.

`max_wal_senders` (integer)

Specifies the maximum number of concurrent connections from standby servers or streaming base backup clients (i.e., the maximum number of simultaneously running WAL sender processes). The default is 10. The value 0 means replication is disabled. Abrupt streaming client disconnection might leave an orphaned connection slot behind until a timeout is reached, so this parameter should

be set slightly higher than the maximum number of expected clients so disconnected clients can immediately reconnect. This parameter can only be set at server start. Also, `wal_level` must be set to `replica` or higher to allow connections from standby servers.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`max_replication_slots` (integer)

Specifies the maximum number of replication slots (see Section 26.2.6) that the server can support. The default is 10. This parameter can only be set at server start. Setting it to a lower value than the number of currently existing replication slots will prevent the server from starting. Also, `wal_level` must be set to `replica` or higher to allow replication slots to be used.

`wal_keep_segments` (integer)

Specifies the minimum number of past log file segments kept in the `pg_wal` directory, in case a standby server needs to fetch them for streaming replication. Each segment is normally 16 megabytes. If a standby server connected to the sending server falls behind by more than `wal_keep_segments` segments, the sending server might remove a WAL segment still needed by the standby, in which case the replication connection will be terminated. Downstream connections will also eventually fail as a result. (However, the standby server can recover by fetching the segment from archive, if WAL archiving is in use.)

This sets only the minimum number of segments retained in `pg_wal`; the system might need to retain more segments for WAL archival or to recover from a checkpoint. If `wal_keep_segments` is zero (the default), the system doesn't keep any extra segments for standby purposes, so the number of old WAL segments available to standby servers is a function of the location of the previous checkpoint and status of WAL archiving. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`wal_init_zero` (boolean)

If set to `on` (the default), this option causes new WAL files to be filled with zeroes. On some file systems, this ensures that space is allocated before we need to write WAL records. However, *Copy-On-Write* (COW) file systems may not benefit from this technique, so the option is given to skip the unnecessary work. If set to `off`, only the final byte is written when the file is created so that it has the expected size.

`wal_recycle` (boolean)

If set to `on` (the default), this option causes WAL files to be recycled by renaming them, avoiding the need to create new ones. On COW file systems, it may be faster to create new ones, so the option is given to disable this behavior.

`wal_sender_timeout` (integer)

Terminate replication connections that are inactive for longer than this amount of time. This is useful for the sending server to detect a standby crash or network outage. If this value is specified without units, it is taken as milliseconds. The default value is 60 seconds. A value of zero disables the timeout mechanism.

With a cluster distributed across multiple geographic locations, using different values per location brings more flexibility in the cluster management. A smaller value is useful for faster failure detection with a standby having a low-latency network connection, and a larger value helps in judging better the health of a standby if located on a remote location, with a high-latency network connection.

`track_commit_timestamp` (boolean)

Record commit time of transactions. This parameter can only be set in `postgresql.conf` file or on the server command line. The default value is `off`.

19.6.2. Master Server

These parameters can be set on the master/primary server that is to send replication data to one or more standby servers. Note that in addition to these parameters, `wal_level` must be set appropriately on the master server, and optionally WAL archiving can be enabled as well (see Section 19.5.3). The values of these parameters on standby servers are irrelevant, although you may wish to set them there in preparation for the possibility of a standby becoming the master.

`synchronous_standby_names` (string)

Specifies a list of standby servers that can support *synchronous replication*, as described in Section 26.2.8. There will be one or more active synchronous standbys; transactions waiting for commit will be allowed to proceed after these standby servers confirm receipt of their data. The synchronous standbys will be those whose names appear in this list, and that are both currently connected and streaming data in real-time (as shown by a state of `streaming` in the `pg_stat_replication` view). Specifying more than one synchronous standby can allow for very high availability and protection against data loss.

The name of a standby server for this purpose is the `application_name` setting of the standby, as set in the standby's connection information. In case of a physical replication standby, this should be set in the `primary_conninfo` setting; the default is the setting of `cluster_name` if set, else `walreceiver`. For logical replication, this can be set in the connection information of the subscription, and it defaults to the subscription name. For other replication stream consumers, consult their documentation.

This parameter specifies a list of standby servers using either of the following syntaxes:

```
[FIRST] num_sync ( standby_name [ , ... ] )
ANY num_sync ( standby_name [ , ... ] )
standby_name [ , ... ]
```

where `num_sync` is the number of synchronous standbys that transactions need to wait for replies from, and `standby_name` is the name of a standby server. `FIRST` and `ANY` specify the method to choose synchronous standbys from the listed servers.

The keyword `FIRST`, coupled with `num_sync`, specifies a priority-based synchronous replication and makes transaction commits wait until their WAL records are replicated to `num_sync` synchronous standbys chosen based on their priorities. For example, a setting of `FIRST 3 (s1, s2, s3, s4)` will cause each commit to wait for replies from three higher-priority standbys chosen from standby servers `s1`, `s2`, `s3` and `s4`. The standbys whose names appear earlier in the list are given higher priority and will be considered as synchronous. Other standby servers appearing later in this list represent potential synchronous standbys. If any of the current synchronous standbys disconnects for whatever reason, it will be replaced immediately with the next-highest-priority standby. The keyword `FIRST` is optional.

The keyword `ANY`, coupled with `num_sync`, specifies a quorum-based synchronous replication and makes transaction commits wait until their WAL records are replicated to *at least* `num_sync` listed standbys. For example, a setting of `ANY 3 (s1, s2, s3, s4)` will cause each commit to proceed as soon as at least any three standbys of `s1`, `s2`, `s3` and `s4` reply.

`FIRST` and `ANY` are case-insensitive. If these keywords are used as the name of a standby server, its `standby_name` must be double-quoted.

The third syntax was used before PostgreSQL version 9.6 and is still supported. It's the same as the first syntax with `FIRST` and `num_sync` equal to 1. For example, `FIRST 1 (s1, s2)` and `s1, s2` have the same meaning: either `s1` or `s2` is chosen as a synchronous standby.

The special entry `*` matches any standby name.

There is no mechanism to enforce uniqueness of standby names. In case of duplicates one of the matching standbys will be considered as higher priority, though exactly which one is indeterminate.

Note

Each *standby_name* should have the form of a valid SQL identifier, unless it is *. You can use double-quoting if necessary. But note that *standby_names* are compared to standby application names case-insensitively, whether double-quoted or not.

If no synchronous standby names are specified here, then synchronous replication is not enabled and transaction commits will not wait for replication. This is the default configuration. Even when synchronous replication is enabled, individual transactions can be configured not to wait for replication by setting the `synchronous_commit` parameter to `local` or `off`.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`vacuum_defer_cleanup_age` (integer)

Specifies the number of transactions by which VACUUM and HOT updates will defer cleanup of dead row versions. The default is zero transactions, meaning that dead row versions can be removed as soon as possible, that is, as soon as they are no longer visible to any open transaction. You may wish to set this to a non-zero value on a primary server that is supporting hot standby servers, as described in Section 26.5. This allows more time for queries on the standby to complete without incurring conflicts due to early cleanup of rows. However, since the value is measured in terms of number of write transactions occurring on the primary server, it is difficult to predict just how much additional grace time will be made available to standby queries. This parameter can only be set in the `postgresql.conf` file or on the server command line.

You should also consider setting `hot_standby_feedback` on standby server(s) as an alternative to using this parameter.

This does not prevent cleanup of dead rows which have reached the age specified by `old_snapshot_threshold`.

19.6.3. Standby Servers

These settings control the behavior of a standby server that is to receive replication data. Their values on the master server are irrelevant.

`primary_conninfo` (string)

Specifies a connection string to be used for the standby server to connect with a sending server. This string is in the format described in Section 33.1.1. If any option is unspecified in this string, then the corresponding environment variable (see Section 33.14) is checked. If the environment variable is not set either, then defaults are used.

The connection string should specify the host name (or address) of the sending server, as well as the port number if it is not the same as the standby server's default. Also specify a user name corresponding to a suitably-privileged role on the sending server (see Section 26.2.5.1). A password needs to be provided too, if the sender demands password authentication. It can be provided in the `primary_conninfo` string, or in a separate `~/.pgpass` file on the standby server (use `replication` as the database name). Do not specify a database name in the `primary_conninfo` string.

This parameter can only be set at server start. This setting has no effect if the server is not in standby mode.

`primary_slot_name` (string)

Optionally specifies an existing replication slot to be used when connecting to the sending server via streaming replication to control resource removal on the upstream node (see Section 26.2.6). This parameter can only be set at server start. This setting has no effect if `primary_conninfo` is not set.

`promote_trigger_file` (string)

Specifies a trigger file whose presence ends recovery in the standby. Even if this value is not set, you can still promote the standby using `pg_ctl promote` or calling `pg_promote`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`hot_standby` (boolean)

Specifies whether or not you can connect and run queries during recovery, as described in Section 26.5. The default value is `on`. This parameter can only be set at server start. It only has effect during archive recovery or in standby mode.

`max_standby_archive_delay` (integer)

When Hot Standby is active, this parameter determines how long the standby server should wait before canceling standby queries that conflict with about-to-be-applied WAL entries, as described in Section 26.5.2. `max_standby_archive_delay` applies when WAL data is being read from WAL archive (and is therefore not current). If this value is specified without units, it is taken as milliseconds. The default is 30 seconds. A value of -1 allows the standby to wait forever for conflicting queries to complete. This parameter can only be set in the `postgresql.conf` file or on the server command line.

Note that `max_standby_archive_delay` is not the same as the maximum length of time a query can run before cancellation; rather it is the maximum total time allowed to apply any one WAL segment's data. Thus, if one query has resulted in significant delay earlier in the WAL segment, subsequent conflicting queries will have much less grace time.

`max_standby_streaming_delay` (integer)

When Hot Standby is active, this parameter determines how long the standby server should wait before canceling standby queries that conflict with about-to-be-applied WAL entries, as described in Section 26.5.2. `max_standby_streaming_delay` applies when WAL data is being received via streaming replication. If this value is specified without units, it is taken as milliseconds. The default is 30 seconds. A value of -1 allows the standby to wait forever for conflicting queries to complete. This parameter can only be set in the `postgresql.conf` file or on the server command line.

Note that `max_standby_streaming_delay` is not the same as the maximum length of time a query can run before cancellation; rather it is the maximum total time allowed to apply WAL data once it has been received from the primary server. Thus, if one query has resulted in significant delay, subsequent conflicting queries will have much less grace time until the standby server has caught up again.

`wal_receiver_status_interval` (integer)

Specifies the minimum frequency for the WAL receiver process on the standby to send information about replication progress to the primary or upstream standby, where it can be seen using the `pg_stat_replication` view. The standby will report the last write-ahead log location it has written, the last position it has flushed to disk, and the last position it has applied. This parameter's value is the maximum amount of time between reports. Updates are sent each time the write or flush positions change, or at least as often as specified by this parameter. Thus, the apply position may lag slightly behind the true position. If this value is specified without units, it is taken as seconds. The default value is 10 seconds. Setting this parameter to zero disables status

updates completely. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`hot_standby_feedback` (boolean)

Specifies whether or not a hot standby will send feedback to the primary or upstream standby about queries currently executing on the standby. This parameter can be used to eliminate query cancels caused by cleanup records, but can cause database bloat on the primary for some workloads. Feedback messages will not be sent more frequently than once per `wal_receiver_status_interval`. The default value is `off`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

If cascaded replication is in use the feedback is passed upstream until it eventually reaches the primary. Standbys make no other use of feedback they receive other than to pass upstream.

This setting does not override the behavior of `old_snapshot_threshold` on the primary; a snapshot on the standby which exceeds the primary's age threshold can become invalid, resulting in cancellation of transactions on the standby. This is because `old_snapshot_threshold` is intended to provide an absolute limit on the time which dead rows can contribute to bloat, which would otherwise be violated because of the configuration of a standby.

`wal_receiver_timeout` (integer)

Terminate replication connections that are inactive for longer than this amount of time. This is useful for the receiving standby server to detect a primary node crash or network outage. If this value is specified without units, it is taken as milliseconds. The default value is 60 seconds. A value of zero disables the timeout mechanism. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`wal_retrieve_retry_interval` (integer)

Specifies how long the standby server should wait when WAL data is not available from any sources (streaming replication, local `pg_wal` or WAL archive) before trying again to retrieve WAL data. If this value is specified without units, it is taken as milliseconds. The default value is 5 seconds. This parameter can only be set in the `postgresql.conf` file or on the server command line.

This parameter is useful in configurations where a node in recovery needs to control the amount of time to wait for new WAL data to be available. For example, in archive recovery, it is possible to make the recovery more responsive in the detection of a new WAL log file by reducing the value of this parameter. On a system with low WAL activity, increasing it reduces the amount of requests necessary to access WAL archives, something useful for example in cloud environments where the amount of times an infrastructure is accessed is taken into account.

`recovery_min_apply_delay` (integer)

By default, a standby server restores WAL records from the sending server as soon as possible. It may be useful to have a time-delayed copy of the data, offering opportunities to correct data loss errors. This parameter allows you to delay recovery by a specified amount of time. For example, if you set this parameter to `5min`, the standby will replay each transaction commit only when the system time on the standby is at least five minutes past the commit time reported by the master. If this value is specified without units, it is taken as milliseconds. The default is zero, adding no delay.

It is possible that the replication delay between servers exceeds the value of this parameter, in which case no delay is added. Note that the delay is calculated between the WAL time stamp as written on master and the current time on the standby. Delays in transfer because of network lag or cascading replication configurations may reduce the actual wait time significantly. If the system clocks on master and standby are not synchronized, this may lead to recovery applying records earlier than expected; but that is not a major issue because useful settings of this parameter are much larger than typical time deviations between servers.

The delay occurs only on WAL records for transaction commits. Other records are replayed as quickly as possible, which is not a problem because MVCC visibility rules ensure their effects are not visible until the corresponding commit record is applied.

The delay occurs once the database in recovery has reached a consistent state, until the standby is promoted or triggered. After that the standby will end recovery without further waiting.

This parameter is intended for use with streaming replication deployments; however, if the parameter is specified it will be honored in all cases except crash recovery. `hot_standby_feedback` will be delayed by use of this feature which could lead to bloat on the master; use both together with care.

Warning

Synchronous replication is affected by this setting when `synchronous_commit` is set to `remote_apply`; every COMMIT will need to wait to be applied.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.6.4. Subscribers

These settings control the behavior of a logical replication subscriber. Their values on the publisher are irrelevant.

Note that `wal_receiver_timeout`, `wal_receiver_status_interval` and `wal_retrieve_retry_interval` configuration parameters affect the logical replication workers as well.

`max_logical_replication_workers` (int)

Specifies maximum number of logical replication workers. This includes both apply workers and table synchronization workers.

Logical replication workers are taken from the pool defined by `max_worker_processes`.

The default value is 4.

`max_sync_workers_per_subscription` (integer)

Maximum number of synchronization workers per subscription. This parameter controls the amount of parallelism of the initial data copy during the subscription initialization or when new tables are added.

Currently, there can be only one synchronization worker per table.

The synchronization workers are taken from the pool defined by `max_logical_replication_workers`.

The default value is 2.

19.7. Query Planning

19.7.1. Planner Method Configuration

These configuration parameters provide a crude method of influencing the query plans chosen by the query optimizer. If the default plan chosen by the optimizer for a particular query is not optimal, a *temporary* solution is to use one of these configuration parameters to force the optimizer to choose a different plan. Better ways to improve the quality of the plans chosen by the optimizer include adjusting

the planner cost constants (see Section 19.7.2), running ANALYZE manually, increasing the value of the `default_statistics_target` configuration parameter, and increasing the amount of statistics collected for specific columns using `ALTER TABLE SET STATISTICS`.

`enable_bitmapscan` (boolean)

Enables or disables the query planner's use of bitmap-scan plan types. The default is `on`.

`enable_gathermerge` (boolean)

Enables or disables the query planner's use of gather merge plan types. The default is `on`.

`enable_hashagg` (boolean)

Enables or disables the query planner's use of hashed aggregation plan types. The default is `on`.

`enable_hashjoin` (boolean)

Enables or disables the query planner's use of hash-join plan types. The default is `on`.

`enable_indexscan` (boolean)

Enables or disables the query planner's use of index-scan plan types. The default is `on`.

`enable_indexonlyscan` (boolean)

Enables or disables the query planner's use of index-only-scan plan types (see Section 11.9). The default is `on`.

`enable_material` (boolean)

Enables or disables the query planner's use of materialization. It is impossible to suppress materialization entirely, but turning this variable off prevents the planner from inserting materialize nodes except in cases where it is required for correctness. The default is `on`.

`enable_mergejoin` (boolean)

Enables or disables the query planner's use of merge-join plan types. The default is `on`.

`enable_nestloop` (boolean)

Enables or disables the query planner's use of nested-loop join plans. It is impossible to suppress nested-loop joins entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_parallel_append` (boolean)

Enables or disables the query planner's use of parallel-aware append plan types. The default is `on`.

`enable_parallel_hash` (boolean)

Enables or disables the query planner's use of hash-join plan types with parallel hash. Has no effect if hash-join plans are not also enabled. The default is `on`.

`enable_partition_pruning` (boolean)

Enables or disables the query planner's ability to eliminate a partitioned table's partitions from query plans. This also controls the planner's ability to generate query plans which allow the query executor to remove (ignore) partitions during query execution. The default is `on`. See Section 5.11.4 for details.

`enable_partitionwise_join` (boolean)

Enables or disables the query planner's use of partitionwise join, which allows a join between partitioned tables to be performed by joining the matching partitions. Partitionwise join currently

applies only when the join conditions include all the partition keys, which must be of the same data type and have exactly matching sets of child partitions. Because partitionwise join planning can use significantly more CPU time and memory during planning, the default is `off`.

`enable_partitionwise_aggregate` (boolean)

Enables or disables the query planner's use of partitionwise grouping or aggregation, which allows grouping or aggregation on a partitioned tables performed separately for each partition. If the `GROUP BY` clause does not include the partition keys, only partial aggregation can be performed on a per-partition basis, and finalization must be performed later. Because partitionwise grouping or aggregation can use significantly more CPU time and memory during planning, the default is `off`.

`enable_seqscan` (boolean)

Enables or disables the query planner's use of sequential scan plan types. It is impossible to suppress sequential scans entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_sort` (boolean)

Enables or disables the query planner's use of explicit sort steps. It is impossible to suppress explicit sorts entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_tidscan` (boolean)

Enables or disables the query planner's use of TID scan plan types. The default is `on`.

19.7.2. Planner Cost Constants

The *cost* variables described in this section are measured on an arbitrary scale. Only their relative values matter, hence scaling them all up or down by the same factor will result in no change in the planner's choices. By default, these cost variables are based on the cost of sequential page fetches; that is, `seq_page_cost` is conventionally set to 1.0 and the other cost variables are set with reference to that. But you can use a different scale if you prefer, such as actual execution times in milliseconds on a particular machine.

Note

Unfortunately, there is no well-defined method for determining ideal values for the cost variables. They are best treated as averages over the entire mix of queries that a particular installation will receive. This means that changing them on the basis of just a few experiments is very risky.

`seq_page_cost` (floating point)

Sets the planner's estimate of the cost of a disk page fetch that is part of a series of sequential fetches. The default is 1.0. This value can be overridden for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name (see `ALTER TABLESPACE`).

`random_page_cost` (floating point)

Sets the planner's estimate of the cost of a non-sequentially-fetched disk page. The default is 4.0. This value can be overridden for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name (see `ALTER TABLESPACE`).

Reducing this value relative to `seq_page_cost` will cause the system to prefer index scans; raising it will make index scans look relatively more expensive. You can raise or lower both values together to change the importance of disk I/O costs relative to CPU costs, which are described by the following parameters.

Random access to mechanical disk storage is normally much more expensive than four times sequential access. However, a lower default is used (4.0) because the majority of random accesses to disk, such as indexed reads, are assumed to be in cache. The default value can be thought of as modeling random access as 40 times slower than sequential, while expecting 90% of random reads to be cached.

If you believe a 90% cache rate is an incorrect assumption for your workload, you can increase `random_page_cost` to better reflect the true cost of random storage reads. Correspondingly, if your data is likely to be completely in cache, such as when the database is smaller than the total server memory, decreasing `random_page_cost` can be appropriate. Storage that has a low random read cost relative to sequential, e.g. solid-state drives, might also be better modeled with a lower value for `random_page_cost`.

Tip

Although the system will let you set `random_page_cost` to less than `seq_page_cost`, it is not physically sensible to do so. However, setting them equal makes sense if the database is entirely cached in RAM, since in that case there is no penalty for touching pages out of sequence. Also, in a heavily-cached database you should lower both values relative to the CPU parameters, since the cost of fetching a page already in RAM is much smaller than it would normally be.

`cpu_tuple_cost` (floating point)

Sets the planner's estimate of the cost of processing each row during a query. The default is 0.01.

`cpu_index_tuple_cost` (floating point)

Sets the planner's estimate of the cost of processing each index entry during an index scan. The default is 0.005.

`cpu_operator_cost` (floating point)

Sets the planner's estimate of the cost of processing each operator or function executed during a query. The default is 0.0025.

`parallel_setup_cost` (floating point)

Sets the planner's estimate of the cost of launching parallel worker processes. The default is 1000.

`parallel_tuple_cost` (floating point)

Sets the planner's estimate of the cost of transferring one tuple from a parallel worker process to another process. The default is 0.1.

`min_parallel_table_scan_size` (integer)

Sets the minimum amount of table data that must be scanned in order for a parallel scan to be considered. For a parallel sequential scan, the amount of table data scanned is always equal to the size of the table, but when indexes are used the amount of table data scanned will normally be less. If this value is specified without units, it is taken as blocks, that is BLCKSZ bytes, typically 8kB. The default is 8 megabytes (8MB).

`min_parallel_index_scan_size` (integer)

Sets the minimum amount of index data that must be scanned in order for a parallel scan to be considered. Note that a parallel index scan typically won't touch the entire index; it is the number of pages which the planner believes will actually be touched by the scan which is relevant. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The default is 512 kilobytes (512kB).

`effective_cache_size` (integer)

Sets the planner's assumption about the effective size of the disk cache that is available to a single query. This is factored into estimates of the cost of using an index; a higher value makes it more likely index scans will be used, a lower value makes it more likely sequential scans will be used. When setting this parameter you should consider both PostgreSQL's shared buffers and the portion of the kernel's disk cache that will be used for PostgreSQL data files, though some data might exist in both places. Also, take into account the expected number of concurrent queries on different tables, since they will have to share the available space. This parameter has no effect on the size of shared memory allocated by PostgreSQL, nor does it reserve kernel disk cache; it is used only for estimation purposes. The system also does not assume data remains in the disk cache between queries. If this value is specified without units, it is taken as blocks, that is `BLCKSZ` bytes, typically 8kB. The default is 4 gigabytes (4GB). (If `BLCKSZ` is not 8kB, the default value scales proportionally to it.)

`jit_above_cost` (floating point)

Sets the query cost above which JIT compilation is activated, if enabled (see Chapter 31). Performing JIT costs planning time but can accelerate query execution. Setting this to `-1` disables JIT compilation. The default is 100000.

`jit_inline_above_cost` (floating point)

Sets the query cost above which JIT compilation attempts to inline functions and operators. Inlining adds planning time, but can improve execution speed. It is not meaningful to set this to less than `jit_above_cost`. Setting this to `-1` disables inlining. The default is 500000.

`jit_optimize_above_cost` (floating point)

Sets the query cost above which JIT compilation applies expensive optimizations. Such optimization adds planning time, but can improve execution speed. It is not meaningful to set this to less than `jit_above_cost`, and it is unlikely to be beneficial to set it to more than `jit_inline_above_cost`. Setting this to `-1` disables expensive optimizations. The default is 500000.

19.7.3. Genetic Query Optimizer

The genetic query optimizer (GEQO) is an algorithm that does query planning using heuristic searching. This reduces planning time for complex queries (those joining many relations), at the cost of producing plans that are sometimes inferior to those found by the normal exhaustive-search algorithm. For more information see Chapter 59.

`geqo` (boolean)

Enables or disables genetic query optimization. This is on by default. It is usually best not to turn it off in production; the `geqo_threshold` variable provides more granular control of GEQO.

`geqo_threshold` (integer)

Use genetic query optimization to plan queries with at least this many `FROM` items involved. (Note that a `FULL OUTER JOIN` construct counts as only one `FROM` item.) The default is 12. For simpler queries it is usually best to use the regular, exhaustive-search planner, but for queries with

many tables the exhaustive search takes too long, often longer than the penalty of executing a suboptimal plan. Thus, a threshold on the size of the query is a convenient way to manage use of GEQO.

`geqo_effort` (integer)

Controls the trade-off between planning time and query plan quality in GEQO. This variable must be an integer in the range from 1 to 10. The default value is five. Larger values increase the time spent doing query planning, but also increase the likelihood that an efficient query plan will be chosen.

`geqo_effort` doesn't actually do anything directly; it is only used to compute the default values for the other variables that influence GEQO behavior (described below). If you prefer, you can set the other parameters by hand instead.

`geqo_pool_size` (integer)

Controls the pool size used by GEQO, that is the number of individuals in the genetic population. It must be at least two, and useful values are typically 100 to 1000. If it is set to zero (the default setting) then a suitable value is chosen based on `geqo_effort` and the number of tables in the query.

`geqo_generations` (integer)

Controls the number of generations used by GEQO, that is the number of iterations of the algorithm. It must be at least one, and useful values are in the same range as the pool size. If it is set to zero (the default setting) then a suitable value is chosen based on `geqo_pool_size`.

`geqo_selection_bias` (floating point)

Controls the selection bias used by GEQO. The selection bias is the selective pressure within the population. Values can be from 1.50 to 2.00; the latter is the default.

`geqo_seed` (floating point)

Controls the initial value of the random number generator used by GEQO to select random paths through the join order search space. The value can range from zero (the default) to one. Varying the value changes the set of join paths explored, and may result in a better or worse best path being found.

19.7.4. Other Planner Options

`default_statistics_target` (integer)

Sets the default statistics target for table columns without a column-specific target set via `ALTER TABLE SET STATISTICS`. Larger values increase the time needed to do `ANALYZE`, but might improve the quality of the planner's estimates. The default is 100. For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

`constraint_exclusion` (enum)

Controls the query planner's use of table constraints to optimize queries. The allowed values of `constraint_exclusion` are `on` (examine constraints for all tables), `off` (never examine constraints), and `partition` (examine constraints only for inheritance child tables and `UNION ALL` subqueries). `partition` is the default setting. It is often used with traditional inheritance trees to improve performance.

When this parameter allows it for a particular table, the planner compares query conditions with the table's `CHECK` constraints, and omits scanning tables for which the conditions contradict the constraints. For example:

```
CREATE TABLE parent(key integer, ...);
CREATE TABLE child1000(check (key between 1000 and 1999))
  INHERITS(parent);
CREATE TABLE child2000(check (key between 2000 and 2999))
  INHERITS(parent);
...
SELECT * FROM parent WHERE key = 2400;
```

With constraint exclusion enabled, this `SELECT` will not scan `child1000` at all, improving performance.

Currently, constraint exclusion is enabled by default only for cases that are often used to implement table partitioning via inheritance trees. Turning it on for all tables imposes extra planning overhead that is quite noticeable on simple queries, and most often will yield no benefit for simple queries. If you have no tables that are partitioned using traditional inheritance, you might prefer to turn it off entirely. (Note that the equivalent feature for partitioned tables is controlled by a separate parameter, `enable_partition_pruning`.)

Refer to Section 5.11.5 for more information on using constraint exclusion to implement partitioning.

`cursor_tuple_fraction` (floating point)

Sets the planner's estimate of the fraction of a cursor's rows that will be retrieved. The default is 0.1. Smaller values of this setting bias the planner towards using “fast start” plans for cursors, which will retrieve the first few rows quickly while perhaps taking a long time to fetch all rows. Larger values put more emphasis on the total estimated time. At the maximum setting of 1.0, cursors are planned exactly like regular queries, considering only the total estimated time and not how soon the first rows might be delivered.

`from_collapse_limit` (integer)

The planner will merge sub-queries into upper queries if the resulting `FROM` list would have no more than this many items. Smaller values reduce planning time but might yield inferior query plans. The default is eight. For more information see Section 14.3.

Setting this value to `geqo_threshold` or more may trigger use of the GEQO planner, resulting in non-optimal plans. See Section 19.7.3.

`jit` (boolean)

Determines whether JIT compilation may be used by PostgreSQL, if available (see Chapter 31). The default is on.

`join_collapse_limit` (integer)

The planner will rewrite explicit `JOIN` constructs (except `FULL JOINS`) into lists of `FROM` items whenever a list of no more than this many items would result. Smaller values reduce planning time but might yield inferior query plans.

By default, this variable is set the same as `from_collapse_limit`, which is appropriate for most uses. Setting it to 1 prevents any reordering of explicit `JOINS`. Thus, the explicit join order specified in the query will be the actual order in which the relations are joined. Because the query planner does not always choose the optimal join order, advanced users can elect to temporarily set this variable to 1, and then specify the join order they desire explicitly. For more information see Section 14.3.

Setting this value to `geqo_threshold` or more may trigger use of the GEQO planner, resulting in non-optimal plans. See Section 19.7.3.

`parallel_leader_participation` (boolean)

Allows the leader process to execute the query plan under `Gather` and `Gather Merge` nodes instead of waiting for worker processes. The default is `on`. Setting this value to `off` reduces the likelihood that workers will become blocked because the leader is not reading tuples fast enough, but requires the leader process to wait for worker processes to start up before the first tuples can be produced. The degree to which the leader can help or hinder performance depends on the plan type, number of workers and query duration.

`force_parallel_mode` (enum)

Allows the use of parallel queries for testing purposes even in cases where no performance benefit is expected. The allowed values of `force_parallel_mode` are `off` (use parallel mode only when it is expected to improve performance), `on` (force parallel query for all queries for which it is thought to be safe), and `regress` (like `on`, but with additional behavior changes as explained below).

More specifically, setting this value to `on` will add a `Gather` node to the top of any query plan for which this appears to be safe, so that the query runs inside of a parallel worker. Even when a parallel worker is not available or cannot be used, operations such as starting a subtransaction that would be prohibited in a parallel query context will be prohibited unless the planner believes that this will cause the query to fail. If failures or unexpected results occur when this option is set, some functions used by the query may need to be marked `PARALLEL UNSAFE` (or, possibly, `PARALLEL RESTRICTED`).

Setting this value to `regress` has all of the same effects as setting it to `on` plus some additional effects that are intended to facilitate automated regression testing. Normally, messages from a parallel worker include a context line indicating that, but a setting of `regress` suppresses this line so that the output is the same as in non-parallel execution. Also, the `Gather` nodes added to plans by this setting are hidden in `EXPLAIN` output so that the output matches what would be obtained if this setting were turned `off`.

`plan_cache_mode` (enum)

Prepared statements (either explicitly prepared or implicitly generated, for example by PL/pgSQL) can be executed using custom or generic plans. Custom plans are made afresh for each execution using its specific set of parameter values, while generic plans do not rely on the parameter values and can be re-used across executions. Thus, use of a generic plan saves planning time, but if the ideal plan depends strongly on the parameter values then a generic plan may be inefficient. The choice between these options is normally made automatically, but it can be overridden with `plan_cache_mode`. The allowed values are `auto` (the default), `force_custom_plan` and `force_generic_plan`. This setting is considered when a cached plan is to be executed, not when it is prepared. For more information see `PREPARE`.

19.8. Error Reporting and Logging

19.8.1. Where to Log

`log_destination` (string)

PostgreSQL supports several methods for logging server messages, including `stderr`, `csvlog` and `syslog`. On Windows, `eventlog` is also supported. Set this parameter to a list of desired log destinations separated by commas. The default is to log to `stderr` only. This parameter can only be set in the `postgresql.conf` file or on the server command line.

If `csvlog` is included in `log_destination`, log entries are output in “comma separated value” (CSV) format, which is convenient for loading logs into programs. See Section 19.8.4 for details. `logging_collector` must be enabled to generate CSV-format log output.

When either `stderr` or `csvlog` are included, the file `current_logfiles` is created to record the location of the log file(s) currently in use by the logging collector and the associated logging destination. This provides a convenient way to find the logs currently in use by the instance. Here is an example of this file's content:

```
stderr log/postgresql.log
csvlog log/postgresql.csv
```

`current_logfiles` is recreated when a new log file is created as an effect of rotation, and when `log_destination` is reloaded. It is removed when neither `stderr` nor `csvlog` are included in `log_destination`, and when the logging collector is disabled.

Note

On most Unix systems, you will need to alter the configuration of your system's syslog daemon in order to make use of the `syslog` option for `log_destination`. PostgreSQL can log to syslog facilities LOCAL0 through LOCAL7 (see `syslog_facility`), but the default syslog configuration on most platforms will discard all such messages. You will need to add something like:

```
local0.* /var/log/postgresql
```

to the syslog daemon's configuration file to make it work.

On Windows, when you use the `eventlog` option for `log_destination`, you should register an event source and its library with the operating system so that the Windows Event Viewer can display event log messages cleanly. See Section 18.12 for details.

`logging_collector` (boolean)

This parameter enables the *logging collector*, which is a background process that captures log messages sent to `stderr` and redirects them into log files. This approach is often more useful than logging to syslog, since some types of messages might not appear in syslog output. (One common example is dynamic-linker failure messages; another is error messages produced by scripts such as `archive_command`.) This parameter can only be set at server start.

Note

It is possible to log to `stderr` without using the logging collector; the log messages will just go to wherever the server's `stderr` is directed. However, that method is only suitable for low log volumes, since it provides no convenient way to rotate log files. Also, on some platforms not using the logging collector can result in lost or garbled log output, because multiple processes writing concurrently to the same log file can overwrite each other's output.

Note

The logging collector is designed to never lose messages. This means that in case of extremely high load, server processes could be blocked while trying to send additional log messages when the collector has fallen behind. In contrast, syslog

prefers to drop messages if it cannot write them, which means it may fail to log some messages in such cases but it will not block the rest of the system.

`log_directory` (string)

When `logging_collector` is enabled, this parameter determines the directory in which log files will be created. It can be specified as an absolute path, or relative to the cluster data directory. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `log`.

`log_filename` (string)

When `logging_collector` is enabled, this parameter sets the file names of the created log files. The value is treated as a `strftime` pattern, so `%`-escapes can be used to specify time-varying file names. (Note that if there are any time-zone-dependent `%`-escapes, the computation is done in the zone specified by `log_timezone`.) The supported `%`-escapes are similar to those listed in the Open Group's `strftime`¹ specification. Note that the system's `strftime` is not used directly, so platform-specific (nonstandard) extensions do not work. The default is `postgresql-%Y-%m-%d_%H%M%S.log`.

If you specify a file name without escapes, you should plan to use a log rotation utility to avoid eventually filling the entire disk. In releases prior to 8.4, if no `%` escapes were present, PostgreSQL would append the epoch of the new log file's creation time, but this is no longer the case.

If CSV-format output is enabled in `log_destination`, `.csv` will be appended to the time-stamped log file name to create the file name for CSV-format output. (If `log_filename` ends in `.log`, the suffix is replaced instead.)

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_file_mode` (integer)

On Unix systems this parameter sets the permissions for log files when `logging_collector` is enabled. (On Microsoft Windows this parameter is ignored.) The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls. (To use the customary octal format the number must start with a 0 (zero).)

The default permissions are `0600`, meaning only the server owner can read or write the log files. The other commonly useful setting is `0640`, allowing members of the owner's group to read the files. Note however that to make use of such a setting, you'll need to alter `log_directory` to store the files somewhere outside the cluster data directory. In any case, it's unwise to make the log files world-readable, since they might contain sensitive data.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_rotation_age` (integer)

When `logging_collector` is enabled, this parameter determines the maximum amount of time to use an individual log file, after which a new log file will be created. If this value is specified without units, it is taken as minutes. The default is 24 hours. Set to zero to disable time-based creation of new log files. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_rotation_size` (integer)

When `logging_collector` is enabled, this parameter determines the maximum size of an individual log file. After this amount of data has been emitted into a log file, a new log file will be

¹ <http://pubs.opengroup.org/onlinepubs/009695399/functions/strftime.html>

created. If this value is specified without units, it is taken as kilobytes. The default is 10 megabytes. Set to zero to disable size-based creation of new log files. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_truncate_on_rotation` (boolean)

When `logging_collector` is enabled, this parameter will cause PostgreSQL to truncate (overwrite), rather than append to, any existing log file of the same name. However, truncation will occur only when a new file is being opened due to time-based rotation, not during server startup or size-based rotation. When off, pre-existing files will be appended to in all cases. For example, using this setting in combination with a `log_filename` like `postgresql-%H.log` would result in generating twenty-four hourly log files and then cyclically overwriting them. This parameter can only be set in the `postgresql.conf` file or on the server command line.

Example: To keep 7 days of logs, one log file per day named `server_log.Mon`, `server_log.Tue`, etc, and automatically overwrite last week's log with this week's log, set `log_filename` to `server_log.%a`, `log_truncate_on_rotation` to `on`, and `log_rotation_age` to 1440.

Example: To keep 24 hours of logs, one log file per hour, but also rotate sooner if the log file size exceeds 1GB, set `log_filename` to `server_log.%H%M`, `log_truncate_on_rotation` to `on`, `log_rotation_age` to 60, and `log_rotation_size` to 1000000. Including `%M` in `log_filename` allows any size-driven rotations that might occur to select a file name different from the hour's initial file name.

`syslog_facility` (enum)

When logging to syslog is enabled, this parameter determines the syslog “facility” to be used. You can choose from `LOCAL0`, `LOCAL1`, `LOCAL2`, `LOCAL3`, `LOCAL4`, `LOCAL5`, `LOCAL6`, `LOCAL7`; the default is `LOCAL0`. See also the documentation of your system's syslog daemon. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`syslog_ident` (string)

When logging to syslog is enabled, this parameter determines the program name used to identify PostgreSQL messages in syslog logs. The default is `postgres`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`syslog_sequence_numbers` (boolean)

When logging to syslog and this is on (the default), then each message will be prefixed by an increasing sequence number (such as `[2]`). This circumvents the “--- last message repeated N times ---” suppression that many syslog implementations perform by default. In more modern syslog implementations, repeated message suppression can be configured (for example, `$RepeatedMsgReduction` in `rsyslog`), so this might not be necessary. Also, you could turn this off if you actually want to suppress repeated messages.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`syslog_split_messages` (boolean)

When logging to syslog is enabled, this parameter determines how messages are delivered to syslog. When on (the default), messages are split by lines, and long lines are split so that they will fit into 1024 bytes, which is a typical size limit for traditional syslog implementations. When off, PostgreSQL server log messages are delivered to the syslog service as is, and it is up to the syslog service to cope with the potentially bulky messages.

If syslog is ultimately logging to a text file, then the effect will be the same either way, and it is best to leave the setting on, since most syslog implementations either cannot handle large messages

or would need to be specially configured to handle them. But if syslog is ultimately writing into some other medium, it might be necessary or more useful to keep messages logically together.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`event_source` (string)

When logging to event log is enabled, this parameter determines the program name used to identify PostgreSQL messages in the log. The default is `PostgreSQL`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.8.2. When to Log

`log_min_messages` (enum)

Controls which message levels are written to the server log. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, `INFO`, `NOTICE`, `WARNING`, `ERROR`, `LOG`, `FATAL`, and `PANIC`. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log. The default is `WARNING`. Note that `LOG` has a different rank here than in `client_min_messages`. Only superusers can change this setting.

`log_min_error_statement` (enum)

Controls which SQL statements that cause an error condition are recorded in the server log. The current SQL statement is included in the log entry for any message of the specified severity or higher. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, `INFO`, `NOTICE`, `WARNING`, `ERROR`, `LOG`, `FATAL`, and `PANIC`. The default is `ERROR`, which means statements causing errors, log messages, fatal errors, or panics will be logged. To effectively turn off logging of failing statements, set this parameter to `PANIC`. Only superusers can change this setting.

`log_min_duration_statement` (integer)

Causes the duration of each completed statement to be logged if the statement ran for at least the specified amount of time. If this value is specified without units, it is taken as milliseconds. Setting this to zero prints all statement durations. Minus-one (the default) disables logging statement durations. For example, if you set it to 250ms then all SQL statements that run 250ms or longer will be logged. Enabling this parameter can be helpful in tracking down unoptimized queries in your applications. Only superusers can change this setting.

For clients using extended query protocol, durations of the Parse, Bind, and Execute steps are logged independently.

Note

When using this option together with `log_statement`, the text of statements that are logged because of `log_statement` will not be repeated in the duration log message. If you are not using syslog, it is recommended that you log the PID or session ID using `log_line_prefix` so that you can link the statement message to the later duration message using the process ID or session ID.

`log_transaction_sample_rate` (real)

Set the fraction of transactions whose statements are all logged, in addition to statements logged for other reasons. It applies to each new transaction regardless of its statements' durations. The default is 0, meaning not to log statements from any additional transaction. Setting this to 1 logs all statements for all transactions. `log_transaction_sample_rate` is helpful to track a sample of transaction. Only superusers can change this setting.

Note

Like all statement-logging options, this option can add significant overhead.

Table 19.1 explains the message severity levels used by PostgreSQL. If logging output is sent to syslog or Windows' eventlog, the severity levels are translated as shown in the table.

Table 19.1. Message Severity Levels

Severity	Usage	syslog	eventlog
DEBUG1..DEBUG5	Provides successively-more-detailed information for use by developers.	DEBUG	INFORMATION
INFO	Provides information implicitly requested by the user, e.g., output from <code>VACUUM VERBOSE</code> .	INFO	INFORMATION
NOTICE	Provides information that might be helpful to users, e.g., notice of truncation of long identifiers.	NOTICE	INFORMATION
WARNING	Provides warnings of likely problems, e.g., <code>COMMIT</code> outside a transaction block.	NOTICE	WARNING
ERROR	Reports an error that caused the current command to abort.	WARNING	ERROR
LOG	Reports information of interest to administrators, e.g., checkpoint activity.	INFO	INFORMATION
FATAL	Reports an error that caused the current session to abort.	ERR	ERROR
PANIC	Reports an error that caused all database sessions to abort.	CRIT	ERROR

19.8.3. What to Log

`application_name` (string)

The `application_name` can be any string of less than `NAMEDATALEN` characters (64 characters in a standard build). It is typically set by an application upon connection to the server. The name will be displayed in the `pg_stat_activity` view and included in CSV log entries. It can also be included in regular log entries via the `log_line_prefix` parameter. Only printable ASCII characters may be used in the `application_name` value. Other characters will be replaced with question marks (?).

`debug_print_parse` (boolean)
`debug_print_rewritten` (boolean)
`debug_print_plan` (boolean)

These parameters enable various debugging output to be emitted. When set, they print the resulting parse tree, the query rewriter output, or the execution plan for each executed query. These messages are emitted at LOG message level, so by default they will appear in the server log but will not be sent to the client. You can change that by adjusting `client_min_messages` and/or `log_min_messages`. These parameters are off by default.

`debug_pretty_print` (boolean)

When set, `debug_pretty_print` indents the messages produced by `debug_print_parse`, `debug_print_rewritten`, or `debug_print_plan`. This results in more readable but much longer output than the “compact” format used when it is off. It is on by default.

`log_checkpoints` (boolean)

Causes checkpoints and restartpoints to be logged in the server log. Some statistics are included in the log messages, including the number of buffers written and the time spent writing them. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is off.

`log_connections` (boolean)

Causes each attempted connection to the server to be logged, as well as successful completion of client authentication. Only superusers can change this parameter at session start, and it cannot be changed at all within a session. The default is off.

Note

Some client programs, like `psql`, attempt to connect twice while determining if a password is required, so duplicate “connection received” messages do not necessarily indicate a problem.

`log_disconnections` (boolean)

Causes session terminations to be logged. The log output provides information similar to `log_connections`, plus the duration of the session. Only superusers can change this parameter at session start, and it cannot be changed at all within a session. The default is off.

`log_duration` (boolean)

Causes the duration of every completed statement to be logged. The default is off. Only superusers can change this setting.

For clients using extended query protocol, durations of the Parse, Bind, and Execute steps are logged independently.

Note

The difference between enabling `log_duration` and setting `log_min_duration_statement` to zero is that exceeding `log_min_duration_statement` forces the text of the query to be logged, but this option doesn't. Thus, if `log_duration` is on and `log_min_duration_statement` has a positive value, all durations are logged but the query text is included only for statements exceed-

ing the threshold. This behavior can be useful for gathering statistics in high-load installations.

`log_error_verbosity` (enum)

Controls the amount of detail written in the server log for each message that is logged. Valid values are `TERSE`, `DEFAULT`, and `VERBOSE`, each adding more fields to displayed messages. `TERSE` excludes the logging of `DETAIL`, `HINT`, `QUERY`, and `CONTEXT` error information. `VERBOSE` output includes the `SQLSTATE` error code (see also Appendix A) and the source code file name, function name, and line number that generated the error. Only superusers can change this setting.

`log_hostname` (boolean)

By default, connection log messages only show the IP address of the connecting host. Turning this parameter on causes logging of the host name as well. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_line_prefix` (string)

This is a `printf`-style string that is output at the beginning of each log line. `%` characters begin “escape sequences” that are replaced with status information as outlined below. Unrecognized escapes are ignored. Other characters are copied straight to the log line. Some escapes are only recognized by session processes, and will be treated as empty by background processes such as the main server process. Status information may be aligned either left or right by specifying a numeric literal after the `%` and before the option. A negative value will cause the status information to be padded on the right with spaces to give it a minimum width, whereas a positive value will pad on the left. Padding can be useful to aid human readability in log files. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `'%m [%p]'` which logs a time stamp and the process ID.

Escape	Effect	Session only
<code>%a</code>	Application name	yes
<code>%u</code>	User name	yes
<code>%d</code>	Database name	yes
<code>%r</code>	Remote host name or IP address, and remote port	yes
<code>%h</code>	Remote host name or IP address	yes
<code>%p</code>	Process ID	no
<code>%t</code>	Time stamp without milliseconds	no
<code>%m</code>	Time stamp with milliseconds	no
<code>%n</code>	Time stamp with milliseconds (as a Unix epoch)	no
<code>%i</code>	Command tag: type of session's current command	yes
<code>%e</code>	<code>SQLSTATE</code> error code	no
<code>%c</code>	Session ID: see below	no
<code>%l</code>	Number of the log line for each session or process, starting at 1	no
<code>%s</code>	Process start time stamp	no

Escape	Effect	Session only
<code>%v</code>	Virtual transaction ID (backendID/localXID)	no
<code>%x</code>	Transaction ID (0 if none is assigned)	no
<code>%q</code>	Produces no output, but tells non-session processes to stop at this point in the string; ignored by session processes	no
<code>%%</code>	Literal %	no

The `%c` escape prints a quasi-unique session identifier, consisting of two 4-byte hexadecimal numbers (without leading zeros) separated by a dot. The numbers are the process start time and the process ID, so `%c` can also be used as a space saving way of printing those items. For example, to generate the session identifier from `pg_stat_activity`, use this query:

```
SELECT to_hex(trunc(EXTRACT(EPOCH FROM backend_start))::integer)
|| '.' ||
       to_hex(pid)
FROM pg_stat_activity;
```

Tip

If you set a nonempty value for `log_line_prefix`, you should usually make its last character be a space, to provide visual separation from the rest of the log line. A punctuation character can be used too.

Tip

Syslog produces its own time stamp and process ID information, so you probably do not want to include those escapes if you are logging to syslog.

Tip

The `%q` escape is useful when including information that is only available in session (backend) context like user or database name. For example:

```
log_line_prefix = '%m [%p] %q%u@d/%a '
```

`log_lock_waits` (boolean)

Controls whether a log message is produced when a session waits longer than `deadlock_timeout` to acquire a lock. This is useful in determining if lock waits are causing poor performance. The default is `off`. Only superusers can change this setting.

`log_statement` (enum)

Controls which SQL statements are logged. Valid values are `none` (`off`), `ddl`, `mod`, and `all` (all statements). `ddl` logs all data definition statements, such as `CREATE`, `ALTER`, and `DROP` statements. `mod` logs all `ddl` statements, plus data-modifying statements such as `INSERT`, `UP-`

DATE, DELETE, TRUNCATE, and COPY FROM. PREPARE, EXECUTE, and EXPLAIN ANALYZE statements are also logged if their contained command is of an appropriate type. For clients using extended query protocol, logging occurs when an Execute message is received, and values of the Bind parameters are included (with any embedded single-quote marks doubled).

The default is none. Only superusers can change this setting.

Note

Statements that contain simple syntax errors are not logged even by the `log_statement = all` setting, because the log message is emitted only after basic parsing has been done to determine the statement type. In the case of extended query protocol, this setting likewise does not log statements that fail before the Execute phase (i.e., during parse analysis or planning). Set `log_min_error_statement` to ERROR (or lower) to log such statements.

`log_replication_commands` (boolean)

Causes each replication command to be logged in the server log. See Section 52.4 for more information about replication command. The default value is off. Only superusers can change this setting.

`log_temp_files` (integer)

Controls logging of temporary file names and sizes. Temporary files can be created for sorts, hashes, and temporary query results. If enabled by this setting, a log entry is emitted for each temporary file when it is deleted. A value of zero logs all temporary file information, while positive values log only files whose size is greater than or equal to the specified amount of data. If this value is specified without units, it is taken as kilobytes. The default setting is -1, which disables such logging. Only superusers can change this setting.

`log_timezone` (string)

Sets the time zone used for timestamps written in the server log. Unlike TimeZone, this value is cluster-wide, so that all sessions will report timestamps consistently. The built-in default is GMT, but that is typically overridden in `postgresql.conf`; `initdb` will install a setting there corresponding to its system environment. See Section 8.5.3 for more information. This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.8.4. Using CSV-Format Log Output

Including `csvlog` in the `log_destination` list provides a convenient way to import log files into a database table. This option emits log lines in comma-separated-values (CSV) format, with these columns: time stamp with milliseconds, user name, database name, process ID, client host:port number, session ID, per-session line number, command tag, session start time, virtual transaction ID, regular transaction ID, error severity, SQLSTATE code, error message, error message detail, hint, internal query that led to the error (if any), character count of the error position therein, error context, user query that led to the error (if any and enabled by `log_min_error_statement`), character count of the error position therein, location of the error in the PostgreSQL source code (if `log_error_verbosity` is set to `verbose`), and application name. Here is a sample table definition for storing CSV-format log output:

```
CREATE TABLE postgres_log
(
  log_time timestamp(3) with time zone,
  user_name text,
```

```
database_name text,  
process_id integer,  
connection_from text,  
session_id text,  
session_line_num bigint,  
command_tag text,  
session_start_time timestamp with time zone,  
virtual_transaction_id text,  
transaction_id bigint,  
error_severity text,  
sql_state_code text,  
message text,  
detail text,  
hint text,  
internal_query text,  
internal_query_pos integer,  
context text,  
query text,  
query_pos integer,  
location text,  
application_name text,  
PRIMARY KEY (session_id, session_line_num)  
);
```

To import a log file into this table, use the `COPY FROM` command:

```
COPY postgres_log FROM '/full/path/to/logfile.csv' WITH csv;
```

There are a few things you need to do to simplify importing CSV log files:

1. Set `log_filename` and `log_rotation_age` to provide a consistent, predictable naming scheme for your log files. This lets you predict what the file name will be and know when an individual log file is complete and therefore ready to be imported.
2. Set `log_rotation_size` to 0 to disable size-based log rotation, as it makes the log file name difficult to predict.
3. Set `log_truncate_on_rotation` to on so that old log data isn't mixed with the new in the same file.
4. The table definition above includes a primary key specification. This is useful to protect against accidentally importing the same information twice. The `COPY` command commits all of the data it imports at one time, so any error will cause the entire import to fail. If you import a partial log file and later import the file again when it is complete, the primary key violation will cause the import to fail. Wait until the log is complete and closed before importing. This procedure will also protect against accidentally importing a partial line that hasn't been completely written, which would also cause `COPY` to fail.

19.8.5. Process Title

These settings control how process titles of server processes are modified. Process titles are typically viewed using programs like `ps` or, on Windows, Process Explorer. See Section 27.1 for details.

`cluster_name` (string)

Sets a name that identifies this database cluster (instance) for various purposes. The cluster name appears in the process title for all server processes in this cluster. Moreover, it is the default application name for a standby connection (see `synchronous_standby_names`.)

The name can be any string of less than `NAMEDATALEN` characters (64 characters in a standard build). Only printable ASCII characters may be used in the `cluster_name` value. Other characters will be replaced with question marks (?). No name is shown if this parameter is set to the empty string '' (which is the default). This parameter can only be set at server start.

`update_process_title` (boolean)

Enables updating of the process title every time a new SQL command is received by the server. This setting defaults to `on` on most platforms, but it defaults to `off` on Windows due to that platform's larger overhead for updating the process title. Only superusers can change this setting.

19.9. Run-time Statistics

19.9.1. Query and Index Statistics Collector

These parameters control server-wide statistics collection features. When statistics collection is enabled, the data that is produced can be accessed via the `pg_stat` and `pg_statio` family of system views. Refer to Chapter 27 for more information.

`track_activities` (boolean)

Enables the collection of information on the currently executing command of each session, along with the time when that command began execution. This parameter is `on` by default. Note that even when enabled, this information is not visible to all users, only to superusers and the user owning the session being reported on, so it should not represent a security risk. Only superusers can change this setting.

`track_activity_query_size` (integer)

Specifies the amount of memory reserved to store the text of the currently executing command for each active session, for the `pg_stat_activity.query` field. If this value is specified without units, it is taken as bytes. The default value is 1024 bytes. This parameter can only be set at server start.

`track_counts` (boolean)

Enables collection of statistics on database activity. This parameter is `on` by default, because the autovacuum daemon needs the collected information. Only superusers can change this setting.

`track_io_timing` (boolean)

Enables timing of database I/O calls. This parameter is `off` by default, because it will repeatedly query the operating system for the current time, which may cause significant overhead on some platforms. You can use the `pg_test_timing` tool to measure the overhead of timing on your system. I/O timing information is displayed in `pg_stat_database`, in the output of `EXPLAIN` when the `BUFFERS` option is used, and by `pg_stat_statements`. Only superusers can change this setting.

`track_functions` (enum)

Enables tracking of function call counts and time used. Specify `p1` to track only procedural-language functions, `all` to also track SQL and C language functions. The default is `none`, which disables function statistics tracking. Only superusers can change this setting.

Note

SQL-language functions that are simple enough to be “inlined” into the calling query will not be tracked, regardless of this setting.

`stats_temp_directory` (string)

Sets the directory to store temporary statistics data in. This can be a path relative to the data directory or an absolute path. The default is `pg_stat_tmp`. Pointing this at a RAM-based file system will decrease physical I/O requirements and can lead to improved performance. This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.9.2. Statistics Monitoring

`log_statement_stats` (boolean)

`log_parser_stats` (boolean)

`log_planner_stats` (boolean)

`log_executor_stats` (boolean)

For each query, output performance statistics of the respective module to the server log. This is a crude profiling instrument, similar to the Unix `getrusage()` operating system facility. `log_statement_stats` reports total statement statistics, while the others report per-module statistics. `log_statement_stats` cannot be enabled together with any of the per-module options. All of these options are disabled by default. Only superusers can change these settings.

19.10. Automatic Vacuuming

These settings control the behavior of the *autovacuum* feature. Refer to Section 24.1.6 for more information. Note that many of these settings can be overridden on a per-table basis; see Storage Parameters.

`autovacuum` (boolean)

Controls whether the server should run the autovacuum launcher daemon. This is on by default; however, `track_counts` must also be enabled for autovacuum to work. This parameter can only be set in the `postgresql.conf` file or on the server command line; however, autovacuuming can be disabled for individual tables by changing table storage parameters.

Note that even when this parameter is disabled, the system will launch autovacuum processes if necessary to prevent transaction ID wraparound. See Section 24.1.5 for more information.

`log_autovacuum_min_duration` (integer)

Causes each action executed by autovacuum to be logged if it ran for at least the specified amount of time. Setting this to zero logs all autovacuum actions. `-1` (the default) disables logging autovacuum actions. If this value is specified without units, it is taken as milliseconds. For example, if you set this to `250ms` then all automatic vacuums and analyzes that run 250ms or longer will be logged. In addition, when this parameter is set to any value other than `-1`, a message will be logged if an autovacuum action is skipped due to a conflicting lock or a concurrently dropped relation. Enabling this parameter can be helpful in tracking autovacuum activity. This parameter can only be set in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_max_workers` (integer)

Specifies the maximum number of autovacuum processes (other than the autovacuum launcher) that may be running at any one time. The default is three. This parameter can only be set at server start.

`autovacuum_naptime` (integer)

Specifies the minimum delay between autovacuum runs on any given database. In each round the daemon examines the database and issues `VACUUM` and `ANALYZE` commands as needed for tables in that database. If this value is specified without units, it is taken as seconds. The default

is one minute (1min). This parameter can only be set in the `postgresql.conf` file or on the server command line.

`autovacuum_vacuum_threshold` (integer)

Specifies the minimum number of updated or deleted tuples needed to trigger a `VACUUM` in any one table. The default is 50 tuples. This parameter can only be set in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_analyze_threshold` (integer)

Specifies the minimum number of inserted, updated or deleted tuples needed to trigger an `ANALYZE` in any one table. The default is 50 tuples. This parameter can only be set in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_vacuum_scale_factor` (floating point)

Specifies a fraction of the table size to add to `autovacuum_vacuum_threshold` when deciding whether to trigger a `VACUUM`. The default is 0.2 (20% of table size). This parameter can only be set in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_analyze_scale_factor` (floating point)

Specifies a fraction of the table size to add to `autovacuum_analyze_threshold` when deciding whether to trigger an `ANALYZE`. The default is 0.1 (10% of table size). This parameter can only be set in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_freeze_max_age` (integer)

Specifies the maximum age (in transactions) that a table's `pg_class.relFrozenxid` field can attain before a `VACUUM` operation is forced to prevent transaction ID wraparound within the table. Note that the system will launch `autovacuum` processes to prevent wraparound even when `autovacuum` is otherwise disabled.

Vacuum also allows removal of old files from the `pg_xact` subdirectory, which is why the default is a relatively low 200 million transactions. This parameter can only be set at server start, but the setting can be reduced for individual tables by changing table storage parameters. For more information see Section 24.1.5.

`autovacuum_multixact_freeze_max_age` (integer)

Specifies the maximum age (in multixacts) that a table's `pg_class.relminmxid` field can attain before a `VACUUM` operation is forced to prevent multixact ID wraparound within the table. Note that the system will launch `autovacuum` processes to prevent wraparound even when `autovacuum` is otherwise disabled.

Vacuuming multixacts also allows removal of old files from the `pg_multixact/members` and `pg_multixact/offsets` subdirectories, which is why the default is a relatively low 400 million multixacts. This parameter can only be set at server start, but the setting can be reduced for individual tables by changing table storage parameters. For more information see Section 24.1.5.1.

`autovacuum_vacuum_cost_delay` (floating point)

Specifies the cost delay value that will be used in automatic `VACUUM` operations. If -1 is specified, the regular `vacuum_cost_delay` value will be used. If this value is specified without units, it is taken as milliseconds. The default value is 2 milliseconds. This parameter can only be set in the

`postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

`autovacuum_vacuum_cost_limit` (integer)

Specifies the cost limit value that will be used in automatic VACUUM operations. If -1 is specified (which is the default), the regular `vacuum_cost_limit` value will be used. Note that the value is distributed proportionally among the running autovacuum workers, if there is more than one, so that the sum of the limits for each worker does not exceed the value of this variable. This parameter can only be set in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

19.11. Client Connection Defaults

19.11.1. Statement Behavior

`client_min_messages` (enum)

Controls which message levels are sent to the client. Valid values are DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, LOG, NOTICE, WARNING, and ERROR. Each level includes all the levels that follow it. The later the level, the fewer messages are sent. The default is NOTICE. Note that LOG has a different rank here than in `log_min_messages`.

INFO level messages are always sent to the client.

`search_path` (string)

This variable specifies the order in which schemas are searched when an object (table, data type, function, etc.) is referenced by a simple name with no schema specified. When there are objects of identical names in different schemas, the one found first in the search path is used. An object that is not in any of the schemas in the search path can only be referenced by specifying its containing schema with a qualified (dotted) name.

The value for `search_path` must be a comma-separated list of schema names. Any name that is not an existing schema, or is a schema for which the user does not have USAGE permission, is silently ignored.

If one of the list items is the special name `$user`, then the schema having the name returned by `CURRENT_USER` is substituted, if there is such a schema and the user has USAGE permission for it. (If not, `$user` is ignored.)

The system catalog schema, `pg_catalog`, is always searched, whether it is mentioned in the path or not. If it is mentioned in the path then it will be searched in the specified order. If `pg_catalog` is not in the path then it will be searched *before* searching any of the path items.

Likewise, the current session's temporary-table schema, `pg_temp_nnn`, is always searched if it exists. It can be explicitly listed in the path by using the alias `pg_temp`. If it is not listed in the path then it is searched first (even before `pg_catalog`). However, the temporary schema is only searched for relation (table, view, sequence, etc) and data type names. It is never searched for function or operator names.

When objects are created without specifying a particular target schema, they will be placed in the first valid schema named in `search_path`. An error is reported if the search path is empty.

The default value for this parameter is "`$user`", `public`. This setting supports shared use of a database (where no users have private schemas, and all share use of `public`), private per-user schemas, and combinations of these. Other effects can be obtained by altering the default search path setting, either globally or per-user.

For more information on schema handling, see Section 5.9. In particular, the default configuration is suitable only when the database has a single user or a few mutually-trusting users.

The current effective value of the search path can be examined via the SQL function `current_schemas` (see Section 9.25). This is not quite the same as examining the value of `search_path`, since `current_schemas` shows how the items appearing in `search_path` were resolved.

`row_security` (boolean)

This variable controls whether to raise an error in lieu of applying a row security policy. When set to `on`, policies apply normally. When set to `off`, queries fail which would otherwise apply at least one policy. The default is `on`. Change to `off` where limited row visibility could cause incorrect results; for example, `pg_dump` makes that change by default. This variable has no effect on roles which bypass every row security policy, to wit, superusers and roles with the `BYPASSRLS` attribute.

For more information on row security policies, see `CREATE POLICY`.

`default_table_access_method` (string)

This parameter specifies the default table access method to use when creating tables or materialized views if the `CREATE` command does not explicitly specify an access method, or when `SELECT . . . INTO` is used, which does not allow to specify a table access method. The default is `heap`.

`default_tablespace` (string)

This variable specifies the default tablespace in which to create objects (tables and indexes) when a `CREATE` command does not explicitly specify a tablespace. It also determines the tablespace that a partitioned relation will direct future partitions to.

The value is either the name of a tablespace, or an empty string to specify using the default tablespace of the current database. If the value does not match the name of any existing tablespace, PostgreSQL will automatically use the default tablespace of the current database. If a nondefault tablespace is specified, the user must have `CREATE` privilege for it, or creation attempts will fail.

This variable is not used for temporary tables; for them, `temp_tablespaces` is consulted instead.

This variable is also not used when creating databases. By default, a new database inherits its tablespace setting from the template database it is copied from.

For more information on tablespaces, see Section 22.6.

`temp_tablespaces` (string)

This variable specifies tablespaces in which to create temporary objects (temp tables and indexes on temp tables) when a `CREATE` command does not explicitly specify a tablespace. Temporary files for purposes such as sorting large data sets are also created in these tablespaces.

The value is a list of names of tablespaces. When there is more than one name in the list, PostgreSQL chooses a random member of the list each time a temporary object is to be created; except that within a transaction, successively created temporary objects are placed in successive tablespaces from the list. If the selected element of the list is an empty string, PostgreSQL will automatically use the default tablespace of the current database instead.

When `temp_tablespaces` is set interactively, specifying a nonexistent tablespace is an error, as is specifying a tablespace for which the user does not have `CREATE` privilege. However, when using a previously set value, nonexistent tablespaces are ignored, as are tablespaces for which the user lacks `CREATE` privilege. In particular, this rule applies when using a value set in `postgresql.conf`.

The default value is an empty string, which results in all temporary objects being created in the default tablespace of the current database.

See also `default_tablespace`.

`check_function_bodies` (boolean)

This parameter is normally on. When set to `off`, it disables validation of the function body string during `CREATE FUNCTION`. Disabling validation avoids side effects of the validation process and avoids false positives due to problems such as forward references. Set this parameter to `off` before loading functions on behalf of other users; `pg_dump` does so automatically.

`default_transaction_isolation` (enum)

Each SQL transaction has an isolation level, which can be either “read uncommitted”, “read committed”, “repeatable read”, or “serializable”. This parameter controls the default isolation level of each new transaction. The default is “read committed”.

Consult Chapter 13 and `SET TRANSACTION` for more information.

`default_transaction_read_only` (boolean)

A read-only SQL transaction cannot alter non-temporary tables. This parameter controls the default read-only status of each new transaction. The default is `off` (read/write).

Consult `SET TRANSACTION` for more information.

`default_transaction_deferrable` (boolean)

When running at the `serializable` isolation level, a deferrable read-only SQL transaction may be delayed before it is allowed to proceed. However, once it begins executing it does not incur any of the overhead required to ensure serializability; so serialization code will have no reason to force it to abort because of concurrent updates, making this option suitable for long-running read-only transactions.

This parameter controls the default deferrable status of each new transaction. It currently has no effect on read-write transactions or those operating at isolation levels lower than `serializable`. The default is `off`.

Consult `SET TRANSACTION` for more information.

`session_replication_role` (enum)

Controls firing of replication-related triggers and rules for the current session. Setting this variable requires superuser privilege and results in discarding any previously cached query plans. Possible values are `origin` (the default), `replica` and `local`.

The intended use of this setting is that logical replication systems set it to `replica` when they are applying replicated changes. The effect of that will be that triggers and rules (that have not been altered from their default configuration) will not fire on the replica. See the `ALTER TABLE` clauses `ENABLE TRIGGER` and `ENABLE RULE` for more information.

PostgreSQL treats the settings `origin` and `local` the same internally. Third-party replication systems may use these two values for their internal purposes, for example using `local` to designate a session whose changes should not be replicated.

Since foreign keys are implemented as triggers, setting this parameter to `replica` also disables all foreign key checks, which can leave data in an inconsistent state if improperly used.

`statement_timeout` (integer)

Abort any statement that takes more than the specified amount of time. If `log_min_error_statement` is set to `ERROR` or lower, the statement that timed out will also be logged. If this

value is specified without units, it is taken as milliseconds. A value of zero (the default) disables the timeout.

The timeout is measured from the time a command arrives at the server until it is completed by the server. In extended query protocol, the timeout starts running when any query-related message (Parse, Bind, Execute, Describe) arrives, and it is cancelled by completion of an Execute or Sync message.

Setting `statement_timeout` in `postgresql.conf` is not recommended because it would affect all sessions.

`lock_timeout (integer)`

Abort any statement that waits longer than the specified amount of time while attempting to acquire a lock on a table, index, row, or other database object. The time limit applies separately to each lock acquisition attempt. The limit applies both to explicit locking requests (such as `LOCK TABLE`, or `SELECT FOR UPDATE` without `NOWAIT`) and to implicitly-acquired locks. If this value is specified without units, it is taken as milliseconds. A value of zero (the default) disables the timeout.

Unlike `statement_timeout`, this timeout can only occur while waiting for locks. Note that if `statement_timeout` is nonzero, it is rather pointless to set `lock_timeout` to the same or larger value, since the statement timeout would always trigger first. If `log_min_error_statement` is set to `ERROR` or lower, the statement that timed out will be logged.

Setting `lock_timeout` in `postgresql.conf` is not recommended because it would affect all sessions.

`idle_in_transaction_session_timeout (integer)`

Terminate any session with an open transaction that has been idle for longer than the specified amount of time. This allows any locks held by that session to be released and the connection slot to be reused; it also allows tuples visible only to this transaction to be vacuumed. See Section 24.1 for more details about this.

If this value is specified without units, it is taken as milliseconds. A value of zero (the default) disables the timeout.

`vacuum_freeze_table_age (integer)`

`VACUUM` performs an aggressive scan if the table's `pg_class.relfrozenxid` field has reached the age specified by this setting. An aggressive scan differs from a regular `VACUUM` in that it visits every page that might contain unfrozen XIDs or MXIDs, not just those that might contain dead tuples. The default is 150 million transactions. Although users can set this value anywhere from zero to two billions, `VACUUM` will silently limit the effective value to 95% of `autovacuum_freeze_max_age`, so that a periodical manual `VACUUM` has a chance to run before an anti-wraparound autovacuum is launched for the table. For more information see Section 24.1.5.

`vacuum_freeze_min_age (integer)`

Specifies the cutoff age (in transactions) that `VACUUM` should use to decide whether to freeze row versions while scanning a table. The default is 50 million transactions. Although users can set this value anywhere from zero to one billion, `VACUUM` will silently limit the effective value to half the value of `autovacuum_freeze_max_age`, so that there is not an unreasonably short time between forced autovacua. For more information see Section 24.1.5.

`vacuum_multixact_freeze_table_age (integer)`

`VACUUM` performs an aggressive scan if the table's `pg_class.relminmxid` field has reached the age specified by this setting. An aggressive scan differs from a regular `VACUUM` in that it visits

every page that might contain unfrozen XIDs or MXIDs, not just those that might contain dead tuples. The default is 150 million multixacts. Although users can set this value anywhere from zero to two billions, `VACUUM` will silently limit the effective value to 95% of `autovacuum_multixact_freeze_max_age`, so that a periodical manual `VACUUM` has a chance to run before an anti-wraparound is launched for the table. For more information see Section 24.1.5.1.

`vacuum_multixact_freeze_min_age` (integer)

Specifies the cutoff age (in multixacts) that `VACUUM` should use to decide whether to replace multixact IDs with a newer transaction ID or multixact ID while scanning a table. The default is 5 million multixacts. Although users can set this value anywhere from zero to one billion, `VACUUM` will silently limit the effective value to half the value of `autovacuum_multixact_freeze_max_age`, so that there is not an unreasonably short time between forced autovacuaums. For more information see Section 24.1.5.1.

`vacuum_cleanup_index_scale_factor` (floating point)

Specifies the fraction of the total number of heap tuples counted in the previous statistics collection that can be inserted without incurring an index scan at the `VACUUM` cleanup stage. This setting currently applies to B-tree indexes only.

If no tuples were deleted from the heap, B-tree indexes are still scanned at the `VACUUM` cleanup stage when at least one of the following conditions is met: the index statistics are stale, or the index contains deleted pages that can be recycled during cleanup. Index statistics are considered to be stale if the number of newly inserted tuples exceeds the `vacuum_cleanup_index_scale_factor` fraction of the total number of heap tuples detected by the previous statistics collection. The total number of heap tuples is stored in the index meta-page. Note that the meta-page does not include this data until `VACUUM` finds no dead tuples, so B-tree index scan at the cleanup stage can only be skipped if the second and subsequent `VACUUM` cycles detect no dead tuples.

The value can range from 0 to 10000000000. When `vacuum_cleanup_index_scale_factor` is set to 0, index scans are never skipped during `VACUUM` cleanup. The default value is 0.1.

`bytea_output` (enum)

Sets the output format for values of type `bytea`. Valid values are `hex` (the default) and `escape` (the traditional PostgreSQL format). See Section 8.4 for more information. The `bytea` type always accepts both formats on input, regardless of this setting.

`xmlbinary` (enum)

Sets how binary values are to be encoded in XML. This applies for example when `bytea` values are converted to XML by the functions `xmlelement` or `xmlforest`. Possible values are `base64` and `hex`, which are both defined in the XML Schema standard. The default is `base64`. For further information about XML-related functions, see Section 9.14.

The actual choice here is mostly a matter of taste, constrained only by possible restrictions in client applications. Both methods support all possible values, although the hex encoding will be somewhat larger than the base64 encoding.

`xmloption` (enum)

Sets whether `DOCUMENT` or `CONTENT` is implicit when converting between XML and character string values. See Section 8.13 for a description of this. Valid values are `DOCUMENT` and `CONTENT`. The default is `CONTENT`.

According to the SQL standard, the command to set this option is

```
SET XML OPTION { DOCUMENT | CONTENT };
```

This syntax is also available in PostgreSQL.

`gin_pending_list_limit` (integer)

Sets the maximum size of a GIN index's pending list, which is used when `fastupdate` is enabled. If the list grows larger than this maximum size, it is cleaned up by moving the entries in it to the index's main GIN data structure in bulk. If this value is specified without units, it is taken as kilobytes. The default is four megabytes (4MB). This setting can be overridden for individual GIN indexes by changing index storage parameters. See Section 66.4.1 and Section 66.5 for more information.

19.11.2. Locale and Formatting

`DateStyle` (string)

Sets the display format for date and time values, as well as the rules for interpreting ambiguous date input values. For historical reasons, this variable contains two independent components: the output format specification (`ISO`, `Postgres`, `SQL`, or `German`) and the input/output specification for year/month/day ordering (`DMY`, `MDY`, or `YMD`). These can be set separately or together. The keywords `Euro` and `European` are synonyms for `DMY`; the keywords `US`, `NonEuro`, and `NonEuropean` are synonyms for `MDY`. See Section 8.5 for more information. The built-in default is `ISO, MDY`, but `initdb` will initialize the configuration file with a setting that corresponds to the behavior of the chosen `lc_time` locale.

`IntervalStyle` (enum)

Sets the display format for interval values. The value `sql_standard` will produce output matching SQL standard interval literals. The value `postgres` (which is the default) will produce output matching PostgreSQL releases prior to 8.4 when the `DateStyle` parameter was set to `ISO`. The value `postgres_verbose` will produce output matching PostgreSQL releases prior to 8.4 when the `DateStyle` parameter was set to non-ISO output. The value `iso_8601` will produce output matching the time interval “format with designators” defined in section 4.4.3.2 of ISO 8601.

The `IntervalStyle` parameter also affects the interpretation of ambiguous interval input. See Section 8.5.4 for more information.

`TimeZone` (string)

Sets the time zone for displaying and interpreting time stamps. The built-in default is `GMT`, but that is typically overridden in `postgresql.conf`; `initdb` will install a setting there corresponding to its system environment. See Section 8.5.3 for more information.

`timezone_abbreviations` (string)

Sets the collection of time zone abbreviations that will be accepted by the server for datetime input. The default is `'Default'`, which is a collection that works in most of the world; there are also `'Australia'` and `'India'`, and other collections can be defined for a particular installation. See Section B.4 for more information.

`extra_float_digits` (integer)

This parameter adjusts the number of digits used for textual output of floating-point values, including `float4`, `float8`, and geometric data types.

If the value is 1 (the default) or above, float values are output in shortest-precise format; see Section 8.1.3. The actual number of digits generated depends only on the value being output, not on the value of this parameter. At most 17 digits are required for `float8` values, and 9 for

`float4` values. This format is both fast and precise, preserving the original binary float value exactly when correctly read. For historical compatibility, values up to 3 are permitted.

If the value is zero or negative, then the output is rounded to a given decimal precision. The precision used is the standard number of digits for the type (`FLT_DIG` or `DBL_DIG` as appropriate) reduced according to the value of this parameter. (For example, specifying `-1` will cause `float4` values to be output rounded to 5 significant digits, and `float8` values rounded to 14 digits.) This format is slower and does not preserve all the bits of the binary float value, but may be more human-readable.

Note

The meaning of this parameter, and its default value, changed in PostgreSQL 12; see Section 8.1.3 for further discussion.

`client_encoding (string)`

Sets the client-side encoding (character set). The default is to use the database encoding. The character sets supported by the PostgreSQL server are described in Section 23.3.1.

`lc_messages (string)`

Sets the language in which messages are displayed. Acceptable values are system-dependent; see Section 23.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

On some systems, this locale category does not exist. Setting this variable will still work, but there will be no effect. Also, there is a chance that no translated messages for the desired language exist. In that case you will continue to see the English messages.

Only superusers can change this setting, because it affects the messages sent to the server log as well as to the client, and an improper value might obscure the readability of the server logs.

`lc_monetary (string)`

Sets the locale to use for formatting monetary amounts, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 23.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`lc_numeric (string)`

Sets the locale to use for formatting numbers, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 23.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`lc_time (string)`

Sets the locale to use for formatting dates and times, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 23.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`default_text_search_config (string)`

Selects the text search configuration that is used by those variants of the text search functions that do not have an explicit argument specifying the configuration. See Chapter 12 for further

information. The built-in default is `pg_catalog.simple`, but `initdb` will initialize the configuration file with a setting that corresponds to the chosen `lc_ctype` locale, if a configuration matching that locale can be identified.

19.11.3. Shared Library Preloading

Several settings are available for preloading shared libraries into the server, in order to load additional functionality or achieve performance benefits. For example, a setting of `'$libdir/mylib'` would cause `mylib.so` (or on some platforms, `mylib.sl`) to be preloaded from the installation's standard library directory. The differences between the settings are when they take effect and what privileges are required to change them.

PostgreSQL procedural language libraries can be preloaded in this way, typically by using the syntax `'$libdir/plXXX'` where `XXX` is `pgsql`, `perl`, `tcl`, or `python`.

Only shared libraries specifically intended to be used with PostgreSQL can be loaded this way. Every PostgreSQL-supported library has a “magic block” that is checked to guarantee compatibility. For this reason, non-PostgreSQL libraries cannot be loaded in this way. You might be able to use operating-system facilities such as `LD_PRELOAD` for that.

In general, refer to the documentation of a specific module for the recommended way to load that module.

`local_preload_libraries` (string)

This variable specifies one or more shared libraries that are to be preloaded at connection start. It contains a comma-separated list of library names, where each name is interpreted as for the `LOAD` command. Whitespace between entries is ignored; surround a library name with double quotes if you need to include whitespace or commas in the name. The parameter value only takes effect at the start of the connection. Subsequent changes have no effect. If a specified library is not found, the connection attempt will fail.

This option can be set by any user. Because of that, the libraries that can be loaded are restricted to those appearing in the `plugins` subdirectory of the installation's standard library directory. (It is the database administrator's responsibility to ensure that only “safe” libraries are installed there.) Entries in `local_preload_libraries` can specify this directory explicitly, for example `$libdir/plugins/mylib`, or just specify the library name — `mylib` would have the same effect as `$libdir/plugins/mylib`.

The intent of this feature is to allow unprivileged users to load debugging or performance-measurement libraries into specific sessions without requiring an explicit `LOAD` command. To that end, it would be typical to set this parameter using the `PGOPTIONS` environment variable on the client or by using `ALTER ROLE SET`.

However, unless a module is specifically designed to be used in this way by non-superusers, this is usually not the right setting to use. Look at `session_preload_libraries` instead.

`session_preload_libraries` (string)

This variable specifies one or more shared libraries that are to be preloaded at connection start. It contains a comma-separated list of library names, where each name is interpreted as for the `LOAD` command. Whitespace between entries is ignored; surround a library name with double quotes if you need to include whitespace or commas in the name. The parameter value only takes effect at the start of the connection. Subsequent changes have no effect. If a specified library is not found, the connection attempt will fail. Only superusers can change this setting.

The intent of this feature is to allow debugging or performance-measurement libraries to be loaded into specific sessions without an explicit `LOAD` command being given. For example, `auto_explain` could be enabled for all sessions under a given user name by setting this parameter with `ALTER ROLE SET`. Also, this parameter can be changed without restarting the server (but changes only

take effect when a new session is started), so it is easier to add new modules this way, even if they should apply to all sessions.

Unlike `shared_preload_libraries`, there is no large performance advantage to loading a library at session start rather than when it is first used. There is some advantage, however, when connection pooling is used.

`shared_preload_libraries` (string)

This variable specifies one or more shared libraries to be preloaded at server start. It contains a comma-separated list of library names, where each name is interpreted as for the `LOAD` command. Whitespace between entries is ignored; surround a library name with double quotes if you need to include whitespace or commas in the name. This parameter can only be set at server start. If a specified library is not found, the server will fail to start.

Some libraries need to perform certain operations that can only take place at postmaster start, such as allocating shared memory, reserving light-weight locks, or starting background workers. Those libraries must be loaded at server start through this parameter. See the documentation of each library for details.

Other libraries can also be preloaded. By preloading a shared library, the library startup time is avoided when the library is first used. However, the time to start each new server process might increase slightly, even if that process never uses the library. So this parameter is recommended only for libraries that will be used in most sessions. Also, changing this parameter requires a server restart, so this is not the right setting to use for short-term debugging tasks, say. Use `session_preload_libraries` for that instead.

Note

On Windows hosts, preloading a library at server start will not reduce the time required to start each new server process; each server process will re-load all preload libraries. However, `shared_preload_libraries` is still useful on Windows hosts for libraries that need to perform operations at postmaster start time.

`jit_provider` (string)

This variable is the name of the JIT provider library to be used (see Section 31.4.2). The default is `llvmjit`. This parameter can only be set at server start.

If set to a non-existent library, JIT will not be available, but no error will be raised. This allows JIT support to be installed separately from the main PostgreSQL package.

19.11.4. Other Defaults

`dynamic_library_path` (string)

If a dynamically loadable module needs to be opened and the file name specified in the `CREATE FUNCTION` or `LOAD` command does not have a directory component (i.e., the name does not contain a slash), the system will search this path for the required file.

The value for `dynamic_library_path` must be a list of absolute directory paths separated by colons (or semi-colons on Windows). If a list element starts with the special string `$libdir`, the compiled-in PostgreSQL package library directory is substituted for `$libdir`; this is where the modules provided by the standard PostgreSQL distribution are installed. (Use `pg_config --pkglibdir` to find out the name of this directory.) For example:

```
dynamic_library_path = '/usr/local/lib/postgresql:/home/  
my_project/lib:$libdir'
```

or, in a Windows environment:

```
dynamic_library_path = 'C:\tools\postgresql;H:\my_project\lib;  
$libdir'
```

The default value for this parameter is '\$libdir'. If the value is set to an empty string, the automatic path search is turned off.

This parameter can be changed at run time by superusers, but a setting done that way will only persist until the end of the client connection, so this method should be reserved for development purposes. The recommended way to set this parameter is in the `postgresql.conf` configuration file.

`gin_fuzzy_search_limit` (integer)

Soft upper limit of the size of the set returned by GIN index scans. For more information see Section 66.5.

19.12. Lock Management

`deadlock_timeout` (integer)

This is the amount of time to wait on a lock before checking to see if there is a deadlock condition. The check for deadlock is relatively expensive, so the server doesn't run it every time it waits for a lock. We optimistically assume that deadlocks are not common in production applications and just wait on the lock for a while before checking for a deadlock. Increasing this value reduces the amount of time wasted in needless deadlock checks, but slows down reporting of real deadlock errors. If this value is specified without units, it is taken as milliseconds. The default is one second (1s), which is probably about the smallest value you would want in practice. On a heavily loaded server you might want to raise it. Ideally the setting should exceed your typical transaction time, so as to improve the odds that a lock will be released before the waiter decides to check for deadlock. Only superusers can change this setting.

When `log_lock_waits` is set, this parameter also determines the amount of time to wait before a log message is issued about the lock wait. If you are trying to investigate locking delays you might want to set a shorter than normal `deadlock_timeout`.

`max_locks_per_transaction` (integer)

The shared lock table tracks locks on `max_locks_per_transaction * (max_connections + max_prepared_transactions)` objects (e.g., tables); hence, no more than this many distinct objects can be locked at any one time. This parameter controls the average number of object locks allocated for each transaction; individual transactions can lock more objects as long as the locks of all transactions fit in the lock table. This is *not* the number of rows that can be locked; that value is unlimited. The default, 64, has historically proven sufficient, but you might need to raise this value if you have queries that touch many different tables in a single transaction, e.g. query of a parent table with many children. This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`max_pred_locks_per_transaction` (integer)

The shared predicate lock table tracks locks on `max_pred_locks_per_transaction * (max_connections + max_prepared_transactions)` objects (e.g., tables); hence, no more than this

many distinct objects can be locked at any one time. This parameter controls the average number of object locks allocated for each transaction; individual transactions can lock more objects as long as the locks of all transactions fit in the lock table. This is *not* the number of rows that can be locked; that value is unlimited. The default, 64, has generally been sufficient in testing, but you might need to raise this value if you have clients that touch many different tables in a single serializable transaction. This parameter can only be set at server start.

`max_pred_locks_per_relation` (integer)

This controls how many pages or tuples of a single relation can be predicate-locked before the lock is promoted to covering the whole relation. Values greater than or equal to zero mean an absolute limit, while negative values mean `max_pred_locks_per_transaction` divided by the absolute value of this setting. The default is -2, which keeps the behavior from previous versions of PostgreSQL. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`max_pred_locks_per_page` (integer)

This controls how many rows on a single page can be predicate-locked before the lock is promoted to covering the whole page. The default is 2. This parameter can only be set in the `postgresql.conf` file or on the server command line.

19.13. Version and Platform Compatibility

19.13.1. Previous PostgreSQL Versions

`array_nulls` (boolean)

This controls whether the array input parser recognizes unquoted NULL as specifying a null array element. By default, this is on, allowing array values containing null values to be entered. However, PostgreSQL versions before 8.2 did not support null values in arrays, and therefore would treat NULL as specifying a normal array element with the string value “NULL”. For backward compatibility with applications that require the old behavior, this variable can be turned `off`.

Note that it is possible to create array values containing null values even when this variable is `off`.

`backslash_quote` (enum)

This controls whether a quote mark can be represented by `\'` in a string literal. The preferred, SQL-standard way to represent a quote mark is by doubling it (`'`) but PostgreSQL has historically also accepted `\'`. However, use of `\'` creates security risks because in some client character set encodings, there are multibyte characters in which the last byte is numerically equivalent to ASCII `\`. If client-side code does escaping incorrectly then a SQL-injection attack is possible. This risk can be prevented by making the server reject queries in which a quote mark appears to be escaped by a backslash. The allowed values of `backslash_quote` are `on` (allow `\'` always), `off` (reject always), and `safe_encoding` (allow only if client encoding does not allow ASCII `\` within a multibyte character). `safe_encoding` is the default setting.

Note that in a standard-conforming string literal, `\` just means `\` anyway. This parameter only affects the handling of non-standard-conforming literals, including escape string syntax (`E' . . . '`).

`escape_string_warning` (boolean)

When on, a warning is issued if a backslash (`\`) appears in an ordinary string literal (`' . . . '` syntax) and `standard_conforming_strings` is off. The default is on.

Applications that wish to use backslash as escape should be modified to use escape string syntax (`E' . . . '`), because the default behavior of ordinary strings is now to treat backslash as an ordinary character, per SQL standard. This variable can be enabled to help locate code that needs to be changed.

`lo_compat_privileges` (boolean)

In PostgreSQL releases prior to 9.0, large objects did not have access privileges and were, therefore, always readable and writable by all users. Setting this variable to `on` disables the new privilege checks, for compatibility with prior releases. The default is `off`. Only superusers can change this setting.

Setting this variable does not disable all security checks related to large objects — only those for which the default behavior has changed in PostgreSQL 9.0.

`operator_precedence_warning` (boolean)

When `on`, the parser will emit a warning for any construct that might have changed meanings since PostgreSQL 9.4 as a result of changes in operator precedence. This is useful for auditing applications to see if precedence changes have broken anything; but it is not meant to be kept turned on in production, since it will warn about some perfectly valid, standard-compliant SQL code. The default is `off`.

See Section 4.1.6 for more information.

`quote_all_identifiers` (boolean)

When the database generates SQL, force all identifiers to be quoted, even if they are not (currently) keywords. This will affect the output of `EXPLAIN` as well as the results of functions like `pg_get_viewdef`. See also the `--quote-all-identifiers` option of `pg_dump` and `pg_dumpall`.

`standard_conforming_strings` (boolean)

This controls whether ordinary string literals (`' . . . '`) treat backslashes literally, as specified in the SQL standard. Beginning in PostgreSQL 9.1, the default is `on` (prior releases defaulted to `off`). Applications can check this parameter to determine how string literals will be processed. The presence of this parameter can also be taken as an indication that the escape string syntax (`E' . . . '`) is supported. Escape string syntax (Section 4.1.2.2) should be used if an application desires backslashes to be treated as escape characters.

`synchronize_seqscans` (boolean)

This allows sequential scans of large tables to synchronize with each other, so that concurrent scans read the same block at about the same time and hence share the I/O workload. When this is enabled, a scan might start in the middle of the table and then “wrap around” the end to cover all rows, so as to synchronize with the activity of scans already in progress. This can result in unpredictable changes in the row ordering returned by queries that have no `ORDER BY` clause. Setting this parameter to `off` ensures the pre-8.3 behavior in which a sequential scan always starts from the beginning of the table. The default is `on`.

19.13.2. Platform and Client Compatibility

`transform_null_equals` (boolean)

When `on`, expressions of the form `expr = NULL` (or `NULL = expr`) are treated as `expr IS NULL`, that is, they return true if `expr` evaluates to the null value, and false otherwise. The correct SQL-spec-compliant behavior of `expr = NULL` is to always return null (unknown). Therefore this parameter defaults to `off`.

However, filtered forms in Microsoft Access generate queries that appear to use `expr = NULL` to test for null values, so if you use that interface to access the database you might want to turn this option on. Since expressions of the form `expr = NULL` always return the null value (using the SQL standard interpretation), they are not very useful and do not appear often in normal

applications so this option does little harm in practice. But new users are frequently confused about the semantics of expressions involving null values, so this option is off by default.

Note that this option only affects the exact form `= NULL`, not other comparison operators or other expressions that are computationally equivalent to some expression involving the equals operator (such as `IN`). Thus, this option is not a general fix for bad programming.

Refer to Section 9.2 for related information.

19.14. Error Handling

`exit_on_error` (boolean)

If on, any error will terminate the current session. By default, this is set to off, so that only FATAL errors will terminate the session.

`restart_after_crash` (boolean)

When set to on, which is the default, PostgreSQL will automatically reinitialize after a backend crash. Leaving this value set to on is normally the best way to maximize the availability of the database. However, in some circumstances, such as when PostgreSQL is being invoked by clusterware, it may be useful to disable the restart so that the clusterware can gain control and take any actions it deems appropriate.

`data_sync_retry` (boolean)

When set to off, which is the default, PostgreSQL will raise a PANIC-level error on failure to flush modified data files to the file system. This causes the database server to crash. This parameter can only be set at server start.

On some operating systems, the status of data in the kernel's page cache is unknown after a write-back failure. In some cases it might have been entirely forgotten, making it unsafe to retry; the second attempt may be reported as successful, when in fact the data has been lost. In these circumstances, the only way to avoid data loss is to recover from the WAL after any failure is reported, preferably after investigating the root cause of the failure and replacing any faulty hardware.

If set to on, PostgreSQL will instead report an error but continue to run so that the data flushing operation can be retried in a later checkpoint. Only set it to on after investigating the operating system's treatment of buffered data in case of write-back failure.

19.15. Preset Options

The following “parameters” are read-only, and are determined when PostgreSQL is compiled or when it is installed. As such, they have been excluded from the sample `postgresql.conf` file. These options report various aspects of PostgreSQL behavior that might be of interest to certain applications, particularly administrative front-ends.

`block_size` (integer)

Reports the size of a disk block. It is determined by the value of `BLCKSZ` when building the server. The default value is 8192 bytes. The meaning of some configuration variables (such as `shared_buffers`) is influenced by `block_size`. See Section 19.4 for information.

`data_checksums` (boolean)

Reports whether data checksums are enabled for this cluster. See data checksums for more information.

`data_directory_mode` (integer)

On Unix systems this parameter reports the permissions of the data directory defined by (`data_directory`) at startup. (On Microsoft Windows this parameter will always display 0700). See group access for more information.

`debug_assertions` (boolean)

Reports whether PostgreSQL has been built with assertions enabled. That is the case if the macro `USE_ASSERT_CHECKING` is defined when PostgreSQL is built (accomplished e.g. by the `configure` option `--enable-cassert`). By default PostgreSQL is built without assertions.

`integer_datetimes` (boolean)

Reports whether PostgreSQL was built with support for 64-bit-integer dates and times. As of PostgreSQL 10, this is always on.

`lc_collate` (string)

Reports the locale in which sorting of textual data is done. See Section 23.1 for more information. This value is determined when a database is created.

`lc_ctype` (string)

Reports the locale that determines character classifications. See Section 23.1 for more information. This value is determined when a database is created. Ordinarily this will be the same as `lc_collate`, but for special applications it might be set differently.

`max_function_args` (integer)

Reports the maximum number of function arguments. It is determined by the value of `FUNC_MAX_ARGS` when building the server. The default value is 100 arguments.

`max_identifier_length` (integer)

Reports the maximum identifier length. It is determined as one less than the value of `NAMEDATALEN` when building the server. The default value of `NAMEDATALEN` is 64; therefore the default `max_identifier_length` is 63 bytes, which can be less than 63 characters when using multibyte encodings.

`max_index_keys` (integer)

Reports the maximum number of index keys. It is determined by the value of `INDEX_MAX_KEYS` when building the server. The default value is 32 keys.

`segment_size` (integer)

Reports the number of blocks (pages) that can be stored within a file segment. It is determined by the value of `RELSEG_SIZE` when building the server. The maximum size of a segment file in bytes is equal to `segment_size` multiplied by `block_size`; by default this is 1GB.

`server_encoding` (string)

Reports the database encoding (character set). It is determined when the database is created. Ordinarily, clients need only be concerned with the value of `client_encoding`.

`server_version` (string)

Reports the version number of the server. It is determined by the value of `PG_VERSION` when building the server.

`server_version_num` (integer)

Reports the version number of the server as an integer. It is determined by the value of `PG_VERSION_NUM` when building the server.

`ssl_library` (string)

Reports the name of the SSL library that this PostgreSQL server was built with (even if SSL is not currently configured or in use on this instance), for example `OpenSSL`, or an empty string if none.

`wal_block_size` (integer)

Reports the size of a WAL disk block. It is determined by the value of `XLOG_BLCKSZ` when building the server. The default value is 8192 bytes.

`wal_segment_size` (integer)

Reports the size of write ahead log segments. The default value is 16MB. See Section 29.4 for more information.

19.16. Customized Options

This feature was designed to allow parameters not normally known to PostgreSQL to be added by add-on modules (such as procedural languages). This allows extension modules to be configured in the standard ways.

Custom options have two-part names: an extension name, then a dot, then the parameter name proper, much like qualified names in SQL. An example is `plpgsql.variable_conflict`.

Because custom options may need to be set in processes that have not loaded the relevant extension module, PostgreSQL will accept a setting for any two-part parameter name. Such variables are treated as placeholders and have no function until the module that defines them is loaded. When an extension module is loaded, it will add its variable definitions, convert any placeholder values according to those definitions, and issue warnings for any unrecognized placeholders that begin with its extension name.

19.17. Developer Options

The following parameters are intended for work on the PostgreSQL source code, and in some cases to assist with recovery of severely damaged databases. There should be no reason to use them on a production database. As such, they have been excluded from the sample `postgresql.conf` file. Note that many of these parameters require special source compilation flags to work at all.

`allow_system_table_mods` (boolean)

Allows modification of the structure of system tables. This is used by `initdb`. This parameter can only be set at server start.

`ignore_system_indexes` (boolean)

Ignore system indexes when reading system tables (but still update the indexes when modifying the tables). This is useful when recovering from damaged system indexes. This parameter cannot be changed after session start.

`post_auth_delay` (integer)

The amount of time to delay when a new server process is started, after it conducts the authentication procedure. This is intended to give developers an opportunity to attach to the server process with a debugger. If this value is specified without units, it is taken as seconds. A value of zero (the default) disables the delay. This parameter cannot be changed after session start.

`pre_auth_delay` (integer)

The amount of time to delay just after a new server process is forked, before it conducts the authentication procedure. This is intended to give developers an opportunity to attach to the server process with a debugger to trace down misbehavior in authentication. If this value is specified without units, it is taken as seconds. A value of zero (the default) disables the delay. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`trace_notify` (boolean)

Generates a great amount of debugging output for the `LISTEN` and `NOTIFY` commands. `client_min_messages` or `log_min_messages` must be `DEBUG1` or lower to send this output to the client or server logs, respectively.

`trace_recovery_messages` (enum)

Enables logging of recovery-related debugging output that otherwise would not be logged. This parameter allows the user to override the normal setting of `log_min_messages`, but only for specific messages. This is intended for use in debugging Hot Standby. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, and `LOG`. The default, `LOG`, does not affect logging decisions at all. The other values cause recovery-related debug messages of that priority or higher to be logged as though they had `LOG` priority; for common settings of `log_min_messages` this results in unconditionally sending them to the server log. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`trace_sort` (boolean)

If on, emit information about resource usage during sort operations. This parameter is only available if the `TRACE_SORT` macro was defined when PostgreSQL was compiled. (However, `TRACE_SORT` is currently defined by default.)

`trace_locks` (boolean)

If on, emit information about lock usage. Information dumped includes the type of lock operation, the type of lock and the unique identifier of the object being locked or unlocked. Also included are bit masks for the lock types already granted on this object as well as for the lock types awaited on this object. For each lock type a count of the number of granted locks and waiting locks is also dumped as well as the totals. An example of the log file output is shown here:

```
LOG:  LockAcquire: new: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0)=0 grant(0,0,0,0,0,0)=0
      wait(0) type(AccessShareLock)
LOG:  GrantLock: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(2) req(1,0,0,0,0,0)=1 grant(1,0,0,0,0,0)=1
      wait(0) type(AccessShareLock)
LOG:  UnGrantLock: updated: lock(0xb7acd844)
      id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0)=0 grant(0,0,0,0,0,0)=0
      wait(0) type(AccessShareLock)
LOG:  CleanUpLock: deleting: lock(0xb7acd844)
      id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0)=0 grant(0,0,0,0,0,0)=0
      wait(0) type(INVALID)
```

Details of the structure being dumped may be found in `src/include/storage/lock.h`.

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`trace_lwlocks` (boolean)

If on, emit information about lightweight lock usage. Lightweight locks are intended primarily to provide mutual exclusion of access to shared-memory data structures.

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`trace_userlocks` (boolean)

If on, emit information about user lock usage. Output is the same as for `trace_locks`, only for advisory locks.

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`trace_lock_oidmin` (integer)

If set, do not trace locks for tables below this OID. (use to avoid output on system tables)

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`trace_lock_table` (integer)

Unconditionally trace locks on this table (OID).

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`debug_deadlocks` (boolean)

If set, dumps information about all current locks when a deadlock timeout occurs.

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`log_btree_build_stats` (boolean)

If set, logs system resource usage statistics (memory and CPU) on various B-tree operations.

This parameter is only available if the `BTREE_BUILD_STATS` macro was defined when PostgreSQL was compiled.

`wal_consistency_checking` (string)

This parameter is intended to be used to check for bugs in the WAL redo routines. When enabled, full-page images of any buffers modified in conjunction with the WAL record are added to the record. If the record is subsequently replayed, the system will first apply each record and then test whether the buffers modified by the record match the stored images. In certain cases (such as hint bits), minor variations are acceptable, and will be ignored. Any unexpected differences will result in a fatal error, terminating recovery.

The default value of this setting is the empty string, which disables the feature. It can be set to `all` to check all records, or to a comma-separated list of resource managers to check only records originating from those resource managers. Currently, the supported resource managers are `heap`, `heap2`, `btree`, `hash`, `gin`, `gist`, `sequence`, `spgist`, `brin`, and `generic`. Only superusers can change this setting.

`wal_debug` (boolean)

If on, emit WAL-related debugging output. This parameter is only available if the `WAL_DEBUG` macro was defined when PostgreSQL was compiled.

`ignore_checksum_failure` (boolean)

Only has effect if data checksums are enabled.

Detection of a checksum failure during a read normally causes PostgreSQL to report an error, aborting the current transaction. Setting `ignore_checksum_failure` to `on` causes the system to ignore the failure (but still report a warning), and continue processing. This behavior may *cause crashes, propagate or hide corruption, or other serious problems*. However, it may allow you to get past the error and retrieve undamaged tuples that might still be present in the table if the block header is still sane. If the header is corrupt an error will be reported even if this option is enabled. The default setting is `off`, and it can only be changed by a superuser.

`zero_damaged_pages` (boolean)

Detection of a damaged page header normally causes PostgreSQL to report an error, aborting the current transaction. Setting `zero_damaged_pages` to `on` causes the system to instead report a warning, zero out the damaged page in memory, and continue processing. This behavior *will destroy data*, namely all the rows on the damaged page. However, it does allow you to get past the error and retrieve rows from any undamaged pages that might be present in the table. It is useful for recovering data if corruption has occurred due to a hardware or software error. You should generally not set this on until you have given up hope of recovering data from the damaged pages of a table. Zeroed-out pages are not forced to disk so it is recommended to recreate the table or the index before turning this parameter off again. The default setting is `off`, and it can only be changed by a superuser.

`jit_debugging_support` (boolean)

If LLVM has the required functionality, register generated functions with GDB. This makes debugging easier. The default setting is `off`. This parameter can only be set at server start.

`jit_dump_bitcode` (boolean)

Writes the generated LLVM IR out to the file system, inside `data_directory`. This is only useful for working on the internals of the JIT implementation. The default setting is `off`. This parameter can only be changed by a superuser.

`jit_expressions` (boolean)

Determines whether expressions are JIT compiled, when JIT compilation is activated (see Section 31.2). The default is `on`.

`jit_profiling_support` (boolean)

If LLVM has the required functionality, emit the data needed to allow `perf` to profile functions generated by JIT. This writes out files to `$HOME/.debug/jit/`; the user is responsible for performing cleanup when desired. The default setting is `off`. This parameter can only be set at server start.

`jit_tuple_deforming` (boolean)

Determines whether tuple deforming is JIT compiled, when JIT compilation is activated (see Section 31.2). The default is `on`.

19.18. Short Options

For convenience there are also single letter command-line option switches available for some parameters. They are described in Table 19.2. Some of these options exist for historical reasons, and their presence as a single-letter option does not necessarily indicate an endorsement to use the option heavily.

Table 19.2. Short Option Key

Short Option	Equivalent
-B x	shared_buffers = x
-d x	log_min_messages = DEBUGx
-e	datestyle = euro
-fb, -fh, -fi, -fm, -fn, -fo, -fs, -ft	enable_bitmapscan = off, enable_hashjoin = off, enable_indexscan = off, enable_mergejoin = off, enable_nestloop = off, enable_indexonlyscan = off, enable_seqscan = off, enable_tidscan = off
-F	fsync = off
-h x	listen_addresses = x
-i	listen_addresses = '*'
-k x	unix_socket_directories = x
-l	ssl = on
-N x	max_connections = x
-O	allow_system_table_mods = on
-p x	port = x
-P	ignore_system_indexes = on
-s	log_statement_stats = on
-S x	work_mem = x
-tpa, -tpl, -te	log_parser_stats = on, log_planner_stats = on, log_executor_stats = on
-W x	post_auth_delay = x

Chapter 20. Client Authentication

When a client application connects to the database server, it specifies which PostgreSQL database user name it wants to connect as, much the same way one logs into a Unix computer as a particular user. Within the SQL environment the active database user name determines access privileges to database objects — see Chapter 21 for more information. Therefore, it is essential to restrict which database users can connect.

Note

As explained in Chapter 21, PostgreSQL actually does privilege management in terms of “roles”. In this chapter, we consistently use *database user* to mean “role with the LOGIN privilege”.

Authentication is the process by which the database server establishes the identity of the client, and by extension determines whether the client application (or the user who runs the client application) is permitted to connect with the database user name that was requested.

PostgreSQL offers a number of different client authentication methods. The method used to authenticate a particular client connection can be selected on the basis of (client) host address, database, and user.

PostgreSQL database user names are logically separate from user names of the operating system in which the server runs. If all the users of a particular server also have accounts on the server's machine, it makes sense to assign database user names that match their operating system user names. However, a server that accepts remote connections might have many database users who have no local operating system account, and in such cases there need be no connection between database user names and OS user names.

20.1. The `pg_hba.conf` File

Client authentication is controlled by a configuration file, which traditionally is named `pg_hba.conf` and is stored in the database cluster's data directory. (HBA stands for host-based authentication.) A default `pg_hba.conf` file is installed when the data directory is initialized by `initdb`. It is possible to place the authentication configuration file elsewhere, however; see the `hba_file` configuration parameter.

The general format of the `pg_hba.conf` file is a set of records, one per line. Blank lines are ignored, as is any text after the `#` comment character. Records cannot be continued across lines. A record is made up of a number of fields which are separated by spaces and/or tabs. Fields can contain white space if the field value is double-quoted. Quoting one of the keywords in a database, user, or address field (e.g., `all` or `replication`) makes the word lose its special meaning, and just match a database, user, or host with that name.

Each record specifies a connection type, a client IP address range (if relevant for the connection type), a database name, a user name, and the authentication method to be used for connections matching these parameters. The first record with a matching connection type, client address, requested database, and user name is used to perform authentication. There is no “fall-through” or “backup”: if one record is chosen and the authentication fails, subsequent records are not considered. If no record matches, access is denied.

A record can have one of the seven formats

```
local      database user auth-method [auth-options]
```

```

host      database user address auth-method [auth-options]
hostssl   database user address auth-method [auth-options]
hostnssl  database user address auth-method [auth-options]
host      database user IP-address IP-mask auth-method [auth-
options]
hostssl   database user IP-address IP-mask auth-method [auth-
options]
hostnssl  database user IP-address IP-mask auth-method [auth-
options]
hostgssenc database user IP-address IP-mask auth-method [auth-
options]
hostnogssenc database user IP-address IP-mask auth-method
[auth-options]

```

The meaning of the fields is as follows:

local

This record matches connection attempts using Unix-domain sockets. Without a record of this type, Unix-domain socket connections are disallowed.

host

This record matches connection attempts made using TCP/IP. `host` records match SSL or non-SSL connection attempts as well as GSSAPI encrypted or non-GSSAPI encrypted connection attempts.

Note

Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the `listen_addresses` configuration parameter, since the default behavior is to listen for TCP/IP connections only on the local loopback address `localhost`.

hostssl

This record matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption.

To make use of this option the server must be built with SSL support. Furthermore, SSL must be enabled by setting the `ssl` configuration parameter (see Section 18.9 for more information). Otherwise, the `hostssl` record is ignored except for logging a warning that it cannot match any connections.

hostnssl

This record type has the opposite behavior of `hostssl`; it only matches connection attempts made over TCP/IP that do not use SSL.

hostgssenc

This record matches connection attempts made using TCP/IP, but only when the connection is made with GSSAPI encryption.

To make use of this option the server must be built with GSSAPI support. Otherwise, the `hostgssenc` record is ignored except for logging a warning that it cannot match any connections.

Note that the only supported authentication methods for use with GSSAPI encryption are `gss`, `reject`, and `trust`.

hostnogssenc

This record type has the opposite behavior of `hostgssenc`; it only matches connection attempts made over TCP/IP that do not use GSSAPI encryption.

database

Specifies which database name(s) this record matches. The value `all` specifies that it matches all databases. The value `sameuser` specifies that the record matches if the requested database has the same name as the requested user. The value `samerole` specifies that the requested user must be a member of the role with the same name as the requested database. (`samegroup` is an obsolete but still accepted spelling of `samerole`.) Superusers are not considered to be members of a role for the purposes of `samerole` unless they are explicitly members of the role, directly or indirectly, and not just by virtue of being a superuser. The value `replication` specifies that the record matches if a physical replication connection is requested (note that replication connections do not specify any particular database). Otherwise, this is the name of a specific PostgreSQL database. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with `@`.

user

Specifies which database user name(s) this record matches. The value `all` specifies that it matches all users. Otherwise, this is either the name of a specific database user, or a group name preceded by `+`. (Recall that there is no real distinction between users and groups in PostgreSQL; a `+` mark really means “match any of the roles that are directly or indirectly members of this role”, while a name without a `+` mark matches only that specific role.) For this purpose, a superuser is only considered to be a member of a role if they are explicitly a member of the role, directly or indirectly, and not just by virtue of being a superuser. Multiple user names can be supplied by separating them with commas. A separate file containing user names can be specified by preceding the file name with `@`.

address

Specifies the client machine address(es) that this record matches. This field can contain either a host name, an IP address range, or one of the special key words mentioned below.

An IP address range is specified using standard numeric notation for the range's starting address, then a slash (`/`) and a CIDR mask length. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this should be zero in the given IP address. There must not be any white space between the IP address, the `/`, and the CIDR mask length.

Typical examples of an IPv4 address range specified this way are `172.20.143.89/32` for a single host, or `172.20.143.0/24` for a small network, or `10.6.0.0/16` for a larger one. An IPv6 address range might look like `::1/128` for a single host (in this case the IPv6 loopback address) or `fe80::7a31:c1ff:0000:0000/96` for a small network. `0.0.0.0/0` represents all IPv4 addresses, and `:::0/0` represents all IPv6 addresses. To specify a single host, use a mask length of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes.

An entry given in IPv4 format will match only IPv4 connections, and an entry given in IPv6 format will match only IPv6 connections, even if the represented address is in the IPv4-in-IPv6 range. Note that entries in IPv6 format will be rejected if the system's C library does not have support for IPv6 addresses.

You can also write `all` to match any IP address, `samehost` to match any of the server's own IP addresses, or `samenet` to match any address in any subnet that the server is directly connected to.

If a host name is specified (anything that is not an IP address range or a special key word is treated as a host name), that name is compared with the result of a reverse name resolution of the client's IP address (e.g., reverse DNS lookup, if DNS is used). Host name comparisons are

case insensitive. If there is a match, then a forward name resolution (e.g., forward DNS lookup) is performed on the host name to check whether any of the addresses it resolves to are equal to the client's IP address. If both directions match, then the entry is considered to match. (The host name that is used in `pg_hba.conf` should be the one that address-to-name resolution of the client's IP address returns, otherwise the line won't be matched. Some host name databases allow associating an IP address with multiple host names, but the operating system will only return one host name when asked to resolve an IP address.)

A host name specification that starts with a dot (.) matches a suffix of the actual host name. So `.example.com` would match `foo.example.com` (but not just `example.com`).

When host names are specified in `pg_hba.conf`, you should make sure that name resolution is reasonably fast. It can be of advantage to set up a local name resolution cache such as `nscd`. Also, you may wish to enable the configuration parameter `log_hostname` to see the client's host name instead of the IP address in the log.

This field only applies to `host`, `hostssl`, and `hostnossl` records.

Note

Users sometimes wonder why host names are handled in this seemingly complicated way, with two name resolutions including a reverse lookup of the client's IP address. This complicates use of the feature in case the client's reverse DNS entry is not set up or yields some undesirable host name. It is done primarily for efficiency: this way, a connection attempt requires at most two resolver lookups, one reverse and one forward. If there is a resolver problem with some address, it becomes only that client's problem. A hypothetical alternative implementation that only did forward lookups would have to resolve every host name mentioned in `pg_hba.conf` during every connection attempt. That could be quite slow if many names are listed. And if there is a resolver problem with one of the host names, it becomes everyone's problem.

Also, a reverse lookup is necessary to implement the suffix matching feature, because the actual client host name needs to be known in order to match it against the pattern.

Note that this behavior is consistent with other popular implementations of host name-based access control, such as the Apache HTTP Server and TCP Wrappers.

IP-address

IP-mask

These two fields can be used as an alternative to the *IP-address/mask-length* notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, `255.0.0.0` represents an IPv4 CIDR mask length of 8, and `255.255.255.255` represents a CIDR mask length of 32.

These fields only apply to `host`, `hostssl`, and `hostnossl` records.

auth-method

Specifies the authentication method to use when a connection matches this record. The possible choices are summarized here; details are in Section 20.3.

`trust`

Allow the connection unconditionally. This method allows anyone that can connect to the PostgreSQL database server to login as any PostgreSQL user they wish, without the need for a password or any other authentication. See Section 20.4 for details.

`reject`

Reject the connection unconditionally. This is useful for “filtering out” certain hosts from a group, for example a `reject` line could block a specific host from connecting, while a later line allows the remaining hosts in a specific network to connect.

`scram-sha-256`

Perform SCRAM-SHA-256 authentication to verify the user's password. See Section 20.5 for details.

`md5`

Perform SCRAM-SHA-256 or MD5 authentication to verify the user's password. See Section 20.5 for details.

`password`

Require the client to supply an unencrypted password for authentication. Since the password is sent in clear text over the network, this should not be used on untrusted networks. See Section 20.5 for details.

`gss`

Use GSSAPI to authenticate the user. This is only available for TCP/IP connections. See Section 20.6 for details. It can be used in conjunction with GSSAPI encryption.

`sspi`

Use SSPI to authenticate the user. This is only available on Windows. See Section 20.7 for details.

`ident`

Obtain the operating system user name of the client by contacting the ident server on the client and check if it matches the requested database user name. Ident authentication can only be used on TCP/IP connections. When specified for local connections, peer authentication will be used instead. See Section 20.8 for details.

`peer`

Obtain the client's operating system user name from the operating system and check if it matches the requested database user name. This is only available for local connections. See Section 20.9 for details.

`ldap`

Authenticate using an LDAP server. See Section 20.10 for details.

`radius`

Authenticate using a RADIUS server. See Section 20.11 for details.

`cert`

Authenticate using SSL client certificates. See Section 20.12 for details.

`pam`

Authenticate using the Pluggable Authentication Modules (PAM) service provided by the operating system. See Section 20.13 for details.

bsd

Authenticate using the BSD Authentication service provided by the operating system. See Section 20.14 for details.

auth-options

After the *auth-method* field, there can be field(s) of the form *name=value* that specify options for the authentication method. Details about which options are available for which authentication methods appear below.

In addition to the method-specific options listed below, there is one method-independent authentication option *clientcert*, which can be specified in any *hostssl* record. This option can be set to *verify-ca* or *verify-full*. Both options require the client to present a valid (trusted) SSL certificate, while *verify-full* additionally enforces that the *cn* (Common Name) in the certificate matches the username or an applicable mapping. This behavior is similar to the *cert* authentication method (see Section 20.12) but enables pairing the verification of client certificates with any authentication method that supports *hostssl* entries.

Files included by @ constructs are read as lists of names, which can be separated by either whitespace or commas. Comments are introduced by #, just as in *pg_hba.conf*, and nested @ constructs are allowed. Unless the file name following @ is an absolute path, it is taken to be relative to the directory containing the referencing file.

Since the *pg_hba.conf* records are examined sequentially for each connection attempt, the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example, one might wish to use *trust* authentication for local TCP/IP connections but require a password for remote TCP/IP connections. In this case a record specifying *trust* authentication for connections from 127.0.0.1 would appear before a record specifying password authentication for a wider range of allowed client IP addresses.

The *pg_hba.conf* file is read on start-up and when the main server process receives a SIGHUP signal. If you edit the file on an active system, you will need to signal the postmaster (using *pg_ctl reload*, calling the SQL function *pg_reload_conf()*, or using *kill -HUP*) to make it re-read the file.

Note

The preceding statement is not true on Microsoft Windows: there, any changes in the *pg_hba.conf* file are immediately applied by subsequent new connections.

The system view *pg_hba_file_rules* can be helpful for pre-testing changes to the *pg_hba.conf* file, or for diagnosing problems if loading of the file did not have the desired effects. Rows in the view with non-null *error* fields indicate problems in the corresponding lines of the file.

Tip

To connect to a particular database, a user must not only pass the *pg_hba.conf* checks, but must have the *CONNECT* privilege for the database. If you wish to restrict which users can connect to which databases, it's usually easier to control this by granting/revoking *CONNECT* privilege than to put the rules in *pg_hba.conf* entries.

Some examples of *pg_hba.conf* entries are shown in Example 20.1. See the next section for details on the different authentication methods.

Example 20.1. Example `pg_hba.conf` Entries

```
# Allow any user on the local system to connect to any database
# with
# any database user name using Unix-domain sockets (the default for
# local
# connections).
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
local  all                  all
trust

# The same using local loopback TCP/IP connections.
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   all                  all            127.0.0.1/32
trust

# The same as the previous line, but using a separate netmask
# column
#
# TYPE  DATABASE          USER          IP-ADDRESS    IP-MASK
# METHOD
host   all                  all            127.0.0.1
255.255.255.255 trust

# The same over IPv6.
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   all                  all            ::1/128
trust

# The same using a host name (would typically cover both IPv4 and
# IPv6).
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   all                  all            localhost
trust

# Allow any user from any host with IP address 192.168.93.x to
# connect
# to database "postgres" as the same user name that ident reports
# for
# the connection (typically the operating system user name).
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host   postgres          all            192.168.93.0/24
ident

# Allow any user from host 192.168.12.10 to connect to database
# "postgres" if the user's password is correctly supplied.
#
```

```

# TYPE  DATABASE          USER          ADDRESS
METHOD
host    postgres            all           192.168.12.10/32
scram-sha-256

# Allow any user from hosts in the example.com domain to connect to
# any database if the user's password is correctly supplied.
#
# Require SCRAM authentication for most users, but make an
# exception
# for user 'mike', who uses an older client that doesn't support
# SCRAM
# authentication.
#
# TYPE  DATABASE          USER          ADDRESS
METHOD
host    all                mike          .example.com      md5
host    all                all           .example.com
scram-sha-256

# In the absence of preceding "host" lines, these three lines will
# reject all connections from 192.168.54.1 (since that entry will
# be
# matched first), but allow GSSAPI-encrypted connections from
# anywhere else
# on the Internet. The zero mask causes no bits of the host IP
# address to
# be considered, so it matches any host. Unencrypted GSSAPI
# connections
# (which "fall through" to the third line since "hostgssenc" only
# matches
# encrypted GSSAPI connections) are allowed, but only from
# 192.168.12.10.
#
# TYPE  DATABASE          USER          ADDRESS
METHOD
host    all                all           192.168.54.1/32
reject
hostgssenc all            all           0.0.0.0/0         gss
host    all                all           192.168.12.10/32  gss

# Allow users from 192.168.x.x hosts to connect to any database, if
# they pass the ident check. If, for example, ident says the user
# is
# "bryanh" and he requests to connect as PostgreSQL user "guest1",
# the
# connection is allowed if there is an entry in pg_ident.conf for
# map
# "omicron" that says "bryanh" is allowed to connect as "guest1".
#
# TYPE  DATABASE          USER          ADDRESS
METHOD
host    all                all           192.168.0.0/16
ident map=omicron

# If these are the only three lines for local connections, they
# will

```

```

# allow local users to connect only to their own databases
  (databases
# with the same name as their database user name) except for
  administrators
# and members of role "support", who can connect to all databases.
  The file
# $PGDATA/admins contains a list of names of administrators.
  Passwords
# are required in all cases.
#
# TYPE  DATABASE          USER                ADDRESS
METHOD
local  sameuser           all                  md5
local  all                 @admins             md5
local  all                 +support            md5

# The last two lines above can be combined into a single line:
local  all                 @admins,+support    md5

# The database column can also use lists and file names:
local  db1,db2,@demodbs  all                  md5

```

20.2. User Name Maps

When using an external authentication system such as Ident or GSSAPI, the name of the operating system user that initiated the connection might not be the same as the database user (role) that is to be used. In this case, a user name map can be applied to map the operating system user name to a database user. To use user name mapping, specify `map=map-name` in the options field in `pg_hba.conf`. This option is supported for all authentication methods that receive external user names. Since different mappings might be needed for different connections, the name of the map to be used is specified in the `map-name` parameter in `pg_hba.conf` to indicate which map to use for each individual connection.

User name maps are defined in the ident map file, which by default is named `pg_ident.conf` and is stored in the cluster's data directory. (It is possible to place the map file elsewhere, however; see the `ident_file` configuration parameter.) The ident map file contains lines of the general form:

```
map-name system-username database-username
```

Comments and whitespace are handled in the same way as in `pg_hba.conf`. The `map-name` is an arbitrary name that will be used to refer to this mapping in `pg_hba.conf`. The other two fields specify an operating system user name and a matching database user name. The same `map-name` can be used repeatedly to specify multiple user-mappings within a single map.

There is no restriction regarding how many database users a given operating system user can correspond to, nor vice versa. Thus, entries in a map should be thought of as meaning “this operating system user is allowed to connect as this database user”, rather than implying that they are equivalent. The connection will be allowed if there is any map entry that pairs the user name obtained from the external authentication system with the database user name that the user has requested to connect as.

If the `system-username` field starts with a slash (/), the remainder of the field is treated as a regular expression. (See Section 9.7.3.1 for details of PostgreSQL's regular expression syntax.) The regular expression can include a single capture, or parenthesized subexpression, which can then be referenced in the `database-username` field as `\1` (backslash-one). This allows the mapping of multiple user names in a single line, which is particularly useful for simple syntax substitutions. For example, these entries

```

mymap    /^(.*)@mydomain\.com$      \1
mymap    /^(.*)@otherdomain\.com$   guest

```

will remove the domain part for users with system user names that end with `@mydomain.com`, and allow any user whose system name ends with `@otherdomain.com` to log in as `guest`.

Tip

Keep in mind that by default, a regular expression can match just part of a string. It's usually wise to use `^` and `$`, as shown in the above example, to force the match to be to the entire system user name.

The `pg_ident.conf` file is read on start-up and when the main server process receives a `SIGHUP` signal. If you edit the file on an active system, you will need to signal the postmaster (using `pg_ctl reload`, calling the SQL function `pg_reload_conf()`, or using `kill -HUP`) to make it re-read the file.

A `pg_ident.conf` file that could be used in conjunction with the `pg_hba.conf` file in Example 20.1 is shown in Example 20.2. In this example, anyone logged in to a machine on the 192.168 network that does not have the operating system user name `bryanh`, `ann`, or `robert` would not be granted access. Unix user `robert` would only be allowed access when he tries to connect as PostgreSQL user `bob`, not as `robert` or anyone else. `ann` would only be allowed to connect as `ann`. User `bryanh` would be allowed to connect as either `bryanh` or as `guest1`.

Example 20.2. An Example `pg_ident.conf` File

```

# MAPNAME          SYSTEM-USERNAME          PG-USERNAME

omicron           bryanh                   bryanh
omicron           ann                      ann
# bob has user name robert on these machines
omicron           robert                  bob
# bryanh can also connect as guest1
omicron           bryanh                  guest1

```

20.3. Authentication Methods

The following sections describe the authentication methods in more detail.

20.4. Trust Authentication

When `trust` authentication is specified, PostgreSQL assumes that anyone who can connect to the server is authorized to access the database with whatever database user name they specify (even superuser names). Of course, restrictions made in the database and user columns still apply. This method should only be used when there is adequate operating-system-level protection on connections to the server.

`trust` authentication is appropriate and very convenient for local connections on a single-user workstation. It is usually *not* appropriate by itself on a multiuser machine. However, you might be able to use `trust` even on a multiuser machine, if you restrict access to the server's Unix-domain socket file using file-system permissions. To do this, set the `unix_socket_permissions` (and possibly `unix_socket_group`) configuration parameters as described in Section 19.3. Or you could set the `unix_socket_directories` configuration parameter to place the socket file in a suitably restricted directory.

Setting file-system permissions only helps for Unix-socket connections. Local TCP/IP connections are not restricted by file-system permissions. Therefore, if you want to use file-system permissions for local security, remove the `host . . . 127.0.0.1 . . .` line from `pg_hba.conf`, or change it to a non-`trust` authentication method.

`trust` authentication is only suitable for TCP/IP connections if you trust every user on every machine that is allowed to connect to the server by the `pg_hba.conf` lines that specify `trust`. It is seldom reasonable to use `trust` for any TCP/IP connections other than those from `localhost` (127.0.0.1).

20.5. Password Authentication

There are several password-based authentication methods. These methods operate similarly but differ in how the users' passwords are stored on the server and how the password provided by a client is sent across the connection.

`scram-sha-256`

The method `scram-sha-256` performs SCRAM-SHA-256 authentication, as described in RFC 7677¹. It is a challenge-response scheme that prevents password sniffing on untrusted connections and supports storing passwords on the server in a cryptographically hashed form that is thought to be secure.

This is the most secure of the currently provided methods, but it is not supported by older client libraries.

`md5`

The method `md5` uses a custom less secure challenge-response mechanism. It prevents password sniffing and avoids storing passwords on the server in plain text but provides no protection if an attacker manages to steal the password hash from the server. Also, the MD5 hash algorithm is nowadays no longer considered secure against determined attacks.

The `md5` method cannot be used with the `db_user_namespace` feature.

To ease transition from the `md5` method to the newer SCRAM method, if `md5` is specified as a method in `pg_hba.conf` but the user's password on the server is encrypted for SCRAM (see below), then SCRAM-based authentication will automatically be chosen instead.

`password`

The method `password` sends the password in clear-text and is therefore vulnerable to password “sniffing” attacks. It should always be avoided if possible. If the connection is protected by SSL encryption then `password` can be used safely, though. (Though SSL certificate authentication might be a better choice if one is depending on using SSL).

PostgreSQL database passwords are separate from operating system user passwords. The password for each database user is stored in the `pg_authid` system catalog. Passwords can be managed with the SQL commands `CREATE ROLE` and `ALTER ROLE`, e.g., **`CREATE ROLE foo WITH LOGIN PASSWORD 'secret'`**, or the `psql` command `\password`. If no password has been set up for a user, the stored password is null and password authentication will always fail for that user.

The availability of the different password-based authentication methods depends on how a user's password on the server is encrypted (or hashed, more accurately). This is controlled by the configuration parameter `password_encryption` at the time the password is set. If a password was encrypted using the `scram-sha-256` setting, then it can be used for the authentication methods `scram-sha-256` and `password` (but password transmission will be in plain text in the latter case). The authentication method specification `md5` will automatically switch to using the `scram-sha-256` method in this

¹ <https://tools.ietf.org/html/rfc7677>

case, as explained above, so it will also work. If a password was encrypted using the `md5` setting, then it can be used only for the `md5` and `password` authentication method specifications (again, with the password transmitted in plain text in the latter case). (Previous PostgreSQL releases supported storing the password on the server in plain text. This is no longer possible.) To check the currently stored password hashes, see the system catalog `pg_authid`.

To upgrade an existing installation from `md5` to `scram-sha-256`, after having ensured that all client libraries in use are new enough to support SCRAM, set `password_encryption = 'scram-sha-256'` in `postgresql.conf`, make all users set new passwords, and change the authentication method specifications in `pg_hba.conf` to `scram-sha-256`.

20.6. GSSAPI Authentication

GSSAPI is an industry-standard protocol for secure authentication defined in RFC 2743. PostgreSQL supports GSSAPI for use as either an encrypted, authenticated layer, or for authentication only. GSSAPI provides automatic authentication (single sign-on) for systems that support it. The authentication itself is secure. If GSSAPI encryption (see `hostgssenc`) or SSL encryption are used, the data sent along the database connection will be encrypted; otherwise, it will not.

GSSAPI support has to be enabled when PostgreSQL is built; see Chapter 16 for more information.

When GSSAPI uses Kerberos, it uses a standard principal in the format `servicename/host-name@realm`. The PostgreSQL server will accept any principal that is included in the keytab used by the server, but care needs to be taken to specify the correct principal details when making the connection from the client using the `krbsrvname` connection parameter. (See also Section 33.1.2.) The installation default can be changed from the default `postgres` at build time using `./configure --with-krb-srvnam=whatever`. In most environments, this parameter never needs to be changed. Some Kerberos implementations might require a different service name, such as Microsoft Active Directory which requires the service name to be in upper case (`POSTGRES`).

`hostname` is the fully qualified host name of the server machine. The service principal's realm is the preferred realm of the server machine.

Client principals can be mapped to different PostgreSQL database user names with `pg_ident.conf`. For example, `pgusername@realm` could be mapped to just `pgusername`. Alternatively, you can use the full `username@realm` principal as the role name in PostgreSQL without any mapping.

PostgreSQL also supports a parameter to strip the realm from the principal. This method is supported for backwards compatibility and is strongly discouraged as it is then impossible to distinguish different users with the same user name but coming from different realms. To enable this, set `include_realm` to 0. For simple single-realm installations, doing that combined with setting the `krb_realm` parameter (which checks that the principal's realm matches exactly what is in the `krb_realm` parameter) is still secure; but this is a less capable approach compared to specifying an explicit mapping in `pg_ident.conf`.

Make sure that your server keytab file is readable (and preferably only readable, not writable) by the PostgreSQL server account. (See also Section 18.1.) The location of the key file is specified by the `krb_server_keyfile` configuration parameter. The default is `/usr/local/pgsql/etc/krb5.keytab` (or whatever directory was specified as `sysconfdir` at build time). For security reasons, it is recommended to use a separate keytab just for the PostgreSQL server rather than opening up permissions on the system keytab file.

The keytab file is generated by the Kerberos software; see the Kerberos documentation for details. The following example is for MIT-compatible Kerberos 5 implementations:

```
kadmin% ank -randkey postgres/server.my.domain.org
kadmin% ktadd -k krb5.keytab postgres/server.my.domain.org
```

When connecting to the database make sure you have a ticket for a principal matching the requested database user name. For example, for database user name `fred`, principal `fred@EXAMPLE.COM` would be able to connect. To also allow principal `fred/users.example.com@EXAMPLE.COM`, use a user name map, as described in Section 20.2.

The following configuration options are supported for GSSAPI:

`include_realm`

If set to 0, the realm name from the authenticated user principal is stripped off before being passed through the user name mapping (Section 20.2). This is discouraged and is primarily available for backwards compatibility, as it is not secure in multi-realm environments unless `krb_realm` is also used. It is recommended to leave `include_realm` set to the default (1) and to provide an explicit mapping in `pg_ident.conf` to convert principal names to PostgreSQL user names.

`map`

Allows for mapping between system and database user names. See Section 20.2 for details. For a GSSAPI/Kerberos principal, such as `username@EXAMPLE.COM` (or, less commonly, `username/hostbased@EXAMPLE.COM`), the user name used for mapping is `username@EXAMPLE.COM` (or `username/hostbased@EXAMPLE.COM`, respectively), unless `include_realm` has been set to 0, in which case `username` (or `username/hostbased`) is what is seen as the system user name when mapping.

`krb_realm`

Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user name mapping is done.

20.7. SSPI Authentication

SSPI is a Windows technology for secure authentication with single sign-on. PostgreSQL will use SSPI in `negotiate` mode, which will use Kerberos when possible and automatically fall back to NTLM in other cases. SSPI authentication only works when both server and client are running Windows, or, on non-Windows platforms, when GSSAPI is available.

When using Kerberos authentication, SSPI works the same way GSSAPI does; see Section 20.6 for details.

The following configuration options are supported for SSPI:

`include_realm`

If set to 0, the realm name from the authenticated user principal is stripped off before being passed through the user name mapping (Section 20.2). This is discouraged and is primarily available for backwards compatibility, as it is not secure in multi-realm environments unless `krb_realm` is also used. It is recommended to leave `include_realm` set to the default (1) and to provide an explicit mapping in `pg_ident.conf` to convert principal names to PostgreSQL user names.

`compat_realm`

If set to 1, the domain's SAM-compatible name (also known as the NetBIOS name) is used for the `include_realm` option. This is the default. If set to 0, the true realm name from the Kerberos user principal name is used.

Do not disable this option unless your server runs under a domain account (this includes virtual service accounts on a domain member system) and all clients authenticating through SSPI are also using domain accounts, or authentication will fail.

upn_username

If this option is enabled along with `compat_realm`, the user name from the Kerberos UPN is used for authentication. If it is disabled (the default), the SAM-compatible user name is used. By default, these two names are identical for new user accounts.

Note that `libpq` uses the SAM-compatible name if no explicit user name is specified. If you use `libpq` or a driver based on it, you should leave this option disabled or explicitly specify user name in the connection string.

map

Allows for mapping between system and database user names. See Section 20.2 for details. For a SSPI/Kerberos principal, such as `username@EXAMPLE.COM` (or, less commonly, `username/hostbased@EXAMPLE.COM`), the user name used for mapping is `username@EXAMPLE.COM` (or `username/hostbased@EXAMPLE.COM`, respectively), unless `include_realm` has been set to 0, in which case `username` (or `username/hostbased`) is what is seen as the system user name when mapping.

krb_realm

Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user name mapping is done.

20.8. Ident Authentication

The ident authentication method works by obtaining the client's operating system user name from an ident server and using it as the allowed database user name (with an optional user name mapping). This is only supported on TCP/IP connections.

Note

When `ident` is specified for a local (non-TCP/IP) connection, peer authentication (see Section 20.9) will be used instead.

The following configuration options are supported for `ident`:

map

Allows for mapping between system and database user names. See Section 20.2 for details.

The “Identification Protocol” is described in RFC 1413. Virtually every Unix-like operating system ships with an ident server that listens on TCP port 113 by default. The basic functionality of an ident server is to answer questions like “What user initiated the connection that goes out of your port *X* and connects to my port *Y*?”. Since PostgreSQL knows both *X* and *Y* when a physical connection is established, it can interrogate the ident server on the host of the connecting client and can theoretically determine the operating system user for any given connection.

The drawback of this procedure is that it depends on the integrity of the client: if the client machine is untrusted or compromised, an attacker could run just about any program on port 113 and return any user name they choose. This authentication method is therefore only appropriate for closed networks where each client machine is under tight control and where the database and system administrators operate in close contact. In other words, you must trust the machine running the ident server. Heed the warning:

The Identification Protocol is not intended as an authorization or access control protocol.

Some ident servers have a nonstandard option that causes the returned user name to be encrypted, using a key that only the originating machine's administrator knows. This option *must not* be used when using the ident server with PostgreSQL, since PostgreSQL does not have any way to decrypt the returned string to determine the actual user name.

20.9. Peer Authentication

The peer authentication method works by obtaining the client's operating system user name from the kernel and using it as the allowed database user name (with optional user name mapping). This method is only supported on local connections.

The following configuration options are supported for peer:

`map`

Allows for mapping between system and database user names. See Section 20.2 for details.

Peer authentication is only available on operating systems providing the `getpeereid()` function, the `SO_PEERCREC` socket parameter, or similar mechanisms. Currently that includes Linux, most flavors of BSD including macOS, and Solaris.

20.10. LDAP Authentication

This authentication method operates similarly to `password` except that it uses LDAP as the password verification method. LDAP is used only to validate the user name/password pairs. Therefore the user must already exist in the database before LDAP can be used for authentication.

LDAP authentication can operate in two modes. In the first mode, which we will call the simple bind mode, the server will bind to the distinguished name constructed as *prefix username suffix*. Typically, the *prefix* parameter is used to specify `cn=`, or `DOMAIN\` in an Active Directory environment. *suffix* is used to specify the remaining part of the DN in a non-Active Directory environment.

In the second mode, which we will call the search+bind mode, the server first binds to the LDAP directory with a fixed user name and password, specified with `ldapbinddn` and `ldapbindpasswd`, and performs a search for the user trying to log in to the database. If no user and password is configured, an anonymous bind will be attempted to the directory. The search will be performed over the subtree at `ldapbasedn`, and will try to do an exact match of the attribute specified in `ldapsearchattribute`. Once the user has been found in this search, the server disconnects and re-binds to the directory as this user, using the password specified by the client, to verify that the login is correct. This mode is the same as that used by LDAP authentication schemes in other software, such as Apache `mod_authnz_ldap` and `pam_ldap`. This method allows for significantly more flexibility in where the user objects are located in the directory, but will cause two separate connections to the LDAP server to be made.

The following configuration options are used in both modes:

`ldapservers`

Names or IP addresses of LDAP servers to connect to. Multiple servers may be specified, separated by spaces.

`ldapport`

Port number on LDAP server to connect to. If no port is specified, the LDAP library's default port setting will be used.

`ldapscheme`

Set to `ldaps` to use LDAPS. This is a non-standard way of using LDAP over SSL, supported by some LDAP server implementations. See also the `ldaptls` option for an alternative.

`ldaptls`

Set to 1 to make the connection between PostgreSQL and the LDAP server use TLS encryption. This uses the `StartTLS` operation per RFC 4513. See also the `ldapscheme` option for an alternative.

Note that using `ldapscheme` or `ldaptls` only encrypts the traffic between the PostgreSQL server and the LDAP server. The connection between the PostgreSQL server and the PostgreSQL client will still be unencrypted unless SSL is used there as well.

The following options are used in simple bind mode only:

`ldapprefix`

String to prepend to the user name when forming the DN to bind as, when doing simple bind authentication.

`ldapsuffix`

String to append to the user name when forming the DN to bind as, when doing simple bind authentication.

The following options are used in search+bind mode only:

`ldapbasedn`

Root DN to begin the search for the user in, when doing search+bind authentication.

`ldapbinddn`

DN of user to bind to the directory with to perform the search when doing search+bind authentication.

`ldapbindpasswd`

Password for user to bind to the directory with to perform the search when doing search+bind authentication.

`ldapsearchattribute`

Attribute to match against the user name in the search when doing search+bind authentication. If no attribute is specified, the `uid` attribute will be used.

`ldapsearchfilter`

The search filter to use when doing search+bind authentication. Occurrences of `$username` will be replaced with the user name. This allows for more flexible search filters than `ldapsearchattribute`.

`ldapurl`

An RFC 4516 LDAP URL. This is an alternative way to write some of the other LDAP options in a more compact and standard form. The format is

```
ldap[s]://host[:port]/basedn[?[attribute][?[scope][?[filter]]]]
```

`scope` must be one of `base`, `one`, `sub`, typically the last. (The default is `base`, which is normally not useful in this application.) `attribute` can nominate a single attribute, in which case

it is used as a value for `ldapsearchattribute`. If *attribute* is empty then *filter* can be used as a value for `ldapsearchfilter`.

The URL scheme `ldaps` chooses the LDAPS method for making LDAP connections over SSL, equivalent to using `ldapscheme=ldaps`. To use encrypted LDAP connections using the StartTLS operation, use the normal URL scheme `ldap` and specify the `ldaptls` option in addition to `ldapurl`.

For non-anonymous binds, `ldapbinddn` and `ldapbindpasswd` must be specified as separate options.

LDAP URLs are currently only supported with OpenLDAP, not on Windows.

It is an error to mix configuration options for simple bind with options for search+bind.

When using search+bind mode, the search can be performed using a single attribute specified with `ldapsearchattribute`, or using a custom search filter specified with `ldapsearchfilter`. Specifying `ldapsearchattribute=foo` is equivalent to specifying `ldapsearchfilter="(foo=$username)"`. If neither option is specified the default is `ldapsearchattribute=uid`.

If PostgreSQL was compiled with OpenLDAP as the LDAP client library, the `ldapservers` setting may be omitted. In that case, a list of host names and ports is looked up via RFC 2782 DNS SRV records. The name `_ldap._tcp.DOMAIN` is looked up, where `DOMAIN` is extracted from `ldapbasedn`.

Here is an example for a simple-bind LDAP configuration:

```
host ... ldap ldapservers=ldap.example.net ldapprefix="cn="
      ldapsuffix=", dc=example, dc=net"
```

When a connection to the database server as database user `someuser` is requested, PostgreSQL will attempt to bind to the LDAP server using the DN `cn=someuser, dc=example, dc=net` and the password provided by the client. If that connection succeeds, the database access is granted.

Here is an example for a search+bind configuration:

```
host ... ldap ldapservers=ldap.example.net ldapbasedn="dc=example,
      dc=net" ldapsearchattribute=uid
```

When a connection to the database server as database user `someuser` is requested, PostgreSQL will attempt to bind anonymously (since `ldapbinddn` was not specified) to the LDAP server, perform a search for `(uid=someuser)` under the specified base DN. If an entry is found, it will then attempt to bind using that found information and the password supplied by the client. If that second connection succeeds, the database access is granted.

Here is the same search+bind configuration written as a URL:

```
host ... ldap ldapurl="ldap://ldap.example.net/dc=example,dc=net?
      uid?sub"
```

Some other software that supports authentication against LDAP uses the same URL format, so it will be easier to share the configuration.

Here is an example for a search+bind configuration that uses `ldapsearchfilter` instead of `ldapsearchattribute` to allow authentication by user ID or email address:

```
host ... ldap ldapserver=ldap.example.net ldapbasedn="dc=example,dc=net" ldapsearchfilter="(|(uid=$username)(mail=$username))"
```

Here is an example for a search+bind configuration that uses DNS SRV discovery to find the host name(s) and port(s) for the LDAP service for the domain name `example.net`:

```
host ... ldap ldapbasedn="dc=example,dc=net"
```

Tip

Since LDAP often uses commas and spaces to separate the different parts of a DN, it is often necessary to use double-quoted parameter values when configuring LDAP options, as shown in the examples.

20.11. RADIUS Authentication

This authentication method operates similarly to `password` except that it uses RADIUS as the password verification method. RADIUS is used only to validate the user name/password pairs. Therefore the user must already exist in the database before RADIUS can be used for authentication.

When using RADIUS authentication, an Access Request message will be sent to the configured RADIUS server. This request will be of type `Authenticate Only`, and include parameters for `user name`, `password` (encrypted) and `NAS Identifier`. The request will be encrypted using a secret shared with the server. The RADIUS server will respond to this server with either `Access Accept` or `Access Reject`. There is no support for RADIUS accounting.

Multiple RADIUS servers can be specified, in which case they will be tried sequentially. If a negative response is received from a server, the authentication will fail. If no response is received, the next server in the list will be tried. To specify multiple servers, put the names within quotes and separate the server names with a comma. If multiple servers are specified, all other RADIUS options can also be given as a comma separate list, to apply individual values to each server. They can also be specified as a single value, in which case this value will apply to all servers.

The following configuration options are supported for RADIUS:

`radiusservers`

The name or IP addresses of the RADIUS servers to connect to. This parameter is required.

`radiussecrets`

The shared secrets used when talking securely to the RADIUS server. This must have exactly the same value on the PostgreSQL and RADIUS servers. It is recommended that this be a string of at least 16 characters. This parameter is required.

Note

The encryption vector used will only be cryptographically strong if PostgreSQL is built with support for OpenSSL. In other cases, the transmission to the RADIUS server should only be considered obfuscated, not secured, and external security measures should be applied if necessary.

`radiusports`

The port number on the RADIUS servers to connect to. If no port is specified, the default port 1812 will be used.

`radiusidentifiers`

The string used as `NAS Identifier` in the RADIUS requests. This parameter can be used as a second parameter identifying for example which database user the user is attempting to authenticate as, which can be used for policy matching on the RADIUS server. If no identifier is specified, the default `postgresql` will be used.

20.12. Certificate Authentication

This authentication method uses SSL client certificates to perform authentication. It is therefore only available for SSL connections. When using this authentication method, the server will require that the client provide a valid, trusted certificate. No password prompt will be sent to the client. The `cn` (Common Name) attribute of the certificate will be compared to the requested database user name, and if they match the login will be allowed. User name mapping can be used to allow `cn` to be different from the database user name.

The following configuration options are supported for SSL certificate authentication:

`map`

Allows for mapping between system and database user names. See Section 20.2 for details.

In a `pg_hba.conf` record specifying certificate authentication, the authentication option `clientcert` is assumed to be `verify-ca` or `verify-full`, and it cannot be turned off since a client certificate is necessary for this method. What the `cert` method adds to the basic `clientcert` certificate validity test is a check that the `cn` attribute matches the database user name.

20.13. PAM Authentication

This authentication method operates similarly to `password` except that it uses PAM (Pluggable Authentication Modules) as the authentication mechanism. The default PAM service name is `postgresql`. PAM is used only to validate user name/password pairs and optionally the connected remote host name or IP address. Therefore the user must already exist in the database before PAM can be used for authentication. For more information about PAM, please read the [Linux-PAM Page](#)².

The following configuration options are supported for PAM:

`pamservice`

PAM service name.

`pam_use_hostname`

Determines whether the remote IP address or the host name is provided to PAM modules through the `PAM_RHOST` item. By default, the IP address is used. Set this option to 1 to use the resolved host name instead. Host name resolution can lead to login delays. (Most PAM configurations don't use this information, so it is only necessary to consider this setting if a PAM configuration was specifically created to make use of it.)

Note

If PAM is set up to read `/etc/shadow`, authentication will fail because the PostgreSQL server is started by a non-root user. However, this is not an issue when PAM is configured to use LDAP or other authentication methods.

² <https://www.kernel.org/pub/linux/libs/pam/>

20.14. BSD Authentication

This authentication method operates similarly to `password` except that it uses BSD Authentication to verify the password. BSD Authentication is used only to validate user name/password pairs. Therefore the user's role must already exist in the database before BSD Authentication can be used for authentication. The BSD Authentication framework is currently only available on OpenBSD.

BSD Authentication in PostgreSQL uses the `auth-postgresql` login type and authenticates with the `postgresql` login class if that's defined in `login.conf`. By default that login class does not exist, and PostgreSQL will use the default login class.

Note

To use BSD Authentication, the PostgreSQL user account (that is, the operating system user running the server) must first be added to the `auth` group. The `auth` group exists by default on OpenBSD systems.

20.15. Authentication Problems

Authentication failures and related problems generally manifest themselves through error messages like the following:

```
FATAL: no pg_hba.conf entry for host "123.123.123.123", user
      "andym", database "testdb"
```

This is what you are most likely to get if you succeed in contacting the server, but it does not want to talk to you. As the message suggests, the server refused the connection request because it found no matching entry in its `pg_hba.conf` configuration file.

```
FATAL: password authentication failed for user "andym"
```

Messages like this indicate that you contacted the server, and it is willing to talk to you, but not until you pass the authorization method specified in the `pg_hba.conf` file. Check the password you are providing, or check your Kerberos or ident software if the complaint mentions one of those authentication types.

```
FATAL: user "andym" does not exist
```

The indicated database user name was not found.

```
FATAL: database "testdb" does not exist
```

The database you are trying to connect to does not exist. Note that if you do not specify a database name, it defaults to the database user name, which might or might not be the right thing.

Tip

The server log might contain more information about an authentication failure than is reported to the client. If you are confused about the reason for a failure, check the server log.

Chapter 21. Database Roles

PostgreSQL manages database access permissions using the concept of *roles*. A role can be thought of as either a database user, or a group of database users, depending on how the role is set up. Roles can own database objects (for example, tables and functions) and can assign privileges on those objects to other roles to control who has access to which objects. Furthermore, it is possible to grant *membership* in a role to another role, thus allowing the member role to use privileges assigned to another role.

The concept of roles subsumes the concepts of “users” and “groups”. In PostgreSQL versions before 8.1, users and groups were distinct kinds of entities, but now there are only roles. Any role can act as a user, a group, or both.

This chapter describes how to create and manage roles. More information about the effects of role privileges on various database objects can be found in Section 5.7.

21.1. Database Roles

Database roles are conceptually completely separate from operating system users. In practice it might be convenient to maintain a correspondence, but this is not required. Database roles are global across a database cluster installation (and not per individual database). To create a role use the CREATE ROLE SQL command:

```
CREATE ROLE name ;
```

name follows the rules for SQL identifiers: either unadorned without special characters, or double-quoted. (In practice, you will usually want to add additional options, such as LOGIN, to the command. More details appear below.) To remove an existing role, use the analogous DROP ROLE command:

```
DROP ROLE name ;
```

For convenience, the programs `createuser` and `dropuser` are provided as wrappers around these SQL commands that can be called from the shell command line:

```
createuser name  
dropuser name
```

To determine the set of existing roles, examine the `pg_roles` system catalog, for example

```
SELECT rolname FROM pg_roles ;
```

The `psql` program's `\du` meta-command is also useful for listing the existing roles.

In order to bootstrap the database system, a freshly initialized system always contains one predefined role. This role is always a “superuser”, and by default (unless altered when running `initdb`) it will have the same name as the operating system user that initialized the database cluster. Customarily, this role will be named `postgres`. In order to create more roles you first have to connect as this initial role.

Every connection to the database server is made using the name of some particular role, and this role determines the initial access privileges for commands issued in that connection. The role name to use for a particular database connection is indicated by the client that is initiating the connection request in an application-specific fashion. For example, the `psql` program uses the `-U` command line option

to indicate the role to connect as. Many applications assume the name of the current operating system user by default (including `createuser` and `psql`). Therefore it is often convenient to maintain a naming correspondence between roles and operating system users.

The set of database roles a given client connection can connect as is determined by the client authentication setup, as explained in Chapter 20. (Thus, a client is not limited to connect as the role matching its operating system user, just as a person's login name need not match his or her real name.) Since the role identity determines the set of privileges available to a connected client, it is important to carefully configure privileges when setting up a multiuser environment.

21.2. Role Attributes

A database role can have a number of attributes that define its privileges and interact with the client authentication system.

login privilege

Only roles that have the `LOGIN` attribute can be used as the initial role name for a database connection. A role with the `LOGIN` attribute can be considered the same as a “database user”. To create a role with login privilege, use either:

```
CREATE ROLE name LOGIN;  
CREATE USER name;
```

(`CREATE USER` is equivalent to `CREATE ROLE` except that `CREATE USER` includes `LOGIN` by default, while `CREATE ROLE` does not.)

superuser status

A database superuser bypasses all permission checks, except the right to log in. This is a dangerous privilege and should not be used carelessly; it is best to do most of your work as a role that is not a superuser. To create a new database superuser, use `CREATE ROLE name SUPERUSER`. You must do this as a role that is already a superuser.

database creation

A role must be explicitly given permission to create databases (except for superusers, since those bypass all permission checks). To create such a role, use `CREATE ROLE name CREATEDB`.

role creation

A role must be explicitly given permission to create more roles (except for superusers, since those bypass all permission checks). To create such a role, use `CREATE ROLE name CREATEROLE`. A role with `CREATEROLE` privilege can alter and drop other roles, too, as well as grant or revoke membership in them. However, to create, alter, drop, or change membership of a superuser role, superuser status is required; `CREATEROLE` is insufficient for that.

initiating replication

A role must explicitly be given permission to initiate streaming replication (except for superusers, since those bypass all permission checks). A role used for streaming replication must have `LOGIN` permission as well. To create such a role, use `CREATE ROLE name REPLICATION LOGIN`.

password

A password is only significant if the client authentication method requires the user to supply a password when connecting to the database. The `password` and `md5` authentication methods make use of passwords. Database passwords are separate from operating system passwords. Specify a password upon role creation with `CREATE ROLE name PASSWORD 'string'`.

A role's attributes can be modified after creation with `ALTER ROLE`. See the reference pages for the `CREATE ROLE` and `ALTER ROLE` commands for details.

Tip

It is good practice to create a role that has the `CREATEDB` and `CREATEROLE` privileges, but is not a superuser, and then use this role for all routine management of databases and roles. This approach avoids the dangers of operating as a superuser for tasks that do not really require it.

A role can also have role-specific defaults for many of the run-time configuration settings described in Chapter 19. For example, if for some reason you want to disable index scans (hint: not a good idea) anytime you connect, you can use:

```
ALTER ROLE myname SET enable_indexscan TO off;
```

This will save the setting (but not set it immediately). In subsequent connections by this role it will appear as though `SET enable_indexscan TO off` had been executed just before the session started. You can still alter this setting during the session; it will only be the default. To remove a role-specific default setting, use `ALTER ROLE rolename RESET varname`. Note that role-specific defaults attached to roles without `LOGIN` privilege are fairly useless, since they will never be invoked.

21.3. Role Membership

It is frequently convenient to group users together to ease management of privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In PostgreSQL this is done by creating a role that represents the group, and then granting *membership* in the group role to individual user roles.

To set up a group role, first create the role:

```
CREATE ROLE name;
```

Typically a role being used as a group would not have the `LOGIN` attribute, though you can set it if you wish.

Once the group role exists, you can add and remove members using the `GRANT` and `REVOKE` commands:

```
GRANT group_role TO role1, ... ;  
REVOKE group_role FROM role1, ... ;
```

You can grant membership to other group roles, too (since there isn't really any distinction between group roles and non-group roles). The database will not let you set up circular membership loops. Also, it is not permitted to grant membership in a role to `PUBLIC`.

The members of a group role can use the privileges of the role in two ways. First, every member of a group can explicitly do `SET ROLE` to temporarily “become” the group role. In this state, the database session has access to the privileges of the group role rather than the original login role, and any database objects created are considered owned by the group role not the login role. Second, member roles that have the `INHERIT` attribute automatically have use of the privileges of roles of which they are members, including any privileges inherited by those roles. As an example, suppose we have done:

```
CREATE ROLE joe LOGIN INHERIT;  
CREATE ROLE admin NOINHERIT;
```

```
CREATE ROLE wheel NOINHERIT;  
GRANT admin TO joe;  
GRANT wheel TO admin;
```

Immediately after connecting as role `joe`, a database session will have use of privileges granted directly to `joe` plus any privileges granted to `admin`, because `joe` “inherits” `admin`'s privileges. However, privileges granted to `wheel` are not available, because even though `joe` is indirectly a member of `wheel`, the membership is via `admin` which has the `NOINHERIT` attribute. After:

```
SET ROLE admin;
```

the session would have use of only those privileges granted to `admin`, and not those granted to `joe`. After:

```
SET ROLE wheel;
```

the session would have use of only those privileges granted to `wheel`, and not those granted to either `joe` or `admin`. The original privilege state can be restored with any of:

```
SET ROLE joe;  
SET ROLE NONE;  
RESET ROLE;
```

Note

The `SET ROLE` command always allows selecting any role that the original login role is directly or indirectly a member of. Thus, in the above example, it is not necessary to become `admin` before becoming `wheel`.

Note

In the SQL standard, there is a clear distinction between users and roles, and users do not automatically inherit privileges while roles do. This behavior can be obtained in PostgreSQL by giving roles being used as SQL roles the `INHERIT` attribute, while giving roles being used as SQL users the `NOINHERIT` attribute. However, PostgreSQL defaults to giving all roles the `INHERIT` attribute, for backward compatibility with pre-8.1 releases in which users always had use of permissions granted to groups they were members of.

The role attributes `LOGIN`, `SUPERUSER`, `CREATEDB`, and `CREATEROLE` can be thought of as special privileges, but they are never inherited as ordinary privileges on database objects are. You must actually `SET ROLE` to a specific role having one of these attributes in order to make use of the attribute. Continuing the above example, we might choose to grant `CREATEDB` and `CREATEROLE` to the `admin` role. Then a session connecting as role `joe` would not have these privileges immediately, only after doing `SET ROLE admin`.

To destroy a group role, use `DROP ROLE`:

```
DROP ROLE name;
```

Any memberships in the group role are automatically revoked (but the member roles are not otherwise affected).

21.4. Dropping Roles

Because roles can own database objects and can hold privileges to access other objects, dropping a role is often not just a matter of a quick `DROP ROLE`. Any objects owned by the role must first be dropped or reassigned to other owners; and any permissions granted to the role must be revoked.

Ownership of objects can be transferred one at a time using `ALTER` commands, for example:

```
ALTER TABLE bobs_table OWNER TO alice;
```

Alternatively, the `REASSIGN OWNED` command can be used to reassign ownership of all objects owned by the role-to-be-dropped to a single other role. Because `REASSIGN OWNED` cannot access objects in other databases, it is necessary to run it in each database that contains objects owned by the role. (Note that the first such `REASSIGN OWNED` will change the ownership of any shared-across-databases objects, that is databases or tablespaces, that are owned by the role-to-be-dropped.)

Once any valuable objects have been transferred to new owners, any remaining objects owned by the role-to-be-dropped can be dropped with the `DROP OWNED` command. Again, this command cannot access objects in other databases, so it is necessary to run it in each database that contains objects owned by the role. Also, `DROP OWNED` will not drop entire databases or tablespaces, so it is necessary to do that manually if the role owns any databases or tablespaces that have not been transferred to new owners.

`DROP OWNED` also takes care of removing any privileges granted to the target role for objects that do not belong to it. Because `REASSIGN OWNED` does not touch such objects, it's typically necessary to run both `REASSIGN OWNED` and `DROP OWNED` (in that order!) to fully remove the dependencies of a role to be dropped.

In short then, the most general recipe for removing a role that has been used to own objects is:

```
REASSIGN OWNED BY doomed_role TO successor_role;
DROP OWNED BY doomed_role;
-- repeat the above commands in each database of the cluster
DROP ROLE doomed_role;
```

When not all owned objects are to be transferred to the same successor owner, it's best to handle the exceptions manually and then perform the above steps to mop up.

If `DROP ROLE` is attempted while dependent objects still remain, it will issue messages identifying which objects need to be reassigned or dropped.

21.5. Default Roles

PostgreSQL provides a set of default roles which provide access to certain, commonly needed, privileged capabilities and information. Administrators can `GRANT` these roles to users and/or other roles in their environment, providing those users with access to the specified capabilities and information.

The default roles are described in Table 21.1. Note that the specific permissions for each of the default roles may change in the future as additional capabilities are added. Administrators should monitor the release notes for changes.

Table 21.1. Default Roles

Role	Allowed Access
<code>pg_read_all_settings</code>	Read all configuration variables, even those normally visible only to superusers.

Role	Allowed Access
<code>pg_read_all_stats</code>	Read all <code>pg_stat_*</code> views and use various statistics related extensions, even those normally visible only to superusers.
<code>pg_stat_scan_tables</code>	Execute monitoring functions that may take <code>ACCESS SHARE</code> locks on tables, potentially for a long time.
<code>pg_monitor</code>	Read/execute various monitoring views and functions. This role is a member of <code>pg_read_all_settings</code> , <code>pg_read_all_stats</code> and <code>pg_stat_scan_tables</code> .
<code>pg_signal_backend</code>	Signal another backend to cancel a query or terminate its session.
<code>pg_read_server_files</code>	Allow reading files from any location the database can access on the server with <code>COPY</code> and other file-access functions.
<code>pg_write_server_files</code>	Allow writing to files in any location the database can access on the server with <code>COPY</code> and other file-access functions.
<code>pg_execute_server_program</code>	Allow executing programs on the database server as the user the database runs as with <code>COPY</code> and other functions which allow executing a server-side program.

The `pg_monitor`, `pg_read_all_settings`, `pg_read_all_stats` and `pg_stat_scan_tables` roles are intended to allow administrators to easily configure a role for the purpose of monitoring the database server. They grant a set of common privileges allowing the role to read various useful configuration settings, statistics and other system information normally restricted to superusers.

The `pg_signal_backend` role is intended to allow administrators to enable trusted, but non-superuser, roles to send signals to other backends. Currently this role enables sending of signals for canceling a query on another backend or terminating its session. A user granted this role cannot however send signals to a backend owned by a superuser. See Section 9.26.2.

The `pg_read_server_files`, `pg_write_server_files` and `pg_execute_server_program` roles are intended to allow administrators to have trusted, but non-superuser, roles which are able to access files and run programs on the database server as the user the database runs as. As these roles are able to access any file on the server file system, they bypass all database-level permission checks when accessing files directly and they could be used to gain superuser-level access, therefore great care should be taken when granting these roles to users.

Care should be taken when granting these roles to ensure they are only used where needed and with the understanding that these roles grant access to privileged information.

Administrators can grant access to these roles to users using the `GRANT` command, for example:

```
GRANT pg_signal_backend TO admin_user;
```

21.6. Function Security

Functions, triggers and row-level security policies allow users to insert code into the backend server that other users might execute unintentionally. Hence, these mechanisms permit users to “Trojan horse” others with relative ease. The strongest protection is tight control over who can define objects. Where that is infeasible, write queries referring only to objects having trusted owners. Remove from `search_path` the public schema and any other schemas that permit untrusted users to create objects.

Functions run inside the backend server process with the operating system permissions of the database server daemon. If the programming language used for the function allows unchecked memory accesses, it is possible to change the server's internal data structures. Hence, among many other things, such functions can circumvent any system access controls. Function languages that allow such access are considered “untrusted”, and PostgreSQL allows only superusers to create functions written in those languages.

Chapter 22. Managing Databases

Every instance of a running PostgreSQL server manages one or more databases. Databases are therefore the topmost hierarchical level for organizing SQL objects (“database objects”). This chapter describes the properties of databases, and how to create, manage, and destroy them.

22.1. Overview

A database is a named collection of SQL objects (“database objects”). Generally, every database object (tables, functions, etc.) belongs to one and only one database. (However there are a few system catalogs, for example `pg_database`, that belong to a whole cluster and are accessible from each database within the cluster.) More accurately, a database is a collection of schemas and the schemas contain the tables, functions, etc. So the full hierarchy is: server, database, schema, table (or some other kind of object, such as a function).

When connecting to the database server, a client must specify in its connection request the name of the database it wants to connect to. It is not possible to access more than one database per connection. However, an application is not restricted in the number of connections it opens to the same or other databases. Databases are physically separated and access control is managed at the connection level. If one PostgreSQL server instance is to house projects or users that should be separate and for the most part unaware of each other, it is therefore recommended to put them into separate databases. If the projects or users are interrelated and should be able to use each other’s resources, they should be put in the same database but possibly into separate schemas. Schemas are a purely logical structure and who can access what is managed by the privilege system. More information about managing schemas is in Section 5.9.

Databases are created with the `CREATE DATABASE` command (see Section 22.2) and destroyed with the `DROP DATABASE` command (see Section 22.5). To determine the set of existing databases, examine the `pg_database` system catalog, for example

```
SELECT datname FROM pg_database;
```

The `psql` program’s `\l` meta-command and `-l` command-line option are also useful for listing the existing databases.

Note

The SQL standard calls databases “catalogs”, but there is no difference in practice.

22.2. Creating a Database

In order to create a database, the PostgreSQL server must be up and running (see Section 18.3).

Databases are created with the SQL command `CREATE DATABASE`:

```
CREATE DATABASE name;
```

where *name* follows the usual rules for SQL identifiers. The current role automatically becomes the owner of the new database. It is the privilege of the owner of a database to remove it later (which also removes all the objects in it, even if they have a different owner).

The creation of databases is a restricted operation. See Section 21.2 for how to grant permission.

Since you need to be connected to the database server in order to execute the `CREATE DATABASE` command, the question remains how the *first* database at any given site can be created. The first database is always created by the `initdb` command when the data storage area is initialized. (See Section 18.2.) This database is called `postgres`. So to create the first “ordinary” database you can connect to `postgres`.

A second database, `template1`, is also created during database cluster initialization. Whenever a new database is created within the cluster, `template1` is essentially cloned. This means that any changes you make in `template1` are propagated to all subsequently created databases. Because of this, avoid creating objects in `template1` unless you want them propagated to every newly created database. More details appear in Section 22.3.

As a convenience, there is a program you can execute from the shell to create new databases, `createdb`.

```
createdb dbname
```

`createdb` does no magic. It connects to the `postgres` database and issues the `CREATE DATABASE` command, exactly as described above. The `createdb` reference page contains the invocation details. Note that `createdb` without any arguments will create a database with the current user name.

Note

Chapter 20 contains information about how to restrict who can connect to a given database.

Sometimes you want to create a database for someone else, and have them become the owner of the new database, so they can configure and manage it themselves. To achieve that, use one of the following commands:

```
CREATE DATABASE dbname OWNER rolename;
```

from the SQL environment, or:

```
createdb -O rolename dbname
```

from the shell. Only the superuser is allowed to create a database for someone else (that is, for a role you are not a member of).

22.3. Template Databases

`CREATE DATABASE` actually works by copying an existing database. By default, it copies the standard system database named `template1`. Thus that database is the “template” from which new databases are made. If you add objects to `template1`, these objects will be copied into subsequently created user databases. This behavior allows site-local modifications to the standard set of objects in databases. For example, if you install the procedural language PL/Perl in `template1`, it will automatically be available in user databases without any extra action being taken when those databases are created.

There is a second standard system database named `template0`. This database contains the same data as the initial contents of `template1`, that is, only the standard objects predefined by your version of PostgreSQL. `template0` should never be changed after the database cluster has been initialized. By instructing `CREATE DATABASE` to copy `template0` instead of `template1`, you can create a “virgin” user database that contains none of the site-local additions in `template1`. This is particularly handy when restoring a `pg_dump` dump: the dump script should be restored in a virgin database

to ensure that one recreates the correct contents of the dumped database, without conflicting with objects that might have been added to `template1` later on.

Another common reason for copying `template0` instead of `template1` is that new encoding and locale settings can be specified when copying `template0`, whereas a copy of `template1` must use the same settings it does. This is because `template1` might contain encoding-specific or locale-specific data, while `template0` is known not to.

To create a database by copying `template0`, use:

```
CREATE DATABASE dbname TEMPLATE template0;
```

from the SQL environment, or:

```
createdb -T template0 dbname
```

from the shell.

It is possible to create additional template databases, and indeed one can copy any database in a cluster by specifying its name as the template for `CREATE DATABASE`. It is important to understand, however, that this is not (yet) intended as a general-purpose “COPY DATABASE” facility. The principal limitation is that no other sessions can be connected to the source database while it is being copied. `CREATE DATABASE` will fail if any other connection exists when it starts; during the copy operation, new connections to the source database are prevented.

Two useful flags exist in `pg_database` for each database: the columns `datistemplate` and `dataallowconn`. `datistemplate` can be set to indicate that a database is intended as a template for `CREATE DATABASE`. If this flag is set, the database can be cloned by any user with `CREATEDB` privileges; if it is not set, only superusers and the owner of the database can clone it. If `dataallowconn` is false, then no new connections to that database will be allowed (but existing sessions are not terminated simply by setting the flag false). The `template0` database is normally marked `dataallowconn = false` to prevent its modification. Both `template0` and `template1` should always be marked with `datistemplate = true`.

Note

`template1` and `template0` do not have any special status beyond the fact that the name `template1` is the default source database name for `CREATE DATABASE`. For example, one could drop `template1` and recreate it from `template0` without any ill effects. This course of action might be advisable if one has carelessly added a bunch of junk in `template1`. (To delete `template1`, it must have `pg_database.datistemplate = false`.)

The `postgres` database is also created when a database cluster is initialized. This database is meant as a default database for users and applications to connect to. It is simply a copy of `template1` and can be dropped and recreated if necessary.

22.4. Database Configuration

Recall from Chapter 19 that the PostgreSQL server provides a large number of run-time configuration variables. You can set database-specific default values for many of these settings.

For example, if for some reason you want to disable the GEQO optimizer for a given database, you'd ordinarily have to either disable it for all databases or make sure that every connecting client is careful to issue `SET geqo TO off`. To make this setting the default within a particular database, you can execute the command:

```
ALTER DATABASE mydb SET geqo TO off;
```

This will save the setting (but not set it immediately). In subsequent connections to this database it will appear as though `SET geqo TO off;` had been executed just before the session started. Note that users can still alter this setting during their sessions; it will only be the default. To undo any such setting, use `ALTER DATABASE dbname RESET varname.`

22.5. Destroying a Database

Databases are destroyed with the command `DROP DATABASE`:

```
DROP DATABASE name;
```

Only the owner of the database, or a superuser, can drop a database. Dropping a database removes all objects that were contained within the database. The destruction of a database cannot be undone.

You cannot execute the `DROP DATABASE` command while connected to the victim database. You can, however, be connected to any other database, including the `template1` database. `template1` would be the only option for dropping the last user database of a given cluster.

For convenience, there is also a shell program to drop databases, `dropdb`:

```
dropdb dbname
```

(Unlike `createdb`, it is not the default action to drop the database with the current user name.)

22.6. Tablespaces

Tablespaces in PostgreSQL allow database administrators to define locations in the file system where the files representing database objects can be stored. Once created, a tablespace can be referred to by name when creating database objects.

By using tablespaces, an administrator can control the disk layout of a PostgreSQL installation. This is useful in at least two ways. First, if the partition or volume on which the cluster was initialized runs out of space and cannot be extended, a tablespace can be created on a different partition and used until the system can be reconfigured.

Second, tablespaces allow an administrator to use knowledge of the usage pattern of database objects to optimize performance. For example, an index which is very heavily used can be placed on a very fast, highly available disk, such as an expensive solid state device. At the same time a table storing archived data which is rarely used or not performance critical could be stored on a less expensive, slower disk system.

Warning

Even though located outside the main PostgreSQL data directory, tablespaces are an integral part of the database cluster and *cannot* be treated as an autonomous collection of data files. They are dependent on metadata contained in the main data directory, and therefore cannot be attached to a different database cluster or backed up individually. Similarly, if you lose a tablespace (file deletion, disk failure, etc), the database cluster might become unreadable or unable to start. Placing a tablespace on a temporary file system like a RAM disk risks the reliability of the entire cluster.

To define a tablespace, use the `CREATE TABLESPACE` command, for example::

```
CREATE TABLESPACE fastspace LOCATION '/ssdl/postgresql/data';
```

The location must be an existing, empty directory that is owned by the PostgreSQL operating system user. All objects subsequently created within the tablespace will be stored in files underneath this directory. The location must not be on removable or transient storage, as the cluster might fail to function if the tablespace is missing or lost.

Note

There is usually not much point in making more than one tablespace per logical file system, since you cannot control the location of individual files within a logical file system. However, PostgreSQL does not enforce any such limitation, and indeed it is not directly aware of the file system boundaries on your system. It just stores files in the directories you tell it to use.

Creation of the tablespace itself must be done as a database superuser, but after that you can allow ordinary database users to use it. To do that, grant them the `CREATE` privilege on it.

Tables, indexes, and entire databases can be assigned to particular tablespaces. To do so, a user with the `CREATE` privilege on a given tablespace must pass the tablespace name as a parameter to the relevant command. For example, the following creates a table in the tablespace `space1`:

```
CREATE TABLE foo(i int) TABLESPACE space1;
```

Alternatively, use the `default_tablespace` parameter:

```
SET default_tablespace = space1;
CREATE TABLE foo(i int);
```

When `default_tablespace` is set to anything but an empty string, it supplies an implicit `TABLESPACE` clause for `CREATE TABLE` and `CREATE INDEX` commands that do not have an explicit one.

There is also a `temp_tablespaces` parameter, which determines the placement of temporary tables and indexes, as well as temporary files that are used for purposes such as sorting large data sets. This can be a list of tablespace names, rather than only one, so that the load associated with temporary objects can be spread over multiple tablespaces. A random member of the list is picked each time a temporary object is to be created.

The tablespace associated with a database is used to store the system catalogs of that database. Furthermore, it is the default tablespace used for tables, indexes, and temporary files created within the database, if no `TABLESPACE` clause is given and no other selection is specified by `default_tablespace` or `temp_tablespaces` (as appropriate). If a database is created without specifying a tablespace for it, it uses the same tablespace as the template database it is copied from.

Two tablespaces are automatically created when the database cluster is initialized. The `pg_global` tablespace is used for shared system catalogs. The `pg_default` tablespace is the default tablespace of the `template1` and `template0` databases (and, therefore, will be the default tablespace for other databases as well, unless overridden by a `TABLESPACE` clause in `CREATE DATABASE`).

Once created, a tablespace can be used from any database, provided the requesting user has sufficient privilege. This means that a tablespace cannot be dropped until all objects in all databases using the tablespace have been removed.

To remove an empty tablespace, use the `DROP TABLESPACE` command.

To determine the set of existing tablespaces, examine the `pg_tablespace` system catalog, for example

```
SELECT spcname FROM pg_tablespace;
```

The `psql` program's `\db` meta-command is also useful for listing the existing tablespaces.

PostgreSQL makes use of symbolic links to simplify the implementation of tablespaces. This means that tablespaces can be used *only* on systems that support symbolic links.

The directory `$PGDATA/pg_tblspc` contains symbolic links that point to each of the non-built-in tablespaces defined in the cluster. Although not recommended, it is possible to adjust the tablespace layout by hand by redefining these links. Under no circumstances perform this operation while the server is running. Note that in PostgreSQL 9.1 and earlier you will also need to update the `pg_tablespace` catalog with the new locations. (If you do not, `pg_dump` will continue to output the old tablespace locations.)

Chapter 23. Localization

This chapter describes the available localization features from the point of view of the administrator. PostgreSQL supports two localization facilities:

- Using the locale features of the operating system to provide locale-specific collation order, number formatting, translated messages, and other aspects. This is covered in Section 23.1 and Section 23.2.
- Providing a number of different character sets to support storing text in all kinds of languages, and providing character set translation between client and server. This is covered in Section 23.3.

23.1. Locale Support

Locale support refers to an application respecting cultural preferences regarding alphabets, sorting, number formatting, etc. PostgreSQL uses the standard ISO C and POSIX locale facilities provided by the server operating system. For additional information refer to the documentation of your system.

23.1.1. Overview

Locale support is automatically initialized when a database cluster is created using `initdb`. `initdb` will initialize the database cluster with the locale setting of its execution environment by default, so if your system is already set to use the locale that you want in your database cluster then there is nothing else you need to do. If you want to use a different locale (or you are not sure which locale your system is set to), you can instruct `initdb` exactly which locale to use by specifying the `--locale` option. For example:

```
initdb --locale=sv_SE
```

This example for Unix systems sets the locale to Swedish (`sv`) as spoken in Sweden (`SE`). Other possibilities might include `en_US` (U.S. English) and `fr_CA` (French Canadian). If more than one character set can be used for a locale then the specifications can take the form *language_territory.codeset*. For example, `fr_BE.UTF-8` represents the French language (`fr`) as spoken in Belgium (`BE`), with a UTF-8 character set encoding.

What locales are available on your system under what names depends on what was provided by the operating system vendor and what was installed. On most Unix systems, the command `locale -a` will provide a list of available locales. Windows uses more verbose locale names, such as `German_Germany` or `Swedish_Sweden.1252`, but the principles are the same.

Occasionally it is useful to mix rules from several locales, e.g., use English collation rules but Spanish messages. To support that, a set of locale subcategories exist that control only certain aspects of the localization rules:

LC_COLLATE	String sort order
LC_CTYPE	Character classification (What is a letter? Its upper-case equivalent?)
LC_MESSAGES	Language of messages
LC_MONETARY	Formatting of currency amounts
LC_NUMERIC	Formatting of numbers
LC_TIME	Formatting of dates and times

The category names translate into names of `initdb` options to override the locale choice for a specific category. For instance, to set the locale to French Canadian, but use U.S. rules for formatting currency, use `initdb --locale=fr_CA --lc-monetary=en_US`.

If you want the system to behave as if it had no locale support, use the special locale name `C`, or equivalently `POSIX`.

Some locale categories must have their values fixed when the database is created. You can use different settings for different databases, but once a database is created, you cannot change them for that database anymore. `LC_COLLATE` and `LC_CTYPE` are these categories. They affect the sort order of indexes, so they must be kept fixed, or indexes on text columns would become corrupt. (But you can alleviate this restriction using collations, as discussed in Section 23.2.) The default values for these categories are determined when `initdb` is run, and those values are used when new databases are created, unless specified otherwise in the `CREATE DATABASE` command.

The other locale categories can be changed whenever desired by setting the server configuration parameters that have the same name as the locale categories (see Section 19.11.2 for details). The values that are chosen by `initdb` are actually only written into the configuration file `postgresql.conf` to serve as defaults when the server is started. If you remove these assignments from `postgresql.conf` then the server will inherit the settings from its execution environment.

Note that the locale behavior of the server is determined by the environment variables seen by the server, not by the environment of any client. Therefore, be careful to configure the correct locale settings before starting the server. A consequence of this is that if client and server are set up in different locales, messages might appear in different languages depending on where they originated.

Note

When we speak of inheriting the locale from the execution environment, this means the following on most operating systems: For a given locale category, say the collation, the following environment variables are consulted in this order until one is found to be set: `LC_ALL`, `LC_COLLATE` (or the variable corresponding to the respective category), `LANG`. If none of these environment variables are set then the locale defaults to `C`.

Some message localization libraries also look at the environment variable `LANGUAGE` which overrides all other locale settings for the purpose of setting the language of messages. If in doubt, please refer to the documentation of your operating system, in particular the documentation about `gettext`.

To enable messages to be translated to the user's preferred language, NLS must have been selected at build time (`configure --enable-nls`). All other locale support is built in automatically.

23.1.2. Behavior

The locale settings influence the following SQL features:

- Sort order in queries using `ORDER BY` or the standard comparison operators on textual data
- The `upper`, `lower`, and `initcap` functions
- Pattern matching operators (`LIKE`, `SIMILAR TO`, and POSIX-style regular expressions); locales affect both case insensitive matching and the classification of characters by character-class regular expressions
- The `to_char` family of functions
- The ability to use indexes with `LIKE` clauses

The drawback of using locales other than `C` or `POSIX` in PostgreSQL is its performance impact. It slows character handling and prevents ordinary indexes from being used by `LIKE`. For this reason use locales only if you actually need them.

As a workaround to allow PostgreSQL to use indexes with `LIKE` clauses under a non-C locale, several custom operator classes exist. These allow the creation of an index that performs a strict character-by-character comparison, ignoring locale comparison rules. Refer to Section 11.10 for more information. Another approach is to create indexes using the C collation, as discussed in Section 23.2.

23.1.3. Problems

If locale support doesn't work according to the explanation above, check that the locale support in your operating system is correctly configured. To check what locales are installed on your system, you can use the command `locale -a` if your operating system provides it.

Check that PostgreSQL is actually using the locale that you think it is. The `LC_COLLATE` and `LC_CTYPE` settings are determined when a database is created, and cannot be changed except by creating a new database. Other locale settings including `LC_MESSAGES` and `LC_MONETARY` are initially determined by the environment the server is started in, but can be changed on-the-fly. You can check the active locale settings using the `SHOW` command.

The directory `src/test/locale` in the source distribution contains a test suite for PostgreSQL's locale support.

Client applications that handle server-side errors by parsing the text of the error message will obviously have problems when the server's messages are in a different language. Authors of such applications are advised to make use of the error code scheme instead.

Maintaining catalogs of message translations requires the on-going efforts of many volunteers that want to see PostgreSQL speak their preferred language well. If messages in your language are currently not available or not fully translated, your assistance would be appreciated. If you want to help, refer to Chapter 54 or write to the developers' mailing list.

23.2. Collation Support

The collation feature allows specifying the sort order and character classification behavior of data per-column, or even per-operation. This alleviates the restriction that the `LC_COLLATE` and `LC_CTYPE` settings of a database cannot be changed after its creation.

23.2.1. Concepts

Conceptually, every expression of a collatable data type has a collation. (The built-in collatable data types are `text`, `varchar`, and `char`. User-defined base types can also be marked collatable, and of course a domain over a collatable data type is collatable.) If the expression is a column reference, the collation of the expression is the defined collation of the column. If the expression is a constant, the collation is the default collation of the data type of the constant. The collation of a more complex expression is derived from the collations of its inputs, as described below.

The collation of an expression can be the “default” collation, which means the locale settings defined for the database. It is also possible for an expression's collation to be indeterminate. In such cases, ordering operations and other operations that need to know the collation will fail.

When the database system has to perform an ordering or a character classification, it uses the collation of the input expression. This happens, for example, with `ORDER BY` clauses and function or operator calls such as `<`. The collation to apply for an `ORDER BY` clause is simply the collation of the sort key. The collation to apply for a function or operator call is derived from the arguments, as described below. In addition to comparison operators, collations are taken into account by functions that convert between lower and upper case letters, such as `lower`, `upper`, and `initcap`; by pattern matching operators; and by `to_char` and related functions.

For a function or operator call, the collation that is derived by examining the argument collations is used at run time for performing the specified operation. If the result of the function or operator call is of

a collatable data type, the collation is also used at parse time as the defined collation of the function or operator expression, in case there is a surrounding expression that requires knowledge of its collation.

The *collation derivation* of an expression can be implicit or explicit. This distinction affects how collations are combined when multiple different collations appear in an expression. An explicit collation derivation occurs when a `COLLATE` clause is used; all other collation derivations are implicit. When multiple collations need to be combined, for example in a function call, the following rules are used:

1. If any input expression has an explicit collation derivation, then all explicitly derived collations among the input expressions must be the same, otherwise an error is raised. If any explicitly derived collation is present, that is the result of the collation combination.
2. Otherwise, all input expressions must have the same implicit collation derivation or the default collation. If any non-default collation is present, that is the result of the collation combination. Otherwise, the result is the default collation.
3. If there are conflicting non-default implicit collations among the input expressions, then the combination is deemed to have indeterminate collation. This is not an error condition unless the particular function being invoked requires knowledge of the collation it should apply. If it does, an error will be raised at run-time.

For example, consider this table definition:

```
CREATE TABLE test1 (
    a text COLLATE "de_DE",
    b text COLLATE "es_ES",
    ...
);
```

Then in

```
SELECT a < 'foo' FROM test1;
```

the `<` comparison is performed according to `de_DE` rules, because the expression combines an implicitly derived collation with the default collation. But in

```
SELECT a < ('foo' COLLATE "fr_FR") FROM test1;
```

the comparison is performed using `fr_FR` rules, because the explicit collation derivation overrides the implicit one. Furthermore, given

```
SELECT a < b FROM test1;
```

the parser cannot determine which collation to apply, since the `a` and `b` columns have conflicting implicit collations. Since the `<` operator does need to know which collation to use, this will result in an error. The error can be resolved by attaching an explicit collation specifier to either input expression, thus:

```
SELECT a < b COLLATE "de_DE" FROM test1;
```

or equivalently

```
SELECT a COLLATE "de_DE" < b FROM test1;
```

On the other hand, the structurally similar case

```
SELECT a || b FROM test1;
```

does not result in an error, because the `||` operator does not care about collations: its result is the same regardless of the collation.

The collation assigned to a function or operator's combined input expressions is also considered to apply to the function or operator's result, if the function or operator delivers a result of a collatable data type. So, in

```
SELECT * FROM test1 ORDER BY a || 'foo';
```

the ordering will be done according to `de_DE` rules. But this query:

```
SELECT * FROM test1 ORDER BY a || b;
```

results in an error, because even though the `||` operator doesn't need to know a collation, the `ORDER BY` clause does. As before, the conflict can be resolved with an explicit collation specifier:

```
SELECT * FROM test1 ORDER BY a || b COLLATE "fr_FR";
```

23.2.2. Managing Collations

A collation is an SQL schema object that maps an SQL name to locales provided by libraries installed in the operating system. A collation definition has a *provider* that specifies which library supplies the locale data. One standard provider name is `libc`, which uses the locales provided by the operating system C library. These are the locales that most tools provided by the operating system use. Another provider is `icu`, which uses the external ICU library. ICU locales can only be used if support for ICU was configured when PostgreSQL was built.

A collation object provided by `libc` maps to a combination of `LC_COLLATE` and `LC_CTYPE` settings, as accepted by the `setlocale()` system library call. (As the name would suggest, the main purpose of a collation is to set `LC_COLLATE`, which controls the sort order. But it is rarely necessary in practice to have an `LC_CTYPE` setting that is different from `LC_COLLATE`, so it is more convenient to collect these under one concept than to create another infrastructure for setting `LC_CTYPE` per expression.) Also, a `libc` collation is tied to a character set encoding (see Section 23.3). The same collation name may exist for different encodings.

A collation object provided by `icu` maps to a named collator provided by the ICU library. ICU does not support separate “collate” and “ctype” settings, so they are always the same. Also, ICU collations are independent of the encoding, so there is always only one ICU collation of a given name in a database.

23.2.2.1. Standard Collations

On all platforms, the collations named `default`, `C`, and `POSIX` are available. Additional collations may be available depending on operating system support. The `default` collation selects the `LC_COLLATE` and `LC_CTYPE` values specified at database creation time. The `C` and `POSIX` collations both specify “traditional C” behavior, in which only the ASCII letters “A” through “Z” are treated as letters, and sorting is done strictly by character code byte values.

Additionally, the SQL standard collation name `ucs_basic` is available for encoding UTF8. It is equivalent to `C` and sorts by Unicode code point.

23.2.2.2. Predefined Collations

If the operating system provides support for using multiple locales within a single program (`newlocale` and related functions), or if support for ICU is configured, then when a database cluster is initialized, `initdb` populates the system catalog `pg_collation` with collations based on all the locales it finds in the operating system at the time.

To inspect the currently available locales, use the query `SELECT * FROM pg_collation`, or the command `\dos+ in psql`.

23.2.2.2.1. libc Collations

For example, the operating system might provide a locale named `de_DE.utf8`. `initdb` would then create a collation named `de_DE.utf8` for encoding UTF8 that has both `LC_COLLATE` and `LC_CTYPE` set to `de_DE.utf8`. It will also create a collation with the `.utf8` tag stripped off the name. So you could also use the collation under the name `de_DE`, which is less cumbersome to write and makes the name less encoding-dependent. Note that, nevertheless, the initial set of collation names is platform-dependent.

The default set of collations provided by `libc` map directly to the locales installed in the operating system, which can be listed using the command `locale -a`. In case a `libc` collation is needed that has different values for `LC_COLLATE` and `LC_CTYPE`, or if new locales are installed in the operating system after the database system was initialized, then a new collation may be created using the `CREATE COLLATION` command. New operating system locales can also be imported en masse using the `pg_import_system_collations()` function.

Within any particular database, only collations that use that database's encoding are of interest. Other entries in `pg_collation` are ignored. Thus, a stripped collation name such as `de_DE` can be considered unique within a given database even though it would not be unique globally. Use of the stripped collation names is recommended, since it will make one less thing you need to change if you decide to change to another database encoding. Note however that the `default`, `C`, and `POSIX` collations can be used regardless of the database encoding.

PostgreSQL considers distinct collation objects to be incompatible even when they have identical properties. Thus for example,

```
SELECT a COLLATE "C" < b COLLATE "POSIX" FROM test1;
```

will draw an error even though the `C` and `POSIX` collations have identical behaviors. Mixing stripped and non-stripped collation names is therefore not recommended.

23.2.2.2.2. ICU Collations

With ICU, it is not sensible to enumerate all possible locale names. ICU uses a particular naming system for locales, but there are many more ways to name a locale than there are actually distinct locales. `initdb` uses the ICU APIs to extract a set of distinct locales to populate the initial set of collations. Collations provided by ICU are created in the SQL environment with names in BCP 47 language tag format, with a “private use” extension `-x-icu` appended, to distinguish them from `libc` locales.

Here are some example collations that might be created:

`de-x-icu`

German collation, default variant

`de-AT-x-icu`

German collation for Austria, default variant

(There are also, say, `de-DE-x-icu` or `de-CH-x-icu`, but as of this writing, they are equivalent to `de-x-icu`.)

`und-x-icu` (for “undefined”)

ICU “root” collation. Use this to get a reasonable language-agnostic sort order.

Some (less frequently used) encodings are not supported by ICU. When the database encoding is one of these, ICU collation entries in `pg_collation` are ignored. Attempting to use one will draw an error along the lines of “collation “de-x-icu” for encoding “WIN874” does not exist”.

23.2.2.3. Creating New Collation Objects

If the standard and predefined collations are not sufficient, users can create their own collation objects using the SQL command `CREATE COLLATION`.

The standard and predefined collations are in the schema `pg_catalog`, like all predefined objects. User-defined collations should be created in user schemas. This also ensures that they are saved by `pg_dump`.

23.2.2.3.1. libc Collations

New libc collations can be created like this:

```
CREATE COLLATION german (provider = libc, locale = 'de_DE');
```

The exact values that are acceptable for the `locale` clause in this command depend on the operating system. On Unix-like systems, the command `locale -a` will show a list.

Since the predefined libc collations already include all collations defined in the operating system when the database instance is initialized, it is not often necessary to manually create new ones. Reasons might be if a different naming system is desired (in which case see also Section 23.2.2.3.3) or if the operating system has been upgraded to provide new locale definitions (in which case see also `pg_import_system_collations()`).

23.2.2.3.2. ICU Collations

ICU allows collations to be customized beyond the basic language+country set that is preloaded by `initdb`. Users are encouraged to define their own collation objects that make use of these facilities to suit the sorting behavior to their requirements. See <http://userguide.icu-project.org/locale> and <http://userguide.icu-project.org/collation/api> for information on ICU locale naming. The set of acceptable names and attributes depends on the particular ICU version.

Here are some examples:

```
CREATE COLLATION "de-u-co-phonebk-x-icu" (provider = icu, locale =
'de-u-co-phonebk');
CREATE COLLATION "de-u-co-phonebk-x-icu" (provider = icu, locale =
'de@collation=phonebook');
```

German collation with phone book collation type

The first example selects the ICU locale using a “language tag” per BCP 47. The second example uses the traditional ICU-specific locale syntax. The first style is preferred going forward, but it is not supported by older ICU versions.

Note that you can name the collation objects in the SQL environment anything you want. In this example, we follow the naming style that the predefined collations use, which in turn also follow BCP 47, but that is not required for user-defined collations.

```
CREATE COLLATION "und-u-co-emoji-x-icu" (provider = icu, locale =
'und-u-co-emoji');
CREATE COLLATION "und-u-co-emoji-x-icu" (provider = icu, locale =
'@collation=emoji');
```

Root collation with Emoji collation type, per Unicode Technical Standard #51

Observe how in the traditional ICU locale naming system, the root locale is selected by an empty string.

```
CREATE COLLATION digitlast (provider = icu, locale = 'en-u-kr-latn-digit');
CREATE COLLATION digitlast (provider = icu, locale = 'en@colReorder=latn-digit');
```

Sort digits after Latin letters. (The default is digits before letters.)

```
CREATE COLLATION upperfirst (provider = icu, locale = 'en-u-kf-upper');
CREATE COLLATION upperfirst (provider = icu, locale = 'en@colCaseFirst=upper');
```

Sort upper-case letters before lower-case letters. (The default is lower-case letters first.)

```
CREATE COLLATION special (provider = icu, locale = 'en-u-kf-upper-kr-latn-digit');
CREATE COLLATION special (provider = icu, locale = 'en@colCaseFirst=upper;colReorder=latn-digit');
```

Combines both of the above options.

```
CREATE COLLATION numeric (provider = icu, locale = 'en-u-kn-true');
CREATE COLLATION numeric (provider = icu, locale = 'en@colNumeric=yes');
```

Numeric ordering, sorts sequences of digits by their numeric value, for example: A-21 < A-123 (also known as natural sort).

See Unicode Technical Standard #35¹ and BCP 47² for details. The list of possible collation types (co subtag) can be found in the CLDR repository³. The ICU Locale Explorer⁴ can be used to check the details of a particular locale definition. The examples using the *k** subtags require at least ICU version 54.

Note that while this system allows creating collations that “ignore case” or “ignore accents” or similar (using the *ks* key), in order for such collations to act in a truly case- or accent-insensitive manner, they also need to be declared as not *deterministic* in `CREATE COLLATION`; see Section 23.2.2.4. Otherwise, any strings that compare equal according to the collation but are not byte-wise equal will be sorted according to their byte values.

Note

By design, ICU will accept almost any string as a locale name and match it to the closest locale it can provide, using the fallback procedure described in its documentation. Thus, there will be no direct feedback if a collation specification is composed using features that the given ICU installation does not actually support. It is therefore recommended to create application-level test cases to check that the collation definitions satisfy one's requirements.

23.2.2.3.3. Copying Collations

The command `CREATE COLLATION` can also be used to create a new collation from an existing collation, which can be useful to be able to use operating-system-independent collation names in applications, create compatibility names, or use an ICU-provided collation under a more readable name. For example:

¹ <http://unicode.org/reports/tr35/tr35-collation.html>

² <https://tools.ietf.org/html/bcp47>

³ <http://www.unicode.org/repos/cldr/trunk/common/bcp47/collation.xml>

⁴ <https://ssl.icu-project.org/icu-bin/locexp>

```
CREATE COLLATION german FROM "de_DE";
CREATE COLLATION french FROM "fr-x-icu";
```

23.2.2.4. Nondeterministic Collations

A collation is either *deterministic* or *nondeterministic*. A deterministic collation uses deterministic comparisons, which means that it considers strings to be equal only if they consist of the same byte sequence. Nondeterministic comparison may determine strings to be equal even if they consist of different bytes. Typical situations include case-insensitive comparison, accent-insensitive comparison, as well as comparison of strings in different Unicode normal forms. It is up to the collation provider to actually implement such insensitive comparisons; the deterministic flag only determines whether ties are to be broken using bitwise comparison. See also Unicode Technical Standard 10⁵ for more information on the terminology.

To create a nondeterministic collation, specify the property `deterministic = false` to `CREATE COLLATION`, for example:

```
CREATE COLLATION ndcoll (provider = icu, locale = 'und',
    deterministic = false);
```

This example would use the standard Unicode collation in a nondeterministic way. In particular, this would allow strings in different normal forms to be compared correctly. More interesting examples make use of the ICU customization facilities explained above. For example:

```
CREATE COLLATION case_insensitive (provider = icu, locale = 'und-u-
ks-level2', deterministic = false);
CREATE COLLATION ignore_accents (provider = icu, locale = 'und-u-
ks-level1-kc-true', deterministic = false);
```

All standard and predefined collations are deterministic, all user-defined collations are deterministic by default. While nondeterministic collations give a more “correct” behavior, especially when considering the full power of Unicode and its many special cases, they also have some drawbacks. Foremost, their use leads to a performance penalty. Also, certain operations are not possible with nondeterministic collations, such as pattern matching operations. Therefore, they should be used only in cases where they are specifically wanted.

23.3. Character Set Support

The character set support in PostgreSQL allows you to store text in a variety of character sets (also called encodings), including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your PostgreSQL database cluster using `initdb`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

An important restriction, however, is that each database's character set must be compatible with the database's `LC_CTYPE` (character classification) and `LC_COLLATE` (string sort order) locale settings. For C or POSIX locale, any character set is allowed, but for other libc-provided locales there is only one character set that will work correctly. (On Windows, however, UTF-8 encoding can be used with any locale.) If you have ICU support configured, ICU-provided locales can be used with most but not all server-side encodings.

23.3.1. Supported Character Sets

Table 23.1 shows the character sets available for use in PostgreSQL.

⁵ <https://unicode.org/reports/tr10>

Table 23.1. PostgreSQL Character Sets

Name	Description	Language	Server?	ICU?	Bytes/Char	Aliases
BIG5	Big Five	Traditional Chinese	No	No	1-2	WIN950, Windows950
EUC_CN	Extended UNIX Code-CN	Simplified Chinese	Yes	Yes	1-3	
EUC_JP	Extended UNIX Code-JP	Japanese	Yes	Yes	1-3	
EUC_JIS_2004	Extended UNIX Code-JP, JIS X 0213	Japanese	Yes	No	1-3	
EUC_KR	Extended UNIX Code-KR	Korean	Yes	Yes	1-3	
EUC_TW	Extended UNIX Code-TW	Traditional Chinese, Taiwanese	Yes	Yes	1-3	
GB18030	National Standard	Chinese	No	No	1-4	
GBK	Extended National Standard	Simplified Chinese	No	No	1-2	WIN936, Windows936
ISO_8859_1	ISO 8859-1, ECMA 113	Latin/Cyrillic	Yes	Yes	1	
ISO_8859_2	ISO 8859-2, ECMA 114	Latin/Arabic	Yes	Yes	1	
ISO_8859_3	ISO 8859-3, ECMA 118	Latin/Greek	Yes	Yes	1	
ISO_8859_4	ISO 8859-4, ECMA 121	Latin/Hebrew	Yes	Yes	1	
JOHAB	JOHAB	Korean (Hangul)	No	No	1-3	
KOI8R	KOI8-R	Cyrillic (Russian)	Yes	Yes	1	KOI8
KOI8U	KOI8-U	Cyrillic (Ukrainian)	Yes	Yes	1	
LATIN1	ISO 8859-1, ECMA 94	Western European	Yes	Yes	1	ISO88591
LATIN2	ISO 8859-2, ECMA 94	Central European	Yes	Yes	1	ISO88592
LATIN3	ISO 8859-3, ECMA 94	South European	Yes	Yes	1	ISO88593
LATIN4	ISO 8859-4, ECMA 94	North European	Yes	Yes	1	ISO88594

Name	Description	Language	Server?	ICU?	Bytes/Char	Aliases
LATIN5	ISO 8859-9, ECMA 128	Turkish	Yes	Yes	1	ISO88599
LATIN6	ISO 8859-10, ECMA 144	Nordic	Yes	Yes	1	ISO885910
LATIN7	ISO 8859-13	Baltic	Yes	Yes	1	ISO885913
LATIN8	ISO 8859-14	Celtic	Yes	Yes	1	ISO885914
LATIN9	ISO 8859-15	LATIN1 with Euro and accents	Yes	Yes	1	ISO885915
LATIN10	ISO 8859-16, ASRO SR 14111	Romanian	Yes	No	1	ISO885916
MULE_INTERNAL	Mule internal code	Multilingual Emacs	Yes	No	1-4	
SJIS	Shift JIS	Japanese	No	No	1-2	Mskanji, ShiftJIS, WIN932, Windows932
SHIFT_JIS	Shift JIS, JIS X 0213	Japanese	No	No	1-2	
SQL_ASCII	unspecified (see text)	<i>any</i>	Yes	No	1	
UHC	Unified Hangul Code	Korean	No	No	1-2	WIN949, Windows949
UTF8	Unicode, 8-bit	<i>all</i>	Yes	Yes	1-4	Unicode
WIN866	Windows CP866	Cyrillic	Yes	Yes	1	ALT
WIN874	Windows CP874	Thai	Yes	No	1	
WIN1250	Windows CP1250	Central European	Yes	Yes	1	
WIN1251	Windows CP1251	Cyrillic	Yes	Yes	1	WIN
WIN1252	Windows CP1252	Western European	Yes	Yes	1	
WIN1253	Windows CP1253	Greek	Yes	Yes	1	
WIN1254	Windows CP1254	Turkish	Yes	Yes	1	
WIN1255	Windows CP1255	Hebrew	Yes	Yes	1	
WIN1256	Windows CP1256	Arabic	Yes	Yes	1	

Name	Description	Language	Server?	ICU?	Bytes/Char	Aliases
WIN1257	Windows CP1257	Baltic	Yes	Yes	1	
WIN1258	Windows CP1258	Vietnamese	Yes	Yes	1	ABC, TCVN, TCVN5712, VSCII

Not all client APIs support all the listed character sets. For example, the PostgreSQL JDBC driver does not support MULE_INTERNAL, LATIN6, LATIN8, and LATIN10.

The SQL_ASCII setting behaves considerably differently from the other settings. When the server character set is SQL_ASCII, the server interprets byte values 0-127 according to the ASCII standard, while byte values 128-255 are taken as uninterpreted characters. No encoding conversion will be done when the setting is SQL_ASCII. Thus, this setting is not so much a declaration that a specific encoding is in use, as a declaration of ignorance about the encoding. In most cases, if you are working with any non-ASCII data, it is unwise to use the SQL_ASCII setting because PostgreSQL will be unable to help you by converting or validating non-ASCII characters.

23.3.2. Setting the Character Set

initdb defines the default character set (encoding) for a PostgreSQL cluster. For example,

```
initdb -E EUC_JP
```

sets the default character set to EUC_JP (Extended Unix Code for Japanese). You can use --encoding instead of -E if you prefer longer option strings. If no -E or --encoding option is given, initdb attempts to determine the appropriate encoding to use based on the specified or default locale.

You can specify a non-default encoding at database creation time, provided that the encoding is compatible with the selected locale:

```
createdb -E EUC_KR -T template0 --lc-collate=ko_KR.euckr --lc-ctype=ko_KR.euckr korean
```

This will create a database named korean that uses the character set EUC_KR, and locale ko_KR. Another way to accomplish this is to use this SQL command:

```
CREATE DATABASE korean WITH ENCODING 'EUC_KR'
LC_COLLATE='ko_KR.euckr' LC_CTYPE='ko_KR.euckr'
TEMPLATE=template0;
```

Notice that the above commands specify copying the template0 database. When copying any other database, the encoding and locale settings cannot be changed from those of the source database, because that might result in corrupt data. For more information see Section 22.3.

The encoding for a database is stored in the system catalog pg_database. You can see it by using the psql -l option or the \l command.

```
$ psql -l
                                List of databases
  Name      | Owner      | Encoding | Collation | Ctype      |
-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+
 clocaledb | hlinnaka  | SQL_ASCII | C          | C          |
 englishdb | hlinnaka  | UTF8      | en_GB.UTF8 | en_GB.UTF8 |
```

```

japanese | hlinnaka | UTF8      | ja_JP.UTF8 | ja_JP.UTF8 |
korean   | hlinnaka | EUC_KR    | ko_KR.euckr | ko_KR.euckr |
postgres | hlinnaka | UTF8      | fi_FI.UTF8 | fi_FI.UTF8 |
template0 | hlinnaka | UTF8      | fi_FI.UTF8 | fi_FI.UTF8 |
{=c/hlinnaka,hlinnaka=CtC/hlinnaka}
template1 | hlinnaka | UTF8      | fi_FI.UTF8 | fi_FI.UTF8 |
{=c/hlinnaka,hlinnaka=CtC/hlinnaka}
(7 rows)

```

Important

On most modern operating systems, PostgreSQL can determine which character set is implied by the `LC_CTYPE` setting, and it will enforce that only the matching database encoding is used. On older systems it is your responsibility to ensure that you use the encoding expected by the locale you have selected. A mistake in this area is likely to lead to strange behavior of locale-dependent operations such as sorting.

PostgreSQL will allow superusers to create databases with `SQL_ASCII` encoding even when `LC_CTYPE` is not `C` or `POSIX`. As noted above, `SQL_ASCII` does not enforce that the data stored in the database has any particular encoding, and so this choice poses risks of locale-dependent misbehavior. Using this combination of settings is deprecated and may someday be forbidden altogether.

23.3.3. Automatic Character Set Conversion Between Server and Client

PostgreSQL supports automatic character set conversion between server and client for certain character set combinations. The conversion information is stored in the `pg_conversion` system catalog. PostgreSQL comes with some predefined conversions, as shown in Table 23.2. You can create a new conversion using the SQL command `CREATE CONVERSION`.

Table 23.2. Client/Server Character Set Conversions

Server Character Set	Available Client Character Sets
BIG5	<i>not supported as a server encoding</i>
EUC_CN	<i>EUC_CN</i> , <i>MULE_INTERNAL</i> , <i>UTF8</i>
EUC_JP	<i>EUC_JP</i> , <i>MULE_INTERNAL</i> , <i>SJIS</i> , <i>UTF8</i>
EUC_JIS_2004	<i>EUC_JIS_2004</i> , <i>SHIFT_JIS_2004</i> , <i>UTF8</i>
EUC_KR	<i>EUC_KR</i> , <i>MULE_INTERNAL</i> , <i>UTF8</i>
EUC_TW	<i>EUC_TW</i> , <i>BIG5</i> , <i>MULE_INTERNAL</i> , <i>UTF8</i>
GB18030	<i>not supported as a server encoding</i>
GBK	<i>not supported as a server encoding</i>
ISO_8859_5	<i>ISO_8859_5</i> , <i>KOI8R</i> , <i>MULE_INTERNAL</i> , <i>UTF8</i> , <i>WIN866</i> , <i>WIN1251</i>
ISO_8859_6	<i>ISO_8859_6</i> , <i>UTF8</i>
ISO_8859_7	<i>ISO_8859_7</i> , <i>UTF8</i>
ISO_8859_8	<i>ISO_8859_8</i> , <i>UTF8</i>
JOHAB	<i>not supported as a server encoding</i>
KOI8R	<i>KOI8R</i> , <i>ISO_8859_5</i> , <i>MULE_INTERNAL</i> , <i>UTF8</i> , <i>WIN866</i> , <i>WIN1251</i>

Server Character Set	Available Client Character Sets
KOI8U	<i>KOI8U</i> , UTF8
LATIN1	<i>LATIN1</i> , MULE_INTERNAL, UTF8
LATIN2	<i>LATIN2</i> , MULE_INTERNAL, UTF8, WIN1250
LATIN3	<i>LATIN3</i> , MULE_INTERNAL, UTF8
LATIN4	<i>LATIN4</i> , MULE_INTERNAL, UTF8
LATIN5	<i>LATIN5</i> , UTF8
LATIN6	<i>LATIN6</i> , UTF8
LATIN7	<i>LATIN7</i> , UTF8
LATIN8	<i>LATIN8</i> , UTF8
LATIN9	<i>LATIN9</i> , UTF8
LATIN10	<i>LATIN10</i> , UTF8
MULE_INTERNAL	<i>MULE_INTERNAL</i> , BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8R, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251
SJIS	<i>not supported as a server encoding</i>
SHIFT_JIS_2004	<i>not supported as a server encoding</i>
SQL_ASCII	<i>any (no conversion will be performed)</i>
UHC	<i>not supported as a server encoding</i>
UTF8	<i>all supported encodings</i>
WIN866	<i>WIN866</i> , ISO_8859_5, KOI8R, MULE_INTERNAL, UTF8, WIN1251
WIN874	<i>WIN874</i> , UTF8
WIN1250	<i>WIN1250</i> , LATIN2, MULE_INTERNAL, UTF8
WIN1251	<i>WIN1251</i> , ISO_8859_5, KOI8R, MULE_INTERNAL, UTF8, WIN866
WIN1252	<i>WIN1252</i> , UTF8
WIN1253	<i>WIN1253</i> , UTF8
WIN1254	<i>WIN1254</i> , UTF8
WIN1255	<i>WIN1255</i> , UTF8
WIN1256	<i>WIN1256</i> , UTF8
WIN1257	<i>WIN1257</i> , UTF8
WIN1258	<i>WIN1258</i> , UTF8

To enable automatic character set conversion, you have to tell PostgreSQL the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- Using the `\encoding` command in `psql`. `\encoding` allows you to change client encoding on the fly. For example, to change the encoding to SJIS, type:

```
\encoding SJIS
```

- `libpq` (Section 33.10) has functions to control the client encoding.
- Using `SET client_encoding TO`. Setting the client encoding can be done with this SQL command:

```
SET CLIENT_ENCODING TO 'value';
```

Also you can use the standard SQL syntax `SET NAMES` for this purpose:

```
SET NAMES 'value';
```

To query the current client encoding:

```
SHOW client_encoding;
```

To return to the default encoding:

```
RESET client_encoding;
```

- Using `PGCLIENTENCODING`. If the environment variable `PGCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)
- Using the configuration variable `client_encoding`. If the `client_encoding` variable is set, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible — suppose you chose `EUC_JP` for the server and `LATIN1` for the client, and some Japanese characters are returned that do not have a representation in `LATIN1` — an error is reported.

If the client character set is defined as `SQL_ASCII`, encoding conversion is disabled, regardless of the server's character set. Just as for the server, use of `SQL_ASCII` is unwise unless you are working with all-ASCII data.

23.3.4. Further Reading

These are good sources to start learning about various kinds of encoding systems.

CJKV Information Processing: Chinese, Japanese, Korean & Vietnamese Computing

Contains detailed explanations of `EUC_JP`, `EUC_CN`, `EUC_KR`, `EUC_TW`.

<http://www.unicode.org/>

The web site of the Unicode Consortium.

RFC 3629

UTF-8 (8-bit UCS/Unicode Transformation Format) is defined here.

Chapter 24. Routine Database Maintenance Tasks

PostgreSQL, like any database software, requires that certain tasks be performed regularly to achieve optimum performance. The tasks discussed here are *required*, but they are repetitive in nature and can easily be automated using standard tools such as cron scripts or Windows' Task Scheduler. It is the database administrator's responsibility to set up appropriate scripts, and to check that they execute successfully.

One obvious maintenance task is the creation of backup copies of the data on a regular schedule. Without a recent backup, you have no chance of recovery after a catastrophe (disk failure, fire, mistakenly dropping a critical table, etc.). The backup and recovery mechanisms available in PostgreSQL are discussed at length in Chapter 25.

The other main category of maintenance task is periodic “vacuuming” of the database. This activity is discussed in Section 24.1. Closely related to this is updating the statistics that will be used by the query planner, as discussed in Section 24.1.3.

Another task that might need periodic attention is log file management. This is discussed in Section 24.3.

`check_postgres`¹ is available for monitoring database health and reporting unusual conditions. `check_postgres` integrates with Nagios and MRTG, but can be run standalone too.

PostgreSQL is low-maintenance compared to some other database management systems. Nonetheless, appropriate attention to these tasks will go far towards ensuring a pleasant and productive experience with the system.

24.1. Routine Vacuuming

PostgreSQL databases require periodic maintenance known as *vacuuming*. For many installations, it is sufficient to let vacuuming be performed by the *autovacuum daemon*, which is described in Section 24.1.6. You might need to adjust the autovacuuming parameters described there to obtain best results for your situation. Some database administrators will want to supplement or replace the daemon's activities with manually-managed `VACUUM` commands, which typically are executed according to a schedule by cron or Task Scheduler scripts. To set up manually-managed vacuuming properly, it is essential to understand the issues discussed in the next few subsections. Administrators who rely on autovacuuming may still wish to skim this material to help them understand and adjust autovacuuming.

24.1.1. Vacuuming Basics

PostgreSQL's `VACUUM` command has to process each table on a regular basis for several reasons:

1. To recover or reuse disk space occupied by updated or deleted rows.
2. To update data statistics used by the PostgreSQL query planner.
3. To update the visibility map, which speeds up index-only scans.
4. To protect against loss of very old data due to *transaction ID wraparound* or *multixact ID wrap-around*.

Each of these reasons dictates performing `VACUUM` operations of varying frequency and scope, as explained in the following subsections.

¹ https://bucardo.org/check_postgres/

There are two variants of `VACUUM`: standard `VACUUM` and `VACUUM FULL`. `VACUUM FULL` can reclaim more disk space but runs much more slowly. Also, the standard form of `VACUUM` can run in parallel with production database operations. (Commands such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE` will continue to function normally, though you will not be able to modify the definition of a table with commands such as `ALTER TABLE` while it is being vacuumed.) `VACUUM FULL` requires exclusive lock on the table it is working on, and therefore cannot be done in parallel with other use of the table. Generally, therefore, administrators should strive to use standard `VACUUM` and avoid `VACUUM FULL`.

`VACUUM` creates a substantial amount of I/O traffic, which can cause poor performance for other active sessions. There are configuration parameters that can be adjusted to reduce the performance impact of background vacuuming — see Section 19.4.4.

24.1.2. Recovering Disk Space

In PostgreSQL, an `UPDATE` or `DELETE` of a row does not immediately remove the old version of the row. This approach is necessary to gain the benefits of multiversion concurrency control (MVCC, see Chapter 13): the row version must not be deleted while it is still potentially visible to other transactions. But eventually, an outdated or deleted row version is no longer of interest to any transaction. The space it occupies must then be reclaimed for reuse by new rows, to avoid unbounded growth of disk space requirements. This is done by running `VACUUM`.

The standard form of `VACUUM` removes dead row versions in tables and indexes and marks the space available for future reuse. However, it will not return the space to the operating system, except in the special case where one or more pages at the end of a table become entirely free and an exclusive table lock can be easily obtained. In contrast, `VACUUM FULL` actively compacts tables by writing a complete new version of the table file with no dead space. This minimizes the size of the table, but can take a long time. It also requires extra disk space for the new copy of the table, until the operation completes.

The usual goal of routine vacuuming is to do standard `VACUUM`s often enough to avoid needing `VACUUM FULL`. The autovacuum daemon attempts to work this way, and in fact will never issue `VACUUM FULL`. In this approach, the idea is not to keep tables at their minimum size, but to maintain steady-state usage of disk space: each table occupies space equivalent to its minimum size plus however much space gets used up between vacuumings. Although `VACUUM FULL` can be used to shrink a table back to its minimum size and return the disk space to the operating system, there is not much point in this if the table will just grow again in the future. Thus, moderately-frequent standard `VACUUM` runs are a better approach than infrequent `VACUUM FULL` runs for maintaining heavily-updated tables.

Some administrators prefer to schedule vacuuming themselves, for example doing all the work at night when load is low. The difficulty with doing vacuuming according to a fixed schedule is that if a table has an unexpected spike in update activity, it may get bloated to the point that `VACUUM FULL` is really necessary to reclaim space. Using the autovacuum daemon alleviates this problem, since the daemon schedules vacuuming dynamically in response to update activity. It is unwise to disable the daemon completely unless you have an extremely predictable workload. One possible compromise is to set the daemon's parameters so that it will only react to unusually heavy update activity, thus keeping things from getting out of hand, while scheduled `VACUUM`s are expected to do the bulk of the work when the load is typical.

For those not using autovacuum, a typical approach is to schedule a database-wide `VACUUM` once a day during a low-usage period, supplemented by more frequent vacuuming of heavily-updated tables as necessary. (Some installations with extremely high update rates vacuum their busiest tables as often as once every few minutes.) If you have multiple databases in a cluster, don't forget to `VACUUM` each one; the program `vacuumdb` might be helpful.

Tip

Plain `VACUUM` may not be satisfactory when a table contains large numbers of dead row versions as a result of massive update or delete activity. If you have such a table

and you need to reclaim the excess disk space it occupies, you will need to use `VACUUM FULL`, or alternatively `CLUSTER` or one of the table-rewriting variants of `ALTER TABLE`. These commands rewrite an entire new copy of the table and build new indexes for it. All these options require exclusive lock. Note that they also temporarily use extra disk space approximately equal to the size of the table, since the old copies of the table and indexes can't be released until the new ones are complete.

Tip

If you have a table whose entire contents are deleted on a periodic basis, consider doing it with `TRUNCATE` rather than using `DELETE` followed by `VACUUM`. `TRUNCATE` removes the entire content of the table immediately, without requiring a subsequent `VACUUM` or `VACUUM FULL` to reclaim the now-unused disk space. The disadvantage is that strict MVCC semantics are violated.

24.1.3. Updating Planner Statistics

The PostgreSQL query planner relies on statistical information about the contents of tables in order to generate good plans for queries. These statistics are gathered by the `ANALYZE` command, which can be invoked by itself or as an optional step in `VACUUM`. It is important to have reasonably accurate statistics, otherwise poor choices of plans might degrade database performance.

The autovacuum daemon, if enabled, will automatically issue `ANALYZE` commands whenever the content of a table has changed sufficiently. However, administrators might prefer to rely on manually-scheduled `ANALYZE` operations, particularly if it is known that update activity on a table will not affect the statistics of “interesting” columns. The daemon schedules `ANALYZE` strictly as a function of the number of rows inserted or updated; it has no knowledge of whether that will lead to meaningful statistical changes.

As with vacuuming for space recovery, frequent updates of statistics are more useful for heavily-updated tables than for seldom-updated ones. But even for a heavily-updated table, there might be no need for statistics updates if the statistical distribution of the data is not changing much. A simple rule of thumb is to think about how much the minimum and maximum values of the columns in the table change. For example, a `timestamp` column that contains the time of row update will have a constantly-increasing maximum value as rows are added and updated; such a column will probably need more frequent statistics updates than, say, a column containing URLs for pages accessed on a website. The URL column might receive changes just as often, but the statistical distribution of its values probably changes relatively slowly.

It is possible to run `ANALYZE` on specific tables and even just specific columns of a table, so the flexibility exists to update some statistics more frequently than others if your application requires it. In practice, however, it is usually best to just analyze the entire database, because it is a fast operation. `ANALYZE` uses a statistically random sampling of the rows of a table rather than reading every single row.

Tip

Although per-column tweaking of `ANALYZE` frequency might not be very productive, you might find it worthwhile to do per-column adjustment of the level of detail of the statistics collected by `ANALYZE`. Columns that are heavily used in `WHERE` clauses and have highly irregular data distributions might require a finer-grain data histogram than other columns. See `ALTER TABLE SET STATISTICS`, or change the database-wide default using the `default_statistics_target` configuration parameter.

Also, by default there is limited information available about the selectivity of functions. However, if you create an expression index that uses a function call, useful statistics

will be gathered about the function, which can greatly improve query plans that use the expression index.

Tip

The autovacuum daemon does not issue `ANALYZE` commands for foreign tables, since it has no means of determining how often that might be useful. If your queries require statistics on foreign tables for proper planning, it's a good idea to run manually-managed `ANALYZE` commands on those tables on a suitable schedule.

24.1.4. Updating the Visibility Map

Vacuum maintains a visibility map for each table to keep track of which pages contain only tuples that are known to be visible to all active transactions (and all future transactions, until the page is again modified). This has two purposes. First, vacuum itself can skip such pages on the next run, since there is nothing to clean up.

Second, it allows PostgreSQL to answer some queries using only the index, without reference to the underlying table. Since PostgreSQL indexes don't contain tuple visibility information, a normal index scan fetches the heap tuple for each matching index entry, to check whether it should be seen by the current transaction. An *index-only scan*, on the other hand, checks the visibility map first. If it's known that all tuples on the page are visible, the heap fetch can be skipped. This is most useful on large data sets where the visibility map can prevent disk accesses. The visibility map is vastly smaller than the heap, so it can easily be cached even when the heap is very large.

24.1.5. Preventing Transaction ID Wraparound Failures

PostgreSQL's MVCC transaction semantics depend on being able to compare transaction ID (XID) numbers: a row version with an insertion XID greater than the current transaction's XID is “in the future” and should not be visible to the current transaction. But since transaction IDs have limited size (32 bits) a cluster that runs for a long time (more than 4 billion transactions) would suffer *transaction ID wraparound*: the XID counter wraps around to zero, and all of a sudden transactions that were in the past appear to be in the future — which means their output become invisible. In short, catastrophic data loss. (Actually the data is still there, but that's cold comfort if you cannot get at it.) To avoid this, it is necessary to vacuum every table in every database at least once every two billion transactions.

The reason that periodic vacuuming solves the problem is that `VACUUM` will mark rows as *frozen*, indicating that they were inserted by a transaction that committed sufficiently far in the past that the effects of the inserting transaction are certain to be visible to all current and future transactions. Normal XIDs are compared using modulo-2³² arithmetic. This means that for every normal XID, there are two billion XIDs that are “older” and two billion that are “newer”; another way to say it is that the normal XID space is circular with no endpoint. Therefore, once a row version has been created with a particular normal XID, the row version will appear to be “in the past” for the next two billion transactions, no matter which normal XID we are talking about. If the row version still exists after more than two billion transactions, it will suddenly appear to be in the future. To prevent this, PostgreSQL reserves a special XID, `FrozenTransactionId`, which does not follow the normal XID comparison rules and is always considered older than every normal XID. Frozen row versions are treated as if the inserting XID were `FrozenTransactionId`, so that they will appear to be “in the past” to all normal transactions regardless of wraparound issues, and so such row versions will be valid until deleted, no matter how long that is.

Note

In PostgreSQL versions before 9.4, freezing was implemented by actually replacing a row's insertion XID with `FrozenTransactionId`, which was visible in the row's

`xmin` system column. Newer versions just set a flag bit, preserving the row's original `xmin` for possible forensic use. However, rows with `xmin` equal to `FrozenTransactionId` (2) may still be found in databases `pg_upgrade`'d from pre-9.4 versions.

Also, system catalogs may contain rows with `xmin` equal to `BootstrapTransactionId` (1), indicating that they were inserted during the first phase of `initdb`. Like `FrozenTransactionId`, this special XID is treated as older than every normal XID.

`vacuum_freeze_min_age` controls how old an XID value has to be before rows bearing that XID will be frozen. Increasing this setting may avoid unnecessary work if the rows that would otherwise be frozen will soon be modified again, but decreasing this setting increases the number of transactions that can elapse before the table must be vacuumed again.

VACUUM uses the visibility map to determine which pages of a table must be scanned. Normally, it will skip pages that don't have any dead row versions even if those pages might still have row versions with old XID values. Therefore, normal VACUUMs won't always freeze every old row version in the table. Periodically, VACUUM will perform an *aggressive vacuum*, skipping only those pages which contain neither dead rows nor any unfrozen XID or MXID values. `vacuum_freeze_table_age` controls when VACUUM does that: all-visible but not all-frozen pages are scanned if the number of transactions that have passed since the last such scan is greater than `vacuum_freeze_table_age` minus `vacuum_freeze_min_age`. Setting `vacuum_freeze_table_age` to 0 forces VACUUM to use this more aggressive strategy for all scans.

The maximum time that a table can go unvacuumed is two billion transactions minus the `vacuum_freeze_min_age` value at the time of the last aggressive vacuum. If it were to go unvacuumed for longer than that, data loss could result. To ensure that this does not happen, autovacuum is invoked on any table that might contain unfrozen rows with XIDs older than the age specified by the configuration parameter `autovacuum_freeze_max_age`. (This will happen even if autovacuum is disabled.)

This implies that if a table is not otherwise vacuumed, autovacuum will be invoked on it approximately once every `autovacuum_freeze_max_age` minus `vacuum_freeze_min_age` transactions. For tables that are regularly vacuumed for space reclamation purposes, this is of little importance. However, for static tables (including tables that receive inserts, but no updates or deletes), there is no need to vacuum for space reclamation, so it can be useful to try to maximize the interval between forced autovacuum on very large static tables. Obviously one can do this either by increasing `autovacuum_freeze_max_age` or decreasing `vacuum_freeze_min_age`.

The effective maximum for `vacuum_freeze_table_age` is $0.95 * \text{autovacuum_freeze_max_age}$; a setting higher than that will be capped to the maximum. A value higher than `autovacuum_freeze_max_age` wouldn't make sense because an anti-wraparound autovacuum would be triggered at that point anyway, and the 0.95 multiplier leaves some breathing room to run a manual VACUUM before that happens. As a rule of thumb, `vacuum_freeze_table_age` should be set to a value somewhat below `autovacuum_freeze_max_age`, leaving enough gap so that a regularly scheduled VACUUM or an autovacuum triggered by normal delete and update activity is run in that window. Setting it too close could lead to anti-wraparound autovacuum, even though the table was recently vacuumed to reclaim space, whereas lower values lead to more frequent aggressive vacuuming.

The sole disadvantage of increasing `autovacuum_freeze_max_age` (and `vacuum_freeze_table_age` along with it) is that the `pg_xact` and `pg_commit_ts` subdirectories of the database cluster will take more space, because it must store the commit status and (if `track_commit_timestamp` is enabled) timestamp of all transactions back to the `autovacuum_freeze_max_age` horizon. The commit status uses two bits per transaction, so if `autovacuum_freeze_max_age` is set to its maximum allowed value of two billion, `pg_xact` can be expected to grow to about half a gigabyte and `pg_commit_ts` to about 20GB. If this is trivial compared to your total database size, setting `autovacuum_freeze_max_age` to its maximum allowed value is recommended. Otherwise, set it depending on what you are willing to allow for `pg_xact` and

`pg_commit_ts` storage. (The default, 200 million transactions, translates to about 50MB of `pg_xact` storage and about 2GB of `pg_commit_ts` storage.)

One disadvantage of decreasing `vacuum_freeze_min_age` is that it might cause `VACUUM` to do useless work: freezing a row version is a waste of time if the row is modified soon thereafter (causing it to acquire a new `XID`). So the setting should be large enough that rows are not frozen until they are unlikely to change any more.

To track the age of the oldest unfrozen `XIDs` in a database, `VACUUM` stores `XID` statistics in the system tables `pg_class` and `pg_database`. In particular, the `relfrozenxid` column of a table's `pg_class` row contains the freeze cutoff `XID` that was used by the last aggressive `VACUUM` for that table. All rows inserted by transactions with `XIDs` older than this cutoff `XID` are guaranteed to have been frozen. Similarly, the `datfrozenxid` column of a database's `pg_database` row is a lower bound on the unfrozen `XIDs` appearing in that database — it is just the minimum of the portable `relfrozenxid` values within the database. A convenient way to examine this information is to execute queries such as:

```
SELECT c.oid::regclass as table_name,  
       greatest(age(c.relfrozenxid),age(t.relfrozenxid)) as age  
FROM pg_class c  
LEFT JOIN pg_class t ON c.reltoastrelid = t.oid  
WHERE c.relkind IN ('r', 'm');
```

```
SELECT datname, age(datfrozenxid) FROM pg_database;
```

The `age` column measures the number of transactions from the cutoff `XID` to the current transaction's `XID`.

`VACUUM` normally only scans pages that have been modified since the last vacuum, but `relfrozenxid` can only be advanced when every page of the table that might contain unfrozen `XIDs` is scanned. This happens when `relfrozenxid` is more than `vacuum_freeze_table_age` transactions old, when `VACUUM`'s `FREEZE` option is used, or when all pages that are not already all-frozen happen to require vacuuming to remove dead row versions. When `VACUUM` scans every page in the table that is not already all-frozen, it should set `age(relfrozenxid)` to a value just a little more than the `vacuum_freeze_min_age` setting that was used (more by the number of transactions started since the `VACUUM` started). If no `relfrozenxid`-advancing `VACUUM` is issued on the table until `autovacuum_freeze_max_age` is reached, an `autovacuum` will soon be forced for the table.

If for some reason `autovacuum` fails to clear old `XIDs` from a table, the system will begin to emit warning messages like this when the database's oldest `XIDs` reach ten million transactions from the wraparound point:

```
WARNING: database "mydb" must be vacuumed within 177009986  
        transactions  
HINT:   To avoid a database shutdown, execute a database-wide VACUUM  
        in "mydb".
```

(A manual `VACUUM` should fix the problem, as suggested by the hint; but note that the `VACUUM` must be performed by a superuser, else it will fail to process system catalogs and thus not be able to advance the database's `datfrozenxid`.) If these warnings are ignored, the system will shut down and refuse to start any new transactions once there are fewer than 1 million transactions left until wraparound:

```
ERROR: database is not accepting commands to avoid wraparound data  
       loss in database "mydb"  
HINT:   Stop the postmaster and vacuum that database in single-user  
       mode.
```

The 1-million-transaction safety margin exists to let the administrator recover without data loss, by manually executing the required `VACUUM` commands. However, since the system will not execute commands once it has gone into the safety shutdown mode, the only way to do this is to stop the server and start the server in single-user mode to execute `VACUUM`. The shutdown mode is not enforced in single-user mode. See the postgres reference page for details about using single-user mode.

24.1.5.1. Multixacts and Wraparound

Multixact IDs are used to support row locking by multiple transactions. Since there is only limited space in a tuple header to store lock information, that information is encoded as a “multiple transaction ID”, or multixact ID for short, whenever there is more than one transaction concurrently locking a row. Information about which transaction IDs are included in any particular multixact ID is stored separately in the `pg_multixact` subdirectory, and only the multixact ID appears in the `xmax` field in the tuple header. Like transaction IDs, multixact IDs are implemented as a 32-bit counter and corresponding storage, all of which requires careful aging management, storage cleanup, and wraparound handling. There is a separate storage area which holds the list of members in each multixact, which also uses a 32-bit counter and which must also be managed.

Whenever `VACUUM` scans any part of a table, it will replace any multixact ID it encounters which is older than `vacuum_multixact_freeze_min_age` by a different value, which can be the zero value, a single transaction ID, or a newer multixact ID. For each table, `pg_class.relminmxid` stores the oldest possible multixact ID still appearing in any tuple of that table. If this value is older than `vacuum_multixact_freeze_table_age`, an aggressive vacuum is forced. As discussed in the previous section, an aggressive vacuum means that only those pages which are known to be all-frozen will be skipped. `mxid_age()` can be used on `pg_class.relminmxid` to find its age.

Aggressive `VACUUM` scans, regardless of what causes them, enable advancing the value for that table. Eventually, as all tables in all databases are scanned and their oldest multixact values are advanced, on-disk storage for older multixacts can be removed.

As a safety device, an aggressive vacuum scan will occur for any table whose multixact-age is greater than `autovacuum_multixact_freeze_max_age`. Aggressive vacuum scans will also occur progressively for all tables, starting with those that have the oldest multixact-age, if the amount of used member storage space exceeds the amount 50% of the addressable storage space. Both of these kinds of aggressive scans will occur even if `autovacuum` is nominally disabled.

24.1.6. The Autovacuum Daemon

PostgreSQL has an optional but highly recommended feature called *autovacuum*, whose purpose is to automate the execution of `VACUUM` and `ANALYZE` commands. When enabled, `autovacuum` checks for tables that have had a large number of inserted, updated or deleted tuples. These checks use the statistics collection facility; therefore, `autovacuum` cannot be used unless `track_counts` is set to `true`. In the default configuration, `autovacuuming` is enabled and the related configuration parameters are appropriately set.

The “autovacuum daemon” actually consists of multiple processes. There is a persistent daemon process, called the *autovacuum launcher*, which is in charge of starting *autovacuum worker* processes for all databases. The launcher will distribute the work across time, attempting to start one worker within each database every `autovacuum_naptime` seconds. (Therefore, if the installation has N databases, a new worker will be launched every $\text{autovacuum_naptime}/N$ seconds.) A maximum of `autovacuum_max_workers` worker processes are allowed to run at the same time. If there are more than `autovacuum_max_workers` databases to be processed, the next database will be processed as soon as the first worker finishes. Each worker process will check each table within its database and execute `VACUUM` and/or `ANALYZE` as needed. `log_autovacuum_min_duration` can be set to monitor `autovacuum workers'` activity.

If several large tables all become eligible for vacuuming in a short amount of time, all `autovacuum workers` might become occupied with vacuuming those tables for a long period. This would result in

other tables and databases not being vacuumed until a worker becomes available. There is no limit on how many workers might be in a single database, but workers do try to avoid repeating work that has already been done by other workers. Note that the number of running workers does not count towards `max_connections` or `superuser_reserved_connections` limits.

Tables whose `relfrozenxid` value is more than `autovacuum_freeze_max_age` transactions old are always vacuumed (this also applies to those tables whose freeze max age has been modified via storage parameters; see below). Otherwise, if the number of tuples obsoleted since the last `VACUUM` exceeds the “vacuum threshold”, the table is vacuumed. The vacuum threshold is defined as:

```
vacuum threshold = vacuum base threshold + vacuum scale factor *  
number of tuples
```

where the vacuum base threshold is `autovacuum_vacuum_threshold`, the vacuum scale factor is `autovacuum_vacuum_scale_factor`, and the number of tuples is `pg_class.rel tuples`. The number of obsolete tuples is obtained from the statistics collector; it is a semi-accurate count updated by each `UPDATE` and `DELETE` operation. (It is only semi-accurate because some information might be lost under heavy load.) If the `relfrozenxid` value of the table is more than `vacuum_freeze_table_age` transactions old, an aggressive vacuum is performed to freeze old tuples and advance `relfrozenxid`; otherwise, only pages that have been modified since the last vacuum are scanned.

For analyze, a similar condition is used: the threshold, defined as:

```
analyze threshold = analyze base threshold + analyze scale factor *  
number of tuples
```

is compared to the total number of tuples inserted, updated, or deleted since the last `ANALYZE`.

Temporary tables cannot be accessed by autovacuum. Therefore, appropriate vacuum and analyze operations should be performed via session SQL commands.

The default thresholds and scale factors are taken from `postgresql.conf`, but it is possible to override them (and many other autovacuum control parameters) on a per-table basis; see [Storage Parameters](#) for more information. If a setting has been changed via a table's storage parameters, that value is used when processing that table; otherwise the global settings are used. See [Section 19.10](#) for more details on the global settings.

When multiple workers are running, the autovacuum cost delay parameters (see [Section 19.4.4](#)) are “balanced” among all the running workers, so that the total I/O impact on the system is the same regardless of the number of workers actually running. However, any workers processing tables whose per-table `autovacuum_vacuum_cost_delay` or `autovacuum_vacuum_cost_limit` storage parameters have been set are not considered in the balancing algorithm.

Autovacuum workers generally don't block other commands. If a process attempts to acquire a lock that conflicts with the `SHARE UPDATE EXCLUSIVE` lock held by autovacuum, lock acquisition will interrupt the autovacuum. For conflicting lock modes, see [Table 13.2](#). However, if the autovacuum is running to prevent transaction ID wraparound (i.e., the autovacuum query name in the `pgstatt_activity` view ends with `(to prevent wraparound)`), the autovacuum is not automatically interrupted.

Warning

Regularly running commands that acquire locks conflicting with a `SHARE UPDATE EXCLUSIVE` lock (e.g., `ANALYZE`) can effectively prevent autovacuum from ever completing.

24.2. Routine Reindexing

In some situations it is worthwhile to rebuild indexes periodically with the `REINDEX` command or a series of individual rebuilding steps.

B-tree index pages that have become completely empty are reclaimed for re-use. However, there is still a possibility of inefficient use of space: if all but a few index keys on a page have been deleted, the page remains allocated. Therefore, a usage pattern in which most, but not all, keys in each range are eventually deleted will see poor use of space. For such usage patterns, periodic reindexing is recommended.

The potential for bloat in non-B-tree indexes has not been well researched. It is a good idea to periodically monitor the index's physical size when using any non-B-tree index type.

Also, for B-tree indexes, a freshly-constructed index is slightly faster to access than one that has been updated many times because logically adjacent pages are usually also physically adjacent in a newly built index. (This consideration does not apply to non-B-tree indexes.) It might be worthwhile to reindex periodically just to improve access speed.

`REINDEX` can be used safely and easily in all cases. This command requires an `ACCESS EXCLUSIVE` lock by default, hence it is often preferable to execute it with its `CONCURRENTLY` option, which requires only a `SHARE UPDATE EXCLUSIVE` lock.

24.3. Log File Maintenance

It is a good idea to save the database server's log output somewhere, rather than just discarding it via `/dev/null`. The log output is invaluable when diagnosing problems. However, the log output tends to be voluminous (especially at higher debug levels) so you won't want to save it indefinitely. You need to *rotate* the log files so that new log files are started and old ones removed after a reasonable period of time.

If you simply direct the `stderr` of `postgres` into a file, you will have log output, but the only way to truncate the log file is to stop and restart the server. This might be acceptable if you are using PostgreSQL in a development environment, but few production servers would find this behavior acceptable.

A better approach is to send the server's `stderr` output to some type of log rotation program. There is a built-in log rotation facility, which you can use by setting the configuration parameter `logging_collector` to `true` in `postgresql.conf`. The control parameters for this program are described in Section 19.8.1. You can also use this approach to capture the log data in machine readable CSV (comma-separated values) format.

Alternatively, you might prefer to use an external log rotation program if you have one that you are already using with other server software. For example, the `rotatelogs` tool included in the Apache distribution can be used with PostgreSQL. One way to do this is to pipe the server's `stderr` output to the desired program. If you start the server with `pg_ctl`, then `stderr` is already redirected to `stdout`, so you just need a pipe command, for example:

```
pg_ctl start | rotatelogs /var/log/pgsql_log 86400
```

You can combine these approaches by setting up `logrotate` to collect log files produced by PostgreSQL built-in logging collector. In this case, the logging collector defines the names and location of the log files, while `logrotate` periodically archives these files. When initiating log rotation, `logrotate` must ensure that the application sends further output to the new file. This is commonly done with a `postrotate` script that sends a `SIGHUP` signal to the application, which then reopens the log file. In PostgreSQL, you can run `pg_ctl` with the `logrotate` option instead. When the server receives this command, the server either switches to a new log file or reopens the existing file, depending on the logging configuration (see Section 19.8.1).

Note

When using static log file names, the server might fail to reopen the log file if the max open file limit is reached or a file table overflow occurs. In this case, log messages are sent to the old log file until a successful log rotation. If `logrotate` is configured to compress the log file and delete it, the server may lose the messages logged in this timeframe. To avoid this issue, you can configure the logging collector to dynamically assign log file names and use a `prerotate` script to ignore open log files.

Another production-grade approach to managing log output is to send it to `syslog` and let `syslog` deal with file rotation. To do this, set the configuration parameter `log_destination` to `syslog` (to log to `syslog` only) in `postgresql.conf`. Then you can send a `SIGHUP` signal to the `syslog` daemon whenever you want to force it to start writing a new log file. If you want to automate log rotation, the `logrotate` program can be configured to work with log files from `syslog`.

On many systems, however, `syslog` is not very reliable, particularly with large log messages; it might truncate or drop messages just when you need them the most. Also, on Linux, `syslog` will flush each message to disk, yielding poor performance. (You can use a “-” at the start of the file name in the `syslog` configuration file to disable syncing.)

Note that all the solutions described above take care of starting new log files at configurable intervals, but they do not handle deletion of old, no-longer-useful log files. You will probably want to set up a batch job to periodically delete old log files. Another possibility is to configure the rotation program so that old log files are overwritten cyclically.

`pgBadger`² is an external project that does sophisticated log file analysis. `check_postgres`³ provides Nagios alerts when important messages appear in the log files, as well as detection of many other extraordinary conditions.

² <https://pgbadger.darold.net/>

³ https://bucardo.org/check_postgres/

Chapter 25. Backup and Restore

As with everything that contains valuable data, PostgreSQL databases should be backed up regularly. While the procedure is essentially simple, it is important to have a clear understanding of the underlying techniques and assumptions.

There are three fundamentally different approaches to backing up PostgreSQL data:

- SQL dump
- File system level backup
- Continuous archiving

Each has its own strengths and weaknesses; each is discussed in turn in the following sections.

25.1. SQL Dump

The idea behind this dump method is to generate a file with SQL commands that, when fed back to the server, will recreate the database in the same state as it was at the time of the dump. PostgreSQL provides the utility program `pg_dump` for this purpose. The basic usage of this command is:

```
pg_dump dbname > dumpfile
```

As you see, `pg_dump` writes its result to the standard output. We will see below how this can be useful. While the above command creates a text file, `pg_dump` can create files in other formats that allow for parallelism and more fine-grained control of object restoration.

`pg_dump` is a regular PostgreSQL client application (albeit a particularly clever one). This means that you can perform this backup procedure from any remote host that has access to the database. But remember that `pg_dump` does not operate with special permissions. In particular, it must have read access to all tables that you want to back up, so in order to back up the entire database you almost always have to run it as a database superuser. (If you do not have sufficient privileges to back up the entire database, you can still back up portions of the database to which you do have access using options such as `-n schema` or `-t table`.)

To specify which database server `pg_dump` should contact, use the command line options `-h host` and `-p port`. The default host is the local host or whatever your `PGHOST` environment variable specifies. Similarly, the default port is indicated by the `PGPORT` environment variable or, failing that, by the compiled-in default. (Conveniently, the server will normally have the same compiled-in default.)

Like any other PostgreSQL client application, `pg_dump` will by default connect with the database user name that is equal to the current operating system user name. To override this, either specify the `-U` option or set the environment variable `PGUSER`. Remember that `pg_dump` connections are subject to the normal client authentication mechanisms (which are described in Chapter 20).

An important advantage of `pg_dump` over the other backup methods described later is that `pg_dump`'s output can generally be re-loaded into newer versions of PostgreSQL, whereas file-level backups and continuous archiving are both extremely server-version-specific. `pg_dump` is also the only method that will work when transferring a database to a different machine architecture, such as going from a 32-bit to a 64-bit server.

Dumps created by `pg_dump` are internally consistent, meaning, the dump represents a snapshot of the database at the time `pg_dump` began running. `pg_dump` does not block other operations on the database while it is working. (Exceptions are those operations that need to operate with an exclusive lock, such as most forms of `ALTER TABLE`.)

25.1.1. Restoring the Dump

Text files created by `pg_dump` are intended to be read in by the `psql` program. The general command form to restore a dump is

```
psql dbname < dumpfile
```

where *dumpfile* is the file output by the `pg_dump` command. The database *dbname* will not be created by this command, so you must create it yourself from `template0` before executing `psql` (e.g., with `createdb -T template0 dbname`). `psql` supports options similar to `pg_dump` for specifying the database server to connect to and the user name to use. See the `psql` reference page for more information. Non-text file dumps are restored using the `pg_restore` utility.

Before restoring an SQL dump, all the users who own objects or were granted permissions on objects in the dumped database must already exist. If they do not, the restore will fail to recreate the objects with the original ownership and/or permissions. (Sometimes this is what you want, but usually it is not.)

By default, the `psql` script will continue to execute after an SQL error is encountered. You might wish to run `psql` with the `ON_ERROR_STOP` variable set to alter that behavior and have `psql` exit with an exit status of 3 if an SQL error occurs:

```
psql --set ON_ERROR_STOP=on dbname < dumpfile
```

Either way, you will only have a partially restored database. Alternatively, you can specify that the whole dump should be restored as a single transaction, so the restore is either fully completed or fully rolled back. This mode can be specified by passing the `-1` or `--single-transaction` command-line options to `psql`. When using this mode, be aware that even a minor error can rollback a restore that has already run for many hours. However, that might still be preferable to manually cleaning up a complex database after a partially restored dump.

The ability of `pg_dump` and `psql` to write to or read from pipes makes it possible to dump a database directly from one server to another, for example:

```
pg_dump -h host1 dbname | psql -h host2 dbname
```

Important

The dumps produced by `pg_dump` are relative to `template0`. This means that any languages, procedures, etc. added via `template1` will also be dumped by `pg_dump`. As a result, when restoring, if you are using a customized `template1`, you must create the empty database from `template0`, as in the example above.

After restoring a backup, it is wise to run `ANALYZE` on each database so the query optimizer has useful statistics; see Section 24.1.3 and Section 24.1.6 for more information. For more advice on how to load large amounts of data into PostgreSQL efficiently, refer to Section 14.4.

25.1.2. Using `pg_dumpall`

`pg_dump` dumps only a single database at a time, and it does not dump information about roles or tablespaces (because those are cluster-wide rather than per-database). To support convenient dumping of the entire contents of a database cluster, the `pg_dumpall` program is provided. `pg_dumpall` backs up each database in a given cluster, and also preserves cluster-wide data such as role and tablespace definitions. The basic usage of this command is:

```
pg_dumpall > dumpfile
```

The resulting dump can be restored with `psql`:

```
psql -f dumpfile postgres
```

(Actually, you can specify any existing database name to start from, but if you are loading into an empty cluster then `postgres` should usually be used.) It is always necessary to have database superuser access when restoring a `pg_dumpall` dump, as that is required to restore the role and tablespace information. If you use tablespaces, make sure that the tablespace paths in the dump are appropriate for the new installation.

`pg_dumpall` works by emitting commands to re-create roles, tablespaces, and empty databases, then invoking `pg_dump` for each database. This means that while each database will be internally consistent, the snapshots of different databases are not synchronized.

Cluster-wide data can be dumped alone using the `pg_dumpall --globals-only` option. This is necessary to fully backup the cluster if running the `pg_dump` command on individual databases.

25.1.3. Handling Large Databases

Some operating systems have maximum file size limits that cause problems when creating large `pg_dump` output files. Fortunately, `pg_dump` can write to the standard output, so you can use standard Unix tools to work around this potential problem. There are several possible methods:

Use compressed dumps. You can use your favorite compression program, for example `gzip`:

```
pg_dump dbname | gzip > filename.gz
```

Reload with:

```
gunzip -c filename.gz | psql dbname
```

or:

```
cat filename.gz | gunzip | psql dbname
```

Use `split`. The `split` command allows you to split the output into smaller files that are acceptable in size to the underlying file system. For example, to make chunks of 1 megabyte:

```
pg_dump dbname | split -b 1m - filename
```

Reload with:

```
cat filename* | psql dbname
```

Use `pg_dump`'s custom dump format. If PostgreSQL was built on a system with the `zlib` compression library installed, the custom dump format will compress data as it writes it to the output file. This will produce dump file sizes similar to using `gzip`, but it has the added advantage that tables can be restored selectively. The following command dumps a database using the custom dump format:

```
pg_dump -Fc dbname > filename
```

A custom-format dump is not a script for `psql`, but instead must be restored with `pg_restore`, for example:

```
pg_restore -d dbname filename
```

See the `pg_dump` and `pg_restore` reference pages for details.

For very large databases, you might need to combine `split` with one of the other two approaches.

Use `pg_dump`'s parallel dump feature. To speed up the dump of a large database, you can use `pg_dump`'s parallel mode. This will dump multiple tables at the same time. You can control the degree of parallelism with the `-j` parameter. Parallel dumps are only supported for the "directory" archive format.

```
pg_dump -j num -F d -f out.dir dbname
```

You can use `pg_restore -j` to restore a dump in parallel. This will work for any archive of either the "custom" or the "directory" archive mode, whether or not it has been created with `pg_dump -j`.

25.2. File System Level Backup

An alternative backup strategy is to directly copy the files that PostgreSQL uses to store the data in the database; Section 18.2 explains where these files are located. You can use whatever method you prefer for doing file system backups; for example:

```
tar -cf backup.tar /usr/local/pgsql/data
```

There are two restrictions, however, which make this method impractical, or at least inferior to the `pg_dump` method:

1. The database server *must* be shut down in order to get a usable backup. Half-way measures such as disallowing all connections will *not* work (in part because `tar` and similar tools do not take an atomic snapshot of the state of the file system, but also because of internal buffering within the server). Information about stopping the server can be found in Section 18.5. Needless to say, you also need to shut down the server before restoring the data.
2. If you have dug into the details of the file system layout of the database, you might be tempted to try to back up or restore only certain individual tables or databases from their respective files or directories. This will *not* work because the information contained in these files is not usable without the commit log files, `pg_xact/*`, which contain the commit status of all transactions. A table file is only usable with this information. Of course it is also impossible to restore only a table and the associated `pg_xact` data because that would render all other tables in the database cluster useless. So file system backups only work for complete backup and restoration of an entire database cluster.

An alternative file-system backup approach is to make a "consistent snapshot" of the data directory, if the file system supports that functionality (and you are willing to trust that it is implemented correctly). The typical procedure is to make a "frozen snapshot" of the volume containing the database, then copy the whole data directory (not just parts, see above) from the snapshot to a backup device, then release the frozen snapshot. This will work even while the database server is running. However, a backup created in this way saves the database files in a state as if the database server was not properly shut down; therefore, when you start the database server on the backed-up data, it will think the previous server instance crashed and will replay the WAL log. This is not a problem; just be aware of it (and be sure to include the WAL files in your backup). You can perform a `CHECKPOINT` before taking the snapshot to reduce recovery time.

If your database is spread across multiple file systems, there might not be any way to obtain exactly-simultaneous frozen snapshots of all the volumes. For example, if your data files and WAL log are on different disks, or if tablespaces are on different file systems, it might not be possible to use snapshot backup because the snapshots *must* be simultaneous. Read your file system documentation very carefully before trusting the consistent-snapshot technique in such situations.

If simultaneous snapshots are not possible, one option is to shut down the database server long enough to establish all the frozen snapshots. Another option is to perform a continuous archiving base backup (Section 25.3.2) because such backups are immune to file system changes during the backup. This requires enabling continuous archiving just during the backup process; restore is done using continuous archive recovery (Section 25.3.4).

Another option is to use `rsync` to perform a file system backup. This is done by first running `rsync` while the database server is running, then shutting down the database server long enough to do an `rsync --checksum`. (`--checksum` is necessary because `rsync` only has file modification-time granularity of one second.) The second `rsync` will be quicker than the first, because it has relatively little data to transfer, and the end result will be consistent because the server was down. This method allows a file system backup to be performed with minimal downtime.

Note that a file system backup will typically be larger than an SQL dump. (`pg_dump` does not need to dump the contents of indexes for example, just the commands to recreate them.) However, taking a file system backup might be faster.

25.3. Continuous Archiving and Point-in-Time Recovery (PITR)

At all times, PostgreSQL maintains a *write ahead log* (WAL) in the `pg_wal/` subdirectory of the cluster's data directory. The log records every change made to the database's data files. This log exists primarily for crash-safety purposes: if the system crashes, the database can be restored to consistency by “replaying” the log entries made since the last checkpoint. However, the existence of the log makes it possible to use a third strategy for backing up databases: we can combine a file-system-level backup with backup of the WAL files. If recovery is needed, we restore the file system backup and then replay from the backed-up WAL files to bring the system to a current state. This approach is more complex to administer than either of the previous approaches, but it has some significant benefits:

- We do not need a perfectly consistent file system backup as the starting point. Any internal inconsistency in the backup will be corrected by log replay (this is not significantly different from what happens during crash recovery). So we do not need a file system snapshot capability, just `tar` or a similar archiving tool.
- Since we can combine an indefinitely long sequence of WAL files for replay, continuous backup can be achieved simply by continuing to archive the WAL files. This is particularly valuable for large databases, where it might not be convenient to take a full backup frequently.
- It is not necessary to replay the WAL entries all the way to the end. We could stop the replay at any point and have a consistent snapshot of the database as it was at that time. Thus, this technique supports *point-in-time recovery*: it is possible to restore the database to its state at any time since your base backup was taken.
- If we continuously feed the series of WAL files to another machine that has been loaded with the same base backup file, we have a *warm standby* system: at any point we can bring up the second machine and it will have a nearly-current copy of the database.

Note

`pg_dump` and `pg_dumpall` do not produce file-system-level backups and cannot be used as part of a continuous-archiving solution. Such dumps are *logical* and do not contain enough information to be used by WAL replay.

As with the plain file-system-backup technique, this method can only support restoration of an entire database cluster, not a subset. Also, it requires a lot of archival storage: the base backup might be bulky, and a busy system will generate many megabytes of WAL traffic that have to be archived. Still, it is the preferred backup technique in many situations where high reliability is needed.

To recover successfully using continuous archiving (also called “online backup” by many database vendors), you need a continuous sequence of archived WAL files that extends back at least as far as the start time of your backup. So to get started, you should set up and test your procedure for archiving WAL files *before* you take your first base backup. Accordingly, we first discuss the mechanics of archiving WAL files.

25.3.1. Setting Up WAL Archiving

In an abstract sense, a running PostgreSQL system produces an indefinitely long sequence of WAL records. The system physically divides this sequence into WAL *segment files*, which are normally 16MB apiece (although the segment size can be altered during `initdb`). The segment files are given numeric names that reflect their position in the abstract WAL sequence. When not using WAL archiving, the system normally creates just a few segment files and then “recycles” them by renaming no-longer-needed segment files to higher segment numbers. It’s assumed that segment files whose contents precede the last checkpoint are no longer of interest and can be recycled.

When archiving WAL data, we need to capture the contents of each segment file once it is filled, and save that data somewhere before the segment file is recycled for reuse. Depending on the application and the available hardware, there could be many different ways of “saving the data somewhere”: we could copy the segment files to an NFS-mounted directory on another machine, write them onto a tape drive (ensuring that you have a way of identifying the original name of each file), or batch them together and burn them onto CDs, or something else entirely. To provide the database administrator with flexibility, PostgreSQL tries not to make any assumptions about how the archiving will be done. Instead, PostgreSQL lets the administrator specify a shell command to be executed to copy a completed segment file to wherever it needs to go. The command could be as simple as a `cp`, or it could invoke a complex shell script — it’s all up to you.

To enable WAL archiving, set the `wal_level` configuration parameter to `replica` or higher, `archive_mode` to `on`, and specify the shell command to use in the `archive_command` configuration parameter. In practice these settings will always be placed in the `postgresql.conf` file. In `archive_command`, `%p` is replaced by the path name of the file to archive, while `%f` is replaced by only the file name. (The path name is relative to the current working directory, i.e., the cluster’s data directory.) Use `%%` if you need to embed an actual `%` character in the command. The simplest useful command is something like:

```
archive_command = 'test ! -f /mnt/server/archivedir/%f && cp %p /
mnt/server/archivedir/%f' # Unix
archive_command = 'copy "%p" "C:\\server\\archivedir\\%f"' #
Windows
```

which will copy archivable WAL segments to the directory `/mnt/server/archivedir`. (This is an example, not a recommendation, and might not work on all platforms.) After the `%p` and `%f` parameters have been replaced, the actual command executed might look like this:

```
test ! -f /mnt/server/archivedir/00000001000000A9000000065
&& cp pg_wal/00000001000000A9000000065 /mnt/server/
archivedir/00000001000000A9000000065
```

A similar command will be generated for each new file to be archived.

The archive command will be executed under the ownership of the same user that the PostgreSQL server is running as. Since the series of WAL files being archived contains effectively everything in your database, you will want to be sure that the archived data is protected from prying eyes; for example, archive into a directory that does not have group or world read access.

It is important that the archive command return zero exit status if and only if it succeeds. Upon getting a zero result, PostgreSQL will assume that the file has been successfully archived, and will remove or

recycle it. However, a nonzero status tells PostgreSQL that the file was not archived; it will try again periodically until it succeeds.

The archive command should generally be designed to refuse to overwrite any pre-existing archive file. This is an important safety feature to preserve the integrity of your archive in case of administrator error (such as sending the output of two different servers to the same archive directory).

It is advisable to test your proposed archive command to ensure that it indeed does not overwrite an existing file, *and that it returns nonzero status in this case*. The example command above for Unix ensures this by including a separate `test` step. On some Unix platforms, `cp` has switches such as `-i` that can be used to do the same thing less verbosely, but you should not rely on these without verifying that the right exit status is returned. (In particular, GNU `cp` will return status zero when `-i` is used and the target file already exists, which is *not* the desired behavior.)

While designing your archiving setup, consider what will happen if the archive command fails repeatedly because some aspect requires operator intervention or the archive runs out of space. For example, this could occur if you write to tape without an autochanger; when the tape fills, nothing further can be archived until the tape is swapped. You should ensure that any error condition or request to a human operator is reported appropriately so that the situation can be resolved reasonably quickly. The `pg_wal/` directory will continue to fill with WAL segment files until the situation is resolved. (If the file system containing `pg_wal/` fills up, PostgreSQL will do a PANIC shutdown. No committed transactions will be lost, but the database will remain offline until you free some space.)

The speed of the archiving command is unimportant as long as it can keep up with the average rate at which your server generates WAL data. Normal operation continues even if the archiving process falls a little behind. If archiving falls significantly behind, this will increase the amount of data that would be lost in the event of a disaster. It will also mean that the `pg_wal/` directory will contain large numbers of not-yet-archived segment files, which could eventually exceed available disk space. You are advised to monitor the archiving process to ensure that it is working as you intend.

In writing your archive command, you should assume that the file names to be archived can be up to 64 characters long and can contain any combination of ASCII letters, digits, and dots. It is not necessary to preserve the original relative path (`%P`) but it is necessary to preserve the file name (`%F`).

Note that although WAL archiving will allow you to restore any modifications made to the data in your PostgreSQL database, it will not restore changes made to configuration files (that is, `postgresql.conf`, `pg_hba.conf` and `pg_ident.conf`), since those are edited manually rather than through SQL operations. You might wish to keep the configuration files in a location that will be backed up by your regular file system backup procedures. See Section 19.2 for how to relocate the configuration files.

The archive command is only invoked on completed WAL segments. Hence, if your server generates only little WAL traffic (or has slack periods where it does so), there could be a long delay between the completion of a transaction and its safe recording in archive storage. To put a limit on how old unarchived data can be, you can set `archive_timeout` to force the server to switch to a new WAL segment file at least that often. Note that archived files that are archived early due to a forced switch are still the same length as completely full files. It is therefore unwise to set a very short `archive_timeout` — it will bloat your archive storage. `archive_timeout` settings of a minute or so are usually reasonable.

Also, you can force a segment switch manually with `pg_switch_wal` if you want to ensure that a just-finished transaction is archived as soon as possible. Other utility functions related to WAL management are listed in Table 9.84.

When `wal_level` is `minimal` some SQL commands are optimized to avoid WAL logging, as described in Section 14.4.7. If archiving or streaming replication were turned on during execution of one of these statements, WAL would not contain enough information for archive recovery. (Crash recovery is unaffected.) For this reason, `wal_level` can only be changed at server start. However, `archive_command` can be changed with a configuration file reload. If you wish to temporarily stop archiving, one way to do it is to set `archive_command` to the empty string (`' '`). This will cause WAL files to accumulate in `pg_wal/` until a working `archive_command` is re-established.

25.3.2. Making a Base Backup

The easiest way to perform a base backup is to use the `pg_basebackup` tool. It can create a base backup either as regular files or as a tar archive. If more flexibility than `pg_basebackup` can provide is required, you can also make a base backup using the low level API (see Section 25.3.3).

It is not necessary to be concerned about the amount of time it takes to make a base backup. However, if you normally run the server with `full_page_writes` disabled, you might notice a drop in performance while the backup runs since `full_page_writes` is effectively forced on during backup mode.

To make use of the backup, you will need to keep all the WAL segment files generated during and after the file system backup. To aid you in doing this, the base backup process creates a *backup history file* that is immediately stored into the WAL archive area. This file is named after the first WAL segment file that you need for the file system backup. For example, if the starting WAL file is `0000000100001234000055CD` the backup history file will be named something like `0000000100001234000055CD.007C9330.backup`. (The second part of the file name stands for an exact position within the WAL file, and can ordinarily be ignored.) Once you have safely archived the file system backup and the WAL segment files used during the backup (as specified in the backup history file), all archived WAL segments with names numerically less are no longer needed to recover the file system backup and can be deleted. However, you should consider keeping several backup sets to be absolutely certain that you can recover your data.

The backup history file is just a small text file. It contains the label string you gave to `pg_basebackup`, as well as the starting and ending times and WAL segments of the backup. If you used the label to identify the associated dump file, then the archived history file is enough to tell you which dump file to restore.

Since you have to keep around all the archived WAL files back to your last base backup, the interval between base backups should usually be chosen based on how much storage you want to expend on archived WAL files. You should also consider how long you are prepared to spend recovering, if recovery should be necessary — the system will have to replay all those WAL segments, and that could take awhile if it has been a long time since the last base backup.

25.3.3. Making a Base Backup Using the Low Level API

The procedure for making a base backup using the low level APIs contains a few more steps than the `pg_basebackup` method, but is relatively simple. It is very important that these steps are executed in sequence, and that the success of a step is verified before proceeding to the next step.

Low level base backups can be made in a non-exclusive or an exclusive way. The non-exclusive method is recommended and the exclusive one is deprecated and will eventually be removed.

25.3.3.1. Making a Non-Exclusive Low-Level Backup

A non-exclusive low level backup is one that allows other concurrent backups to be running (both those started using the same backup API and those started using `pg_basebackup`).

1. Ensure that WAL archiving is enabled and working.
2. Connect to the server (it does not matter which database) as a user with rights to run `pg_start_backup` (superuser, or a user who has been granted `EXECUTE` on the function) and issue the command:

```
SELECT pg_start_backup('label', false, false);
```

where `label` is any string you want to use to uniquely identify this backup operation. The connection calling `pg_start_backup` must be maintained until the end of the backup, or the backup will be automatically aborted.

By default, `pg_start_backup` can take a long time to finish. This is because it performs a checkpoint, and the I/O required for the checkpoint will be spread out over a significant period of time, by default half your inter-checkpoint interval (see the configuration parameter `checkpoint_completion_target`). This is usually what you want, because it minimizes the impact on query processing. If you want to start the backup as soon as possible, change the second parameter to `true`, which will issue an immediate checkpoint using as much I/O as available.

The third parameter being `false` tells `pg_start_backup` to initiate a non-exclusive base backup.

3. Perform the backup, using any convenient file-system-backup tool such as `tar` or `cpio` (not `pg_dump` or `pg_dumpall`). It is neither necessary nor desirable to stop normal operation of the database while you do this. See Section 25.3.3.3 for things to consider during this backup.
4. In the same connection as before, issue the command:

```
SELECT * FROM pg_stop_backup(false, true);
```

This terminates backup mode. On a primary, it also performs an automatic switch to the next WAL segment. On a standby, it is not possible to automatically switch WAL segments, so you may wish to run `pg_switch_wal` on the primary to perform a manual switch. The reason for the switch is to arrange for the last WAL segment file written during the backup interval to be ready to archive.

The `pg_stop_backup` will return one row with three values. The second of these fields should be written to a file named `backup_label` in the root directory of the backup. The third field should be written to a file named `tablespace_map` unless the field is empty. These files are vital to the backup working, and must be written without modification.

5. Once the WAL segment files active during the backup are archived, you are done. The file identified by `pg_stop_backup`'s first return value is the last segment that is required to form a complete set of backup files. On a primary, if `archive_mode` is enabled and the `wait_for_archive` parameter is `true`, `pg_stop_backup` does not return until the last segment has been archived. On a standby, `archive_mode` must be always in order for `pg_stop_backup` to wait. Archiving of these files happens automatically since you have already configured `archive_command`. In most cases this happens quickly, but you are advised to monitor your archive system to ensure there are no delays. If the archive process has fallen behind because of failures of the archive command, it will keep retrying until the archive succeeds and the backup is complete. If you wish to place a time limit on the execution of `pg_stop_backup`, set an appropriate `statement_timeout` value, but make note that if `pg_stop_backup` terminates because of this your backup may not be valid.

If the backup process monitors and ensures that all WAL segment files required for the backup are successfully archived then the `wait_for_archive` parameter (which defaults to `true`) can be set to `false` to have `pg_stop_backup` return as soon as the stop backup record is written to the WAL. By default, `pg_stop_backup` will wait until all WAL has been archived, which can take some time. This option must be used with caution: if WAL archiving is not monitored correctly then the backup might not include all of the WAL files and will therefore be incomplete and not able to be restored.

25.3.3.2. Making an Exclusive Low-Level Backup

Note

The exclusive backup method is deprecated and should be avoided. Prior to PostgreSQL 9.6, this was the only low-level method available, but it is now recommended that all users upgrade their scripts to use non-exclusive backups.

The process for an exclusive backup is mostly the same as for a non-exclusive one, but it differs in a few key steps. This type of backup can only be taken on a primary and does not allow concurrent backups. Moreover, because it creates a backup label file, as described below, it can block automatic restart of the master server after a crash. On the other hand, the erroneous removal of this file from a backup or standby is a common mistake, which can result in serious data corruption. If it is necessary to use this method, the following steps may be used.

1. Ensure that WAL archiving is enabled and working.
2. Connect to the server (it does not matter which database) as a user with rights to run `pg_start_backup` (superuser, or a user who has been granted EXECUTE on the function) and issue the command:

```
SELECT pg_start_backup('label');
```

where `label` is any string you want to use to uniquely identify this backup operation. `pg_start_backup` creates a *backup label* file, called `backup_label`, in the cluster directory with information about your backup, including the start time and label string. The function also creates a *tablespace map* file, called `tablespace_map`, in the cluster directory with information about tablespace symbolic links in `pg_tblspc/` if one or more such link is present. Both files are critical to the integrity of the backup, should you need to restore from it.

By default, `pg_start_backup` can take a long time to finish. This is because it performs a checkpoint, and the I/O required for the checkpoint will be spread out over a significant period of time, by default half your inter-checkpoint interval (see the configuration parameter `checkpoint_completion_target`). This is usually what you want, because it minimizes the impact on query processing. If you want to start the backup as soon as possible, use:

```
SELECT pg_start_backup('label', true);
```

This forces the checkpoint to be done as quickly as possible.

3. Perform the backup, using any convenient file-system-backup tool such as tar or cpio (not `pg_dump` or `pg_dumpall`). It is neither necessary nor desirable to stop normal operation of the database while you do this. See Section 25.3.3.3 for things to consider during this backup.

As noted above, if the server crashes during the backup it may not be possible to restart until the `backup_label` file has been manually deleted from the PGDATA directory. Note that it is very important to never remove the `backup_label` file when restoring a backup, because this will result in corruption. Confusion about when it is appropriate to remove this file is a common cause of data corruption when using this method; be very certain that you remove the file only on an existing master and never when building a standby or restoring a backup, even if you are building a standby that will subsequently be promoted to a new master.

4. Again connect to the database as a user with rights to run `pg_stop_backup` (superuser, or a user who has been granted EXECUTE on the function), and issue the command:

```
SELECT pg_stop_backup();
```

This function terminates backup mode and performs an automatic switch to the next WAL segment. The reason for the switch is to arrange for the last WAL segment written during the backup interval to be ready to archive.

5. Once the WAL segment files active during the backup are archived, you are done. The file identified by `pg_stop_backup`'s result is the last segment that is required to form a complete set of backup files. If `archive_mode` is enabled, `pg_stop_backup` does not return until the last segment has been archived. Archiving of these files happens automatically since you have already configured `archive_command`. In most cases this happens quickly, but you are advised to monitor your

archive system to ensure there are no delays. If the archive process has fallen behind because of failures of the archive command, it will keep retrying until the archive succeeds and the backup is complete.

When using exclusive backup mode, it is absolutely imperative to ensure that `pg_stop_backup` completes successfully at the end of the backup. Even if the backup itself fails, for example due to lack of disk space, failure to call `pg_stop_backup` will leave the server in backup mode indefinitely, causing future backups to fail and increasing the risk of a restart failure during the time that `backup_label` exists.

25.3.3.3. Backing Up the Data Directory

Some file system backup tools emit warnings or errors if the files they are trying to copy change while the copy proceeds. When taking a base backup of an active database, this situation is normal and not an error. However, you need to ensure that you can distinguish complaints of this sort from real errors. For example, some versions of `rsync` return a separate exit code for “vanished source files”, and you can write a driver script to accept this exit code as a non-error case. Also, some versions of GNU `tar` return an error code indistinguishable from a fatal error if a file was truncated while `tar` was copying it. Fortunately, GNU `tar` versions 1.16 and later exit with 1 if a file was changed during the backup, and 2 for other errors. With GNU `tar` version 1.23 and later, you can use the warning options `--warning=no-file-changed` `--warning=no-file-removed` to hide the related warning messages.

Be certain that your backup includes all of the files under the database cluster directory (e.g., `/usr/local/pgsql/data`). If you are using tablespaces that do not reside underneath this directory, be careful to include them as well (and be sure that your backup archives symbolic links as links, otherwise the restore will corrupt your tablespaces).

You should, however, omit from the backup the files within the cluster's `pg_wal/` subdirectory. This slight adjustment is worthwhile because it reduces the risk of mistakes when restoring. This is easy to arrange if `pg_wal/` is a symbolic link pointing to someplace outside the cluster directory, which is a common setup anyway for performance reasons. You might also want to exclude `postmaster.pid` and `postmaster.opts`, which record information about the running postmaster, not about the postmaster which will eventually use this backup. (These files can confuse `pg_ctl`.)

It is often a good idea to also omit from the backup the files within the cluster's `pg_replslot/` directory, so that replication slots that exist on the master do not become part of the backup. Otherwise, the subsequent use of the backup to create a standby may result in indefinite retention of WAL files on the standby, and possibly bloat on the master if hot standby feedback is enabled, because the clients that are using those replication slots will still be connecting to and updating the slots on the master, not the standby. Even if the backup is only intended for use in creating a new master, copying the replication slots isn't expected to be particularly useful, since the contents of those slots will likely be badly out of date by the time the new master comes on line.

The contents of the directories `pg_dynshmem/`, `pg_notify/`, `pg_serial/`, `pg_snapshots/`, `pg_stat_tmp/`, and `pg_subtrans/` (but not the directories themselves) can be omitted from the backup as they will be initialized on postmaster startup. If `stats_temp_directory` is set and is under the data directory then the contents of that directory can also be omitted.

Any file or directory beginning with `pgsql_tmp` can be omitted from the backup. These files are removed on postmaster start and the directories will be recreated as needed.

`pg_internal.init` files can be omitted from the backup whenever a file of that name is found. These files contain relation cache data that is always rebuilt when recovering.

The backup label file includes the label string you gave to `pg_start_backup`, as well as the time at which `pg_start_backup` was run, and the name of the starting WAL file. In case of confusion it is therefore possible to look inside a backup file and determine exactly which backup session the dump file came from. The tablespace map file includes the symbolic link names as they exist in the directory

`pg_tblspc/` and the full path of each symbolic link. These files are not merely for your information; their presence and contents are critical to the proper operation of the system's recovery process.

It is also possible to make a backup while the server is stopped. In this case, you obviously cannot use `pg_start_backup` or `pg_stop_backup`, and you will therefore be left to your own devices to keep track of which backup is which and how far back the associated WAL files go. It is generally better to follow the continuous archiving procedure above.

25.3.4. Recovering Using a Continuous Archive Backup

Okay, the worst has happened and you need to recover from your backup. Here is the procedure:

1. Stop the server, if it's running.
2. If you have the space to do so, copy the whole cluster data directory and any tablespaces to a temporary location in case you need them later. Note that this precaution will require that you have enough free space on your system to hold two copies of your existing database. If you do not have enough space, you should at least save the contents of the cluster's `pg_wal` subdirectory, as it might contain logs which were not archived before the system went down.
3. Remove all existing files and subdirectories under the cluster data directory and under the root directories of any tablespaces you are using.
4. Restore the database files from your file system backup. Be sure that they are restored with the right ownership (the database system user, not `root`!) and with the right permissions. If you are using tablespaces, you should verify that the symbolic links in `pg_tblspc/` were correctly restored.
5. Remove any files present in `pg_wal/`; these came from the file system backup and are therefore probably obsolete rather than current. If you didn't archive `pg_wal/` at all, then recreate it with proper permissions, being careful to ensure that you re-establish it as a symbolic link if you had it set up that way before.
6. If you have unarchived WAL segment files that you saved in step 2, copy them into `pg_wal/`. (It is best to copy them, not move them, so you still have the unmodified files if a problem occurs and you have to start over.)
7. Set recovery configuration settings in `postgresql.conf` (see Section 19.5.4) and create a file `recovery.signal` in the cluster data directory. You might also want to temporarily modify `pg_hba.conf` to prevent ordinary users from connecting until you are sure the recovery was successful.
8. Start the server. The server will go into recovery mode and proceed to read through the archived WAL files it needs. Should the recovery be terminated because of an external error, the server can simply be restarted and it will continue recovery. Upon completion of the recovery process, the server will remove `recovery.signal` (to prevent accidentally re-entering recovery mode later) and then commence normal database operations.
9. Inspect the contents of the database to ensure you have recovered to the desired state. If not, return to step 1. If all is well, allow your users to connect by restoring `pg_hba.conf` to normal.

The key part of all this is to set up a recovery configuration that describes how you want to recover and how far the recovery should run. The one thing that you absolutely must specify is the `restore_command`, which tells PostgreSQL how to retrieve archived WAL file segments. Like the `archive_command`, this is a shell command string. It can contain `%f`, which is replaced by the name of the desired log file, and `%p`, which is replaced by the path name to copy the log file to. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Write `%%` if you need to embed an actual `%` character in the command. The simplest useful command is something like:

```
restore_command = 'cp /mnt/server/archivedir/%f %p'
```

which will copy previously archived WAL segments from the directory `/mnt/server/archivedir`. Of course, you can use something much more complicated, perhaps even a shell script that requests the operator to mount an appropriate tape.

It is important that the command return nonzero exit status on failure. The command *will* be called requesting files that are not present in the archive; it must return nonzero when so asked. This is not an error condition. An exception is that if the command was terminated by a signal (other than SIGTERM, which is used as part of a database server shutdown) or an error by the shell (such as command not found), then recovery will abort and the server will not start up.

Not all of the requested files will be WAL segment files; you should also expect requests for files with a suffix of `.history`. Also be aware that the base name of the `%p` path will be different from `%f`; do not expect them to be interchangeable.

WAL segments that cannot be found in the archive will be sought in `pg_wal/`; this allows use of recent un-archived segments. However, segments that are available from the archive will be used in preference to files in `pg_wal/`.

Normally, recovery will proceed through all available WAL segments, thereby restoring the database to the current point in time (or as close as possible given the available WAL segments). Therefore, a normal recovery will end with a “file not found” message, the exact text of the error message depending upon your choice of `restore_command`. You may also see an error message at the start of recovery for a file named something like `00000001.history`. This is also normal and does not indicate a problem in simple recovery situations; see Section 25.3.5 for discussion.

If you want to recover to some previous point in time (say, right before the junior DBA dropped your main transaction table), just specify the required stopping point. You can specify the stop point, known as the “recovery target”, either by date/time, named restore point or by completion of a specific transaction ID. As of this writing only the date/time and named restore point options are very usable, since there are no tools to help you identify with any accuracy which transaction ID to use.

Note

The stop point must be after the ending time of the base backup, i.e., the end time of `pg_stop_backup`. You cannot use a base backup to recover to a time when that backup was in progress. (To recover to such a time, you must go back to your previous base backup and roll forward from there.)

If recovery finds corrupted WAL data, recovery will halt at that point and the server will not start. In such a case the recovery process could be re-run from the beginning, specifying a “recovery target” before the point of corruption so that recovery can complete normally. If recovery fails for an external reason, such as a system crash or if the WAL archive has become inaccessible, then the recovery can simply be restarted and it will restart almost from where it failed. Recovery restart works much like checkpointing in normal operation: the server periodically forces all its state to disk, and then updates the `pg_control` file to indicate that the already-processed WAL data need not be scanned again.

25.3.5. Timelines

The ability to restore the database to a previous point in time creates some complexities that are akin to science-fiction stories about time travel and parallel universes. For example, in the original history of the database, suppose you dropped a critical table at 5:15PM on Tuesday evening, but didn't realize your mistake until Wednesday noon. Unfazed, you get out your backup, restore to the point-in-time 5:14PM Tuesday evening, and are up and running. In *this* history of the database universe, you never dropped the table. But suppose you later realize this wasn't such a great idea, and would like to return to sometime Wednesday morning in the original history. You won't be able to if, while your database

was up-and-running, it overwrote some of the WAL segment files that led up to the time you now wish you could get back to. Thus, to avoid this, you need to distinguish the series of WAL records generated after you've done a point-in-time recovery from those that were generated in the original database history.

To deal with this problem, PostgreSQL has a notion of *timelines*. Whenever an archive recovery completes, a new timeline is created to identify the series of WAL records generated after that recovery. The timeline ID number is part of WAL segment file names so a new timeline does not overwrite the WAL data generated by previous timelines. It is in fact possible to archive many different timelines. While that might seem like a useless feature, it's often a lifesaver. Consider the situation where you aren't quite sure what point-in-time to recover to, and so have to do several point-in-time recoveries by trial and error until you find the best place to branch off from the old history. Without timelines this process would soon generate an unmanageable mess. With timelines, you can recover to *any* prior state, including states in timeline branches that you abandoned earlier.

Every time a new timeline is created, PostgreSQL creates a “timeline history” file that shows which timeline it branched off from and when. These history files are necessary to allow the system to pick the right WAL segment files when recovering from an archive that contains multiple timelines. Therefore, they are archived into the WAL archive area just like WAL segment files. The history files are just small text files, so it's cheap and appropriate to keep them around indefinitely (unlike the segment files which are large). You can, if you like, add comments to a history file to record your own notes about how and why this particular timeline was created. Such comments will be especially valuable when you have a thicket of different timelines as a result of experimentation.

The default behavior of recovery is to recover along the same timeline that was current when the base backup was taken. If you wish to recover into some child timeline (that is, you want to return to some state that was itself generated after a recovery attempt), you need to specify the target timeline ID in `recovery_target_timeline`. You cannot recover into timelines that branched off earlier than the base backup.

25.3.6. Tips and Examples

Some tips for configuring continuous archiving are given here.

25.3.6.1. Standalone Hot Backups

It is possible to use PostgreSQL's backup facilities to produce standalone hot backups. These are backups that cannot be used for point-in-time recovery, yet are typically much faster to backup and restore than `pg_dump` dumps. (They are also much larger than `pg_dump` dumps, so in some cases the speed advantage might be negated.)

As with base backups, the easiest way to produce a standalone hot backup is to use the `pg_basebackup` tool. If you include the `-X` parameter when calling it, all the write-ahead log required to use the backup will be included in the backup automatically, and no special action is required to restore the backup.

If more flexibility in copying the backup files is needed, a lower level process can be used for standalone hot backups as well. To prepare for low level standalone hot backups, make sure `wal_level` is set to `replica` or higher, `archive_mode` to `on`, and set up an `archive_command` that performs archiving only when a *switch file* exists. For example:

```
archive_command = 'test ! -f /var/lib/pgsql/backup_in_progress
|| (test ! -f /var/lib/pgsql/archive/%f && cp %p /var/lib/pgsql/
archive/%f)'
```

This command will perform archiving when `/var/lib/pgsql/backup_in_progress` exists, and otherwise silently return zero exit status (allowing PostgreSQL to recycle the unwanted WAL file).

With this preparation, a backup can be taken using a script like the following:

```
touch /var/lib/pgsql/backup_in_progress
psql -c "select pg_start_backup('hot_backup');"
tar -cf /var/lib/pgsql/backup.tar /var/lib/pgsql/data/
psql -c "select pg_stop_backup();"
rm /var/lib/pgsql/backup_in_progress
tar -rf /var/lib/pgsql/backup.tar /var/lib/pgsql/archive/
```

The switch file `/var/lib/pgsql/backup_in_progress` is created first, enabling archiving of completed WAL files to occur. After the backup the switch file is removed. Archived WAL files are then added to the backup so that both base backup and all required WAL files are part of the same tar file. Please remember to add error handling to your backup scripts.

25.3.6.2. Compressed Archive Logs

If archive storage size is a concern, you can use `gzip` to compress the archive files:

```
archive_command = 'gzip < %p > /var/lib/pgsql/archive/%f'
```

You will then need to use `gunzip` during recovery:

```
restore_command = 'gunzip < /mnt/server/archivedir/%f > %p'
```

25.3.6.3. archive_command Scripts

Many people choose to use scripts to define their `archive_command`, so that their `postgresql.conf` entry looks very simple:

```
archive_command = 'local_backup_script.sh "%p" "%f"'
```

Using a separate script file is advisable any time you want to use more than a single command in the archiving process. This allows all complexity to be managed within the script, which can be written in a popular scripting language such as `bash` or `perl`.

Examples of requirements that might be solved within a script include:

- Copying data to secure off-site data storage
- Batching WAL files so that they are transferred every three hours, rather than one at a time
- Interfacing with other backup and recovery software
- Interfacing with monitoring software to report errors

Tip

When using an `archive_command` script, it's desirable to enable `logging_collector`. Any messages written to `stderr` from the script will then appear in the database server log, allowing complex configurations to be diagnosed easily if they fail.

25.3.7. Caveats

At this writing, there are several limitations of the continuous archiving technique. These will probably be fixed in future releases:

- If a `CREATE DATABASE` command is executed while a base backup is being taken, and then the template database that the `CREATE DATABASE` copied is modified while the base backup is still in progress, it is possible that recovery will cause those modifications to be propagated into the created database as well. This is of course undesirable. To avoid this risk, it is best not to modify any template databases while taking a base backup.
- `CREATE TABLESPACE` commands are WAL-logged with the literal absolute path, and will therefore be replayed as tablespace creations with the same absolute path. This might be undesirable if the log is being replayed on a different machine. It can be dangerous even if the log is being replayed on the same machine, but into a new data directory: the replay will still overwrite the contents of the original tablespace. To avoid potential gotchas of this sort, the best practice is to take a new base backup after creating or dropping tablespaces.

It should also be noted that the default WAL format is fairly bulky since it includes many disk page snapshots. These page snapshots are designed to support crash recovery, since we might need to fix partially-written disk pages. Depending on your system hardware and software, the risk of partial writes might be small enough to ignore, in which case you can significantly reduce the total volume of archived logs by turning off page snapshots using the `full_page_writes` parameter. (Read the notes and warnings in Chapter 29 before you do so.) Turning off page snapshots does not prevent use of the logs for PITR operations. An area for future development is to compress archived WAL data by removing unnecessary page copies even when `full_page_writes` is on. In the meantime, administrators might wish to reduce the number of page snapshots included in WAL by increasing the checkpoint interval parameters as much as feasible.

Chapter 26. High Availability, Load Balancing, and Replication

Database servers can work together to allow a second server to take over quickly if the primary server fails (high availability), or to allow several computers to serve the same data (load balancing). Ideally, database servers could work together seamlessly. Web servers serving static web pages can be combined quite easily by merely load-balancing web requests to multiple machines. In fact, read-only database servers can be combined relatively easily too. Unfortunately, most database servers have a read/write mix of requests, and read/write servers are much harder to combine. This is because though read-only data needs to be placed on each server only once, a write to any server has to be propagated to all servers so that future read requests to those servers return consistent results.

This synchronization problem is the fundamental difficulty for servers working together. Because there is no single solution that eliminates the impact of the sync problem for all use cases, there are multiple solutions. Each solution addresses this problem in a different way, and minimizes its impact for a specific workload.

Some solutions deal with synchronization by allowing only one server to modify the data. Servers that can modify data are called read/write, *master* or *primary* servers. Servers that track changes in the master are called *standby* or *secondary* servers. A standby server that cannot be connected to until it is promoted to a master server is called a *warm standby* server, and one that can accept connections and serves read-only queries is called a *hot standby* server.

Some solutions are synchronous, meaning that a data-modifying transaction is not considered committed until all servers have committed the transaction. This guarantees that a failover will not lose any data and that all load-balanced servers will return consistent results no matter which server is queried. In contrast, asynchronous solutions allow some delay between the time of a commit and its propagation to the other servers, opening the possibility that some transactions might be lost in the switch to a backup server, and that load balanced servers might return slightly stale results. Asynchronous communication is used when synchronous would be too slow.

Solutions can also be categorized by their granularity. Some solutions can deal only with an entire database server, while others allow control at the per-table or per-database level.

Performance must be considered in any choice. There is usually a trade-off between functionality and performance. For example, a fully synchronous solution over a slow network might cut performance by more than half, while an asynchronous one might have a minimal performance impact.

The remainder of this section outlines various failover, replication, and load balancing solutions.

26.1. Comparison of Different Solutions

Shared Disk Failover

Shared disk failover avoids synchronization overhead by having only one copy of the database. It uses a single disk array that is shared by multiple servers. If the main database server fails, the standby server is able to mount and start the database as though it were recovering from a database crash. This allows rapid failover with no data loss.

Shared hardware functionality is common in network storage devices. Using a network file system is also possible, though care must be taken that the file system has full POSIX behavior (see Section 18.2.2.1). One significant limitation of this method is that if the shared disk array fails or becomes corrupt, the primary and standby servers are both nonfunctional. Another issue is that the standby server should never access the shared storage while the primary server is running.

File System (Block Device) Replication

A modified version of shared hardware functionality is file system replication, where all changes to a file system are mirrored to a file system residing on another computer. The only restriction is that the mirroring must be done in a way that ensures the standby server has a consistent copy of the file system — specifically, writes to the standby must be done in the same order as those on the master. DRBD is a popular file system replication solution for Linux.

Write-Ahead Log Shipping

Warm and hot standby servers can be kept current by reading a stream of write-ahead log (WAL) records. If the main server fails, the standby contains almost all of the data of the main server, and can be quickly made the new master database server. This can be synchronous or asynchronous and can only be done for the entire database server.

A standby server can be implemented using file-based log shipping (Section 26.2) or streaming replication (see Section 26.2.5), or a combination of both. For information on hot standby, see Section 26.5.

Logical Replication

Logical replication allows a database server to send a stream of data modifications to another server. PostgreSQL logical replication constructs a stream of logical data modifications from the WAL. Logical replication allows the data changes from individual tables to be replicated. Logical replication doesn't require a particular server to be designated as a master or a replica but allows data to flow in multiple directions. For more information on logical replication, see Chapter 30. Through the logical decoding interface (Chapter 48), third-party extensions can also provide similar functionality.

Trigger-Based Master-Standby Replication

A master-standby replication setup sends all data modification queries to the master server. The master server asynchronously sends data changes to the standby server. The standby can answer read-only queries while the master server is running. The standby server is ideal for data warehouse queries.

Slony-I is an example of this type of replication, with per-table granularity, and support for multiple standby servers. Because it updates the standby server asynchronously (in batches), there is possible data loss during fail over.

Statement-Based Replication Middleware

With statement-based replication middleware, a program intercepts every SQL query and sends it to one or all servers. Each server operates independently. Read-write queries must be sent to all servers, so that every server receives any changes. But read-only queries can be sent to just one server, allowing the read workload to be distributed among them.

If queries are simply broadcast unmodified, functions like `random()`, `CURRENT_TIMESTAMP`, and sequences can have different values on different servers. This is because each server operates independently, and because SQL queries are broadcast (and not actual modified rows). If this is unacceptable, either the middleware or the application must query such values from a single server and then use those values in write queries. Another option is to use this replication option with a traditional master-standby setup, i.e. data modification queries are sent only to the master and are propagated to the standby servers via master-standby replication, not by the replication middleware. Care must also be taken that all transactions either commit or abort on all servers, perhaps using two-phase commit (PREPARE TRANSACTION and COMMIT PREPARED). Pgpool-II and Continuent Tungsten are examples of this type of replication.

Asynchronous Multimaster Replication

For servers that are not regularly connected or have slow communication links, like laptops or remote servers, keeping data consistent among servers is a challenge. Using asynchronous mul-

timaster replication, each server works independently, and periodically communicates with the other servers to identify conflicting transactions. The conflicts can be resolved by users or conflict resolution rules. Bucardo is an example of this type of replication.

Synchronous Multimaster Replication

In synchronous multimaster replication, each server can accept write requests, and modified data is transmitted from the original server to every other server before each transaction commits. Heavy write activity can cause excessive locking and commit delays, leading to poor performance. Read requests can be sent to any server. Some implementations use shared disk to reduce the communication overhead. Synchronous multimaster replication is best for mostly read workloads, though its big advantage is that any server can accept write requests — there is no need to partition workloads between master and standby servers, and because the data changes are sent from one server to another, there is no problem with non-deterministic functions like `random()`.

PostgreSQL does not offer this type of replication, though PostgreSQL two-phase commit (`PREPARE TRANSACTION` and `COMMIT PREPARED`) can be used to implement this in application code or middleware.

Commercial Solutions

Because PostgreSQL is open source and easily extended, a number of companies have taken PostgreSQL and created commercial closed-source solutions with unique failover, replication, and load balancing capabilities.

Table 26.1 summarizes the capabilities of the various solutions listed above.

Table 26.1. High Availability, Load Balancing, and Replication Feature Matrix

Feature	Shared Disk Failover	File System Replication	Write-Ahead Log Shipping	Logical Replication	Trigger-Based Master-Standby Replication	State-Based Replication Middleware	Asynchronous Multi-master Replication	Synchronous Multi-master Replication
Most common implementations	NAS	DRBD	built-in streaming replication	built-in logical replication, pg-logical	Londiste, Slony	pgpool-II	Bucardo	
Communication method	shared disk	disk blocks	WAL	logical decoding	table rows	SQL	table rows	table rows and row locks
No special hardware required		•	•	•	•	•	•	•
Allows multiple master servers				•		•	•	•
No master server overhead	•		•	•		•		
No waiting for multiple servers	•		with sync off	with sync off	•		•	

Feature	Shared Disk Failover	File System Replication	Write-Ahead Log Shipping	Logical Replication	Trigger-Based Master-Standby Replication	State-Based Replication Middleware	Asynchronous Multi-master Replication	Synchronous Multi-master Replication
Master failure will never lose data	•	•	with sync on	with sync on		•		•
Replicas accept read-only queries			with hot standby	•	•	•	•	•
Per-table granularity				•	•		•	•
No conflict resolution necessary	•	•	•		•			•

There are a few solutions that do not fit into the above categories:

Data Partitioning

Data partitioning splits tables into data sets. Each set can be modified by only one server. For example, data can be partitioned by offices, e.g., London and Paris, with a server in each office. If queries combining London and Paris data are necessary, an application can query both servers, or master/standby replication can be used to keep a read-only copy of the other office's data on each server.

Multiple-Server Parallel Query Execution

Many of the above solutions allow multiple servers to handle multiple queries, but none allow a single query to use multiple servers to complete faster. This solution allows multiple servers to work concurrently on a single query. It is usually accomplished by splitting the data among servers and having each server execute its part of the query and return results to a central server where they are combined and returned to the user. Pgpool-II has this capability. Also, this can be implemented using the PL/Proxy tool set.

26.2. Log-Shipping Standby Servers

Continuous archiving can be used to create a *high availability* (HA) cluster configuration with one or more *standby servers* ready to take over operations if the primary server fails. This capability is widely referred to as *warm standby* or *log shipping*.

The primary and standby server work together to provide this capability, though the servers are only loosely coupled. The primary server operates in continuous archiving mode, while each standby server operates in continuous recovery mode, reading the WAL files from the primary. No changes to the database tables are required to enable this capability, so it offers low administration overhead compared to some other replication solutions. This configuration also has relatively low performance impact on the primary server.

Directly moving WAL records from one database server to another is typically described as log shipping. PostgreSQL implements file-based log shipping by transferring WAL records one file (WAL

segment) at a time. WAL files (16MB) can be shipped easily and cheaply over any distance, whether it be to an adjacent system, another system at the same site, or another system on the far side of the globe. The bandwidth required for this technique varies according to the transaction rate of the primary server. Record-based log shipping is more granular and streams WAL changes incrementally over a network connection (see Section 26.2.5).

It should be noted that log shipping is asynchronous, i.e., the WAL records are shipped after transaction commit. As a result, there is a window for data loss should the primary server suffer a catastrophic failure; transactions not yet shipped will be lost. The size of the data loss window in file-based log shipping can be limited by use of the `archive_timeout` parameter, which can be set as low as a few seconds. However such a low setting will substantially increase the bandwidth required for file shipping. Streaming replication (see Section 26.2.5) allows a much smaller window of data loss.

Recovery performance is sufficiently good that the standby will typically be only moments away from full availability once it has been activated. As a result, this is called a warm standby configuration which offers high availability. Restoring a server from an archived base backup and rollforward will take considerably longer, so that technique only offers a solution for disaster recovery, not high availability. A standby server can also be used for read-only queries, in which case it is called a Hot Standby server. See Section 26.5 for more information.

26.2.1. Planning

It is usually wise to create the primary and standby servers so that they are as similar as possible, at least from the perspective of the database server. In particular, the path names associated with tablespaces will be passed across unmodified, so both primary and standby servers must have the same mount paths for tablespaces if that feature is used. Keep in mind that if `CREATE TABLESPACE` is executed on the primary, any new mount point needed for it must be created on the primary and all standby servers before the command is executed. Hardware need not be exactly the same, but experience shows that maintaining two identical systems is easier than maintaining two dissimilar ones over the lifetime of the application and system. In any case the hardware architecture must be the same — shipping from, say, a 32-bit to a 64-bit system will not work.

In general, log shipping between servers running different major PostgreSQL release levels is not possible. It is the policy of the PostgreSQL Global Development Group not to make changes to disk formats during minor release upgrades, so it is likely that running different minor release levels on primary and standby servers will work successfully. However, no formal support for that is offered and you are advised to keep primary and standby servers at the same release level as much as possible. When updating to a new minor release, the safest policy is to update the standby servers first — a new minor release is more likely to be able to read WAL files from a previous minor release than vice versa.

26.2.2. Standby Server Operation

In standby mode, the server continuously applies WAL received from the master server. The standby server can read WAL from a WAL archive (see `restore_command`) or directly from the master over a TCP connection (streaming replication). The standby server will also attempt to restore any WAL found in the standby cluster's `pg_wal` directory. That typically happens after a server restart, when the standby replays again WAL that was streamed from the master before the restart, but you can also manually copy files to `pg_wal` at any time to have them replayed.

At startup, the standby begins by restoring all WAL available in the archive location, calling `restore_command`. Once it reaches the end of WAL available there and `restore_command` fails, it tries to restore any WAL available in the `pg_wal` directory. If that fails, and streaming replication has been configured, the standby tries to connect to the primary server and start streaming WAL from the last valid record found in archive or `pg_wal`. If that fails or streaming replication is not configured, or if the connection is later disconnected, the standby goes back to step 1 and tries to restore the file from the archive again. This loop of retries from the archive, `pg_wal`, and via streaming replication goes on until the server is stopped or failover is triggered by a trigger file.

Standby mode is exited and the server switches to normal operation when `pg_ctl promote` is run or a trigger file is found (`promote_trigger_file`). Before failover, any WAL immediately available in the archive or in `pg_wal` will be restored, but no attempt is made to connect to the master.

26.2.3. Preparing the Master for Standby Servers

Set up continuous archiving on the primary to an archive directory accessible from the standby, as described in Section 25.3. The archive location should be accessible from the standby even when the master is down, i.e. it should reside on the standby server itself or another trusted server, not on the master server.

If you want to use streaming replication, set up authentication on the primary server to allow replication connections from the standby server(s); that is, create a role and provide a suitable entry or entries in `pg_hba.conf` with the database field set to `replication`. Also ensure `max_wal_senders` is set to a sufficiently large value in the configuration file of the primary server. If replication slots will be used, ensure that `max_replication_slots` is set sufficiently high as well.

Take a base backup as described in Section 25.3.2 to bootstrap the standby server.

26.2.4. Setting Up a Standby Server

To set up the standby server, restore the base backup taken from primary server (see Section 25.3.4). Create a file `standby.signal` in the standby's cluster data directory. Set `restore_command` to a simple command to copy files from the WAL archive. If you plan to have multiple standby servers for high availability purposes, make sure that `recovery_target_timeline` is set to `latest` (the default), to make the standby server follow the timeline change that occurs at failover to another standby.

Note

Do not use `pg_standby` or similar tools with the built-in standby mode described here. `restore_command` should return immediately if the file does not exist; the server will retry the command again if necessary. See Section 26.4 for using tools like `pg_standby`.

If you want to use streaming replication, fill in `primary_conninfo` with a libpq connection string, including the host name (or IP address) and any additional details needed to connect to the primary server. If the primary needs a password for authentication, the password needs to be specified in `primary_conninfo` as well.

If you're setting up the standby server for high availability purposes, set up WAL archiving, connections and authentication like the primary server, because the standby server will work as a primary server after failover.

If you're using a WAL archive, its size can be minimized using the `archive_cleanup_command` parameter to remove files that are no longer required by the standby server. The `pg_archivecleanup` utility is designed specifically to be used with `archive_cleanup_command` in typical single-standby configurations, see `pg_archivecleanup`. Note however, that if you're using the archive for backup purposes, you need to retain files needed to recover from at least the latest base backup, even if they're no longer needed by the standby.

A simple example of configuration is:

```
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo
password=foopass options='-c wal_sender_timeout=5000''
restore_command = 'cp /path/to/archive/%f %p'
archive_cleanup_command = 'pg_archivecleanup /path/to/archive %r'
```

You can have any number of standby servers, but if you use streaming replication, make sure you set `max_wal_senders` high enough in the primary to allow them to be connected simultaneously.

26.2.5. Streaming Replication

Streaming replication allows a standby server to stay more up-to-date than is possible with file-based log shipping. The standby connects to the primary, which streams WAL records to the standby as they're generated, without waiting for the WAL file to be filled.

Streaming replication is asynchronous by default (see Section 26.2.8), in which case there is a small delay between committing a transaction in the primary and the changes becoming visible in the standby. This delay is however much smaller than with file-based log shipping, typically under one second assuming the standby is powerful enough to keep up with the load. With streaming replication, `archive_timeout` is not required to reduce the data loss window.

If you use streaming replication without file-based continuous archiving, the server might recycle old WAL segments before the standby has received them. If this occurs, the standby will need to be reinitialized from a new base backup. You can avoid this by setting `wal_keep_segments` to a value large enough to ensure that WAL segments are not recycled too early, or by configuring a replication slot for the standby. If you set up a WAL archive that's accessible from the standby, these solutions are not required, since the standby can always use the archive to catch up provided it retains enough segments.

To use streaming replication, set up a file-based log-shipping standby server as described in Section 26.2. The step that turns a file-based log-shipping standby into streaming replication standby is setting the `primary_conninfo` setting to point to the primary server. Set `listen_addresses` and authentication options (see `pg_hba.conf`) on the primary so that the standby server can connect to the replication pseudo-database on the primary server (see Section 26.2.5.1).

On systems that support the `keepalive` socket option, setting `tcp_keepalives_idle`, `tcp_keepalives_interval` and `tcp_keepalives_count` helps the primary promptly notice a broken connection.

Set the maximum number of concurrent connections from the standby servers (see `max_wal_senders` for details).

When the standby is started and `primary_conninfo` is set correctly, the standby will connect to the primary after replaying all WAL files available in the archive. If the connection is established successfully, you will see a `walreceiver` process in the standby, and a corresponding `walsender` process in the primary.

26.2.5.1. Authentication

It is very important that the access privileges for replication be set up so that only trusted users can read the WAL stream, because it is easy to extract privileged information from it. Standby servers must authenticate to the primary as a superuser or an account that has the `REPLICATION` privilege. It is recommended to create a dedicated user account with `REPLICATION` and `LOGIN` privileges for replication. While `REPLICATION` privilege gives very high permissions, it does not allow the user to modify any data on the primary system, which the `SUPERUSER` privilege does.

Client authentication for replication is controlled by a `pg_hba.conf` record specifying `replication` in the `database` field. For example, if the standby is running on host IP `192.168.1.100` and the account name for replication is `foo`, the administrator can add the following line to the `pg_hba.conf` file on the primary:

```
# Allow the user "foo" from host 192.168.1.100 to connect to the
primary
# as a replication standby if the user's password is correctly
supplied.
```

```
#
# TYPE  DATABASE          USER          ADDRESS
# METHOD
host    replication          foo           192.168.1.100/32      md5
```

The host name and port number of the primary, connection user name, and password are specified in the `primary_conninfo`. The password can also be set in the `~/.pgpass` file on the standby (specify `replication` in the `database` field). For example, if the primary is running on host IP `192.168.1.50`, port `5432`, the account name for replication is `foo`, and the password is `foopass`, the administrator can add the following line to the `postgresql.conf` file on the standby:

```
# The standby connects to the primary that is running on host
192.168.1.50
# and port 5432 as the user "foo" whose password is "foopass".
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo
password=foopass'
```

26.2.5.2. Monitoring

An important health indicator of streaming replication is the amount of WAL records generated in the primary, but not yet applied in the standby. You can calculate this lag by comparing the current WAL write location on the primary with the last WAL location received by the standby. These locations can be retrieved using `pg_current_wal_lsn` on the primary and `pg_last_wal_receive_lsn` on the standby, respectively (see Table 9.84 and Table 9.85 for details). The last WAL receive location in the standby is also displayed in the process status of the WAL receiver process, displayed using the `ps` command (see Section 27.1 for details).

You can retrieve a list of WAL sender processes via the `pg_stat_replication` view. Large differences between `pg_current_wal_lsn` and the view's `sent_lsn` field might indicate that the master server is under heavy load, while differences between `sent_lsn` and `pg_last_wal_receive_lsn` on the standby might indicate network delay, or that the standby is under heavy load.

On a hot standby, the status of the WAL receiver process can be retrieved via the `pg_stat_wal_receiver` view. A large difference between `pg_last_wal_replay_lsn` and the view's `received_lsn` indicates that WAL is being received faster than it can be replayed.

26.2.6. Replication Slots

Replication slots provide an automated way to ensure that the master does not remove WAL segments until they have been received by all standbys, and that the master does not remove rows which could cause a recovery conflict even when the standby is disconnected.

In lieu of using replication slots, it is possible to prevent the removal of old WAL segments using `wal_keep_segments`, or by storing the segments in an archive using `archive_command`. However, these methods often result in retaining more WAL segments than required, whereas replication slots retain only the number of segments known to be needed. An advantage of these methods is that they bound the space requirement for `pg_wal`; there is currently no way to do this using replication slots.

Similarly, `hot_standby_feedback` and `vacuum_defer_cleanup_age` provide protection against relevant rows being removed by vacuum, but the former provides no protection during any time period when the standby is not connected, and the latter often needs to be set to a high value to provide adequate protection. Replication slots overcome these disadvantages.

26.2.6.1. Querying and Manipulating Replication Slots

Each replication slot has a name, which can contain lower-case letters, numbers, and the underscore character.

Existing replication slots and their state can be seen in the `pg_replication_slots` view.

Slots can be created and dropped either via the streaming replication protocol (see Section 52.4) or via SQL functions (see Section 9.26.6).

26.2.6.2. Configuration Example

You can create a replication slot like this:

```
postgres=# SELECT * FROM
pg_create_physical_replication_slot('node_a_slot');
 slot_name | lsn
-----+-----
node_a_slot |

postgres=# SELECT slot_name, slot_type, active FROM
pg_replication_slots;
 slot_name | slot_type | active
-----+-----+-----
node_a_slot | physical  | f
(1 row)
```

To configure the standby to use this slot, `primary_slot_name` should be configured on the standby. Here is a simple example:

```
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo
password=foopass'
primary_slot_name = 'node_a_slot'
```

26.2.7. Cascading Replication

The cascading replication feature allows a standby server to accept replication connections and stream WAL records to other standbys, acting as a relay. This can be used to reduce the number of direct connections to the master and also to minimize inter-site bandwidth overheads.

A standby acting as both a receiver and a sender is known as a cascading standby. Standbys that are more directly connected to the master are known as upstream servers, while those standby servers further away are downstream servers. Cascading replication does not place limits on the number or arrangement of downstream servers, though each standby connects to only one upstream server which eventually links to a single master/primary server.

A cascading standby sends not only WAL records received from the master but also those restored from the archive. So even if the replication connection in some upstream connection is terminated, streaming replication continues downstream for as long as new WAL records are available.

Cascading replication is currently asynchronous. Synchronous replication (see Section 26.2.8) settings have no effect on cascading replication at present.

Hot Standby feedback propagates upstream, whatever the cascaded arrangement.

If an upstream standby server is promoted to become new master, downstream servers will continue to stream from the new master if `recovery_target_timeline` is set to 'latest' (the default).

To use cascading replication, set up the cascading standby so that it can accept replication connections (that is, set `max_wal_senders` and `hot_standby`, and configure host-based authentication). You will also need to set `primary_conninfo` in the downstream standby to point to the cascading standby.

26.2.8. Synchronous Replication

PostgreSQL streaming replication is asynchronous by default. If the primary server crashes then some transactions that were committed may not have been replicated to the standby server, causing data loss. The amount of data loss is proportional to the replication delay at the time of failover.

Synchronous replication offers the ability to confirm that all changes made by a transaction have been transferred to one or more synchronous standby servers. This extends that standard level of durability offered by a transaction commit. This level of protection is referred to as 2-safe replication in computer science theory, and group-1-safe (group-safe and 1-safe) when `synchronous_commit` is set to `remote_write`.

When requesting synchronous replication, each commit of a write transaction will wait until confirmation is received that the commit has been written to the write-ahead log on disk of both the primary and standby server. The only possibility that data can be lost is if both the primary and the standby suffer crashes at the same time. This can provide a much higher level of durability, though only if the sysadmin is cautious about the placement and management of the two servers. Waiting for confirmation increases the user's confidence that the changes will not be lost in the event of server crashes but it also necessarily increases the response time for the requesting transaction. The minimum wait time is the round-trip time between primary to standby.

Read only transactions and transaction rollbacks need not wait for replies from standby servers. Sub-transaction commits do not wait for responses from standby servers, only top-level commits. Long running actions such as data loading or index building do not wait until the very final commit message. All two-phase commit actions require commit waits, including both prepare and commit.

A synchronous standby can be a physical replication standby or a logical replication subscriber. It can also be any other physical or logical WAL replication stream consumer that knows how to send the appropriate feedback messages. Besides the built-in physical and logical replication systems, this includes special programs such as `pg_receivewal` and `pg_recvlogical` as well as some third-party replication systems and custom programs. Check the respective documentation for details on synchronous replication support.

26.2.8.1. Basic Configuration

Once streaming replication has been configured, configuring synchronous replication requires only one additional configuration step: `synchronous_standby_names` must be set to a non-empty value. `synchronous_commit` must also be set to `on`, but since this is the default value, typically no change is required. (See Section 19.5.1 and Section 19.6.2.) This configuration will cause each commit to wait for confirmation that the standby has written the commit record to durable storage. `synchronous_commit` can be set by individual users, so it can be configured in the configuration file, for particular users or databases, or dynamically by applications, in order to control the durability guarantee on a per-transaction basis.

After a commit record has been written to disk on the primary, the WAL record is then sent to the standby. The standby sends reply messages each time a new batch of WAL data is written to disk, unless `wal_receiver_status_interval` is set to zero on the standby. In the case that `synchronous_commit` is set to `remote_apply`, the standby sends reply messages when the commit record is replayed, making the transaction visible. If the standby is chosen as a synchronous standby, according to the setting of `synchronous_standby_names` on the primary, the reply messages from that standby will be considered along with those from other synchronous standbys to decide when to release transactions waiting for confirmation that the commit record has been received. These parameters allow the administrator to specify which standby servers should be synchronous standbys. Note that the configuration of synchronous replication is mainly on the master. Named standbys must be directly connected to the master; the master knows nothing about downstream standby servers using cascaded replication.

Setting `synchronous_commit` to `remote_write` will cause each commit to wait for confirmation that the standby has received the commit record and written it out to its own operating system, but not for the data to be flushed to disk on the standby. This setting provides a weaker guarantee of durability than `on` does: the standby could lose the data in the event of an operating system crash,

though not a PostgreSQL crash. However, it's a useful setting in practice because it can decrease the response time for the transaction. Data loss could only occur if both the primary and the standby crash and the database of the primary gets corrupted at the same time.

Setting `synchronous_commit` to `remote_apply` will cause each commit to wait until the current synchronous standbys report that they have replayed the transaction, making it visible to user queries. In simple cases, this allows for load balancing with causal consistency.

Users will stop waiting if a fast shutdown is requested. However, as when using asynchronous replication, the server will not fully shutdown until all outstanding WAL records are transferred to the currently connected standby servers.

26.2.8.2. Multiple Synchronous Standbys

Synchronous replication supports one or more synchronous standby servers; transactions will wait until all the standby servers which are considered as synchronous confirm receipt of their data. The number of synchronous standbys that transactions must wait for replies from is specified in `synchronous_standby_names`. This parameter also specifies a list of standby names and the method (FIRST and ANY) to choose synchronous standbys from the listed ones.

The method `FIRST` specifies a priority-based synchronous replication and makes transaction commits wait until their WAL records are replicated to the requested number of synchronous standbys chosen based on their priorities. The standbys whose names appear earlier in the list are given higher priority and will be considered as synchronous. Other standby servers appearing later in this list represent potential synchronous standbys. If any of the current synchronous standbys disconnects for whatever reason, it will be replaced immediately with the next-highest-priority standby.

An example of `synchronous_standby_names` for a priority-based multiple synchronous standbys is:

```
synchronous_standby_names = 'FIRST 2 (s1, s2, s3)'
```

In this example, if four standby servers `s1`, `s2`, `s3` and `s4` are running, the two standbys `s1` and `s2` will be chosen as synchronous standbys because their names appear early in the list of standby names. `s3` is a potential synchronous standby and will take over the role of synchronous standby when either of `s1` or `s2` fails. `s4` is an asynchronous standby since its name is not in the list.

The method `ANY` specifies a quorum-based synchronous replication and makes transaction commits wait until their WAL records are replicated to *at least* the requested number of synchronous standbys in the list.

An example of `synchronous_standby_names` for a quorum-based multiple synchronous standbys is:

```
synchronous_standby_names = 'ANY 2 (s1, s2, s3)'
```

In this example, if four standby servers `s1`, `s2`, `s3` and `s4` are running, transaction commits will wait for replies from at least any two standbys of `s1`, `s2` and `s3`. `s4` is an asynchronous standby since its name is not in the list.

The synchronous states of standby servers can be viewed using the `pg_stat_replication` view.

26.2.8.3. Planning for Performance

Synchronous replication usually requires carefully planned and placed standby servers to ensure applications perform acceptably. Waiting doesn't utilize system resources, but transaction locks continue to be held until the transfer is confirmed. As a result, incautious use of synchronous replication will reduce performance for database applications because of increased response times and higher contention.

PostgreSQL allows the application developer to specify the durability level required via replication. This can be specified for the system overall, though it can also be specified for specific users or connections, or even individual transactions.

For example, an application workload might consist of: 10% of changes are important customer details, while 90% of changes are less important data that the business can more easily survive if it is lost, such as chat messages between users.

With synchronous replication options specified at the application level (on the primary) we can offer synchronous replication for the most important changes, without slowing down the bulk of the total workload. Application level options are an important and practical tool for allowing the benefits of synchronous replication for high performance applications.

You should consider that the network bandwidth must be higher than the rate of generation of WAL data.

26.2.8.4. Planning for High Availability

`synchronous_standby_names` specifies the number and names of synchronous standbys that transaction commits made when `synchronous_commit` is set to `on`, `remote_apply` or `remote_write` will wait for responses from. Such transaction commits may never be completed if any one of synchronous standbys should crash.

The best solution for high availability is to ensure you keep as many synchronous standbys as requested. This can be achieved by naming multiple potential synchronous standbys using `synchronous_standby_names`.

In a priority-based synchronous replication, the standbys whose names appear earlier in the list will be used as synchronous standbys. Standbys listed after these will take over the role of synchronous standby if one of current ones should fail.

In a quorum-based synchronous replication, all the standbys appearing in the list will be used as candidates for synchronous standbys. Even if one of them should fail, the other standbys will keep performing the role of candidates of synchronous standby.

When a standby first attaches to the primary, it will not yet be properly synchronized. This is described as `catchup` mode. Once the lag between standby and primary reaches zero for the first time we move to real-time `streaming` state. The catch-up duration may be long immediately after the standby has been created. If the standby is shut down, then the catch-up period will increase according to the length of time the standby has been down. The standby is only able to become a synchronous standby once it has reached `streaming` state. This state can be viewed using the `pg_stat_replication` view.

If primary restarts while commits are waiting for acknowledgment, those waiting transactions will be marked fully committed once the primary database recovers. There is no way to be certain that all standbys have received all outstanding WAL data at time of the crash of the primary. Some transactions may not show as committed on the standby, even though they show as committed on the primary. The guarantee we offer is that the application will not receive explicit acknowledgment of the successful commit of a transaction until the WAL data is known to be safely received by all the synchronous standbys.

If you really cannot keep as many synchronous standbys as requested then you should decrease the number of synchronous standbys that transaction commits must wait for responses from in `synchronous_standby_names` (or disable it) and reload the configuration file on the primary server.

If the primary is isolated from remaining standby servers you should fail over to the best candidate of those other remaining standby servers.

If you need to re-create a standby server while transactions are waiting, make sure that the commands `pg_start_backup()` and `pg_stop_backup()` are run in a session with `synchronous_commit = off`, otherwise those requests will wait forever for the standby to appear.

26.2.9. Continuous Archiving in Standby

When continuous WAL archiving is used in a standby, there are two different scenarios: the WAL archive can be shared between the primary and the standby, or the standby can have its own WAL archive. When the standby has its own WAL archive, set `archive_mode` to `always`, and the standby will call the archive command for every WAL segment it receives, whether it's by restoring from the archive or by streaming replication. The shared archive can be handled similarly, but the `archive_command` must test if the file being archived exists already, and if the existing file has identical contents. This requires more care in the `archive_command`, as it must be careful to not overwrite an existing file with different contents, but return success if the exactly same file is archived twice. And all that must be done free of race conditions, if two servers attempt to archive the same file at the same time.

If `archive_mode` is set to `on`, the archiver is not enabled during recovery or standby mode. If the standby server is promoted, it will start archiving after the promotion, but will not archive any WAL it did not generate itself. To get a complete series of WAL files in the archive, you must ensure that all WAL is archived, before it reaches the standby. This is inherently true with file-based log shipping, as the standby can only restore files that are found in the archive, but not if streaming replication is enabled. When a server is not in recovery mode, there is no difference between `on` and `always` modes.

26.3. Failover

If the primary server fails then the standby server should begin failover procedures.

If the standby server fails then no failover need take place. If the standby server can be restarted, even some time later, then the recovery process can also be restarted immediately, taking advantage of restartable recovery. If the standby server cannot be restarted, then a full new standby server instance should be created.

If the primary server fails and the standby server becomes the new primary, and then the old primary restarts, you must have a mechanism for informing the old primary that it is no longer the primary. This is sometimes known as STONITH (Shoot The Other Node In The Head), which is necessary to avoid situations where both systems think they are the primary, which will lead to confusion and ultimately data loss.

Many failover systems use just two systems, the primary and the standby, connected by some kind of heartbeat mechanism to continually verify the connectivity between the two and the viability of the primary. It is also possible to use a third system (called a witness server) to prevent some cases of inappropriate failover, but the additional complexity might not be worthwhile unless it is set up with sufficient care and rigorous testing.

PostgreSQL does not provide the system software required to identify a failure on the primary and notify the standby database server. Many such tools exist and are well integrated with the operating system facilities required for successful failover, such as IP address migration.

Once failover to the standby occurs, there is only a single server in operation. This is known as a degenerate state. The former standby is now the primary, but the former primary is down and might stay down. To return to normal operation, a standby server must be recreated, either on the former primary system when it comes up, or on a third, possibly new, system. The `pg_rewind` utility can be used to speed up this process on large clusters. Once complete, the primary and standby can be considered to have switched roles. Some people choose to use a third server to provide backup for the new primary until the new standby server is recreated, though clearly this complicates the system configuration and operational processes.

So, switching from primary to standby server can be fast but requires some time to re-prepare the failover cluster. Regular switching from primary to standby is useful, since it allows regular downtime on each system for maintenance. This also serves as a test of the failover mechanism to ensure that it will really work when you need it. Written administration procedures are advised.

To trigger failover of a log-shipping standby server, run `pg_ctl promote`, call `pg_promote`, or create a trigger file with the file name and path specified by the `promote_trigger_file`. If you're planning to use `pg_ctl promote` or to call `pg_promote` to fail over, `promote_trigger_file` is not required. If you're setting up the reporting servers that are only used to offload read-only queries from the primary, not for high availability purposes, you don't need to promote it.

26.4. Alternative Method for Log Shipping

An alternative to the built-in standby mode described in the previous sections is to use a `restore_command` that polls the archive location. This was the only option available in versions 8.4 and below. See the `pg_standby` module for a reference implementation of this.

Note that in this mode, the server will apply WAL one file at a time, so if you use the standby server for queries (see Hot Standby), there is a delay between an action in the master and when the action becomes visible in the standby, corresponding the time it takes to fill up the WAL file. `archive_timeout` can be used to make that delay shorter. Also note that you can't combine streaming replication with this method.

The operations that occur on both primary and standby servers are normal continuous archiving and recovery tasks. The only point of contact between the two database servers is the archive of WAL files that both share: primary writing to the archive, standby reading from the archive. Care must be taken to ensure that WAL archives from separate primary servers do not become mixed together or confused. The archive need not be large if it is only required for standby operation.

The magic that makes the two loosely coupled servers work together is simply a `restore_command` used on the standby that, when asked for the next WAL file, waits for it to become available from the primary. Normal recovery processing would request a file from the WAL archive, reporting failure if the file was unavailable. For standby processing it is normal for the next WAL file to be unavailable, so the standby must wait for it to appear. For files ending in `.history` there is no need to wait, and a non-zero return code must be returned. A waiting `restore_command` can be written as a custom script that loops after polling for the existence of the next WAL file. There must also be some way to trigger failover, which should interrupt the `restore_command`, break the loop and return a file-not-found error to the standby server. This ends recovery and the standby will then come up as a normal server.

Pseudocode for a suitable `restore_command` is:

```
triggered = false;
while (!NextWALFileReady() && !triggered)
{
    sleep(100000L);          /* wait for ~0.1 sec */
    if (CheckForExternalTrigger())
        triggered = true;
}
if (!triggered)
    CopyWALFileForRecovery();
```

A working example of a waiting `restore_command` is provided in the `pg_standby` module. It should be used as a reference on how to correctly implement the logic described above. It can also be extended as needed to support specific configurations and environments.

The method for triggering failover is an important part of planning and design. One potential option is the `restore_command` command. It is executed once for each WAL file, but the process running the `restore_command` is created and dies for each file, so there is no daemon or server process, and signals or a signal handler cannot be used. Therefore, the `restore_command` is not suitable to trigger failover. It is possible to use a simple timeout facility, especially if used in conjunction with a known `archive_timeout` setting on the primary. However, this is somewhat error prone

since a network problem or busy primary server might be sufficient to initiate failover. A notification mechanism such as the explicit creation of a trigger file is ideal, if this can be arranged.

26.4.1. Implementation

The short procedure for configuring a standby server using this alternative method is as follows. For full details of each step, refer to previous sections as noted.

1. Set up primary and standby systems as nearly identical as possible, including two identical copies of PostgreSQL at the same release level.
2. Set up continuous archiving from the primary to a WAL archive directory on the standby server. Ensure that `archive_mode`, `archive_command` and `archive_timeout` are set appropriately on the primary (see Section 25.3.1).
3. Make a base backup of the primary server (see Section 25.3.2), and load this data onto the standby.
4. Begin recovery on the standby server from the local WAL archive, using `restore_command` that waits as described previously (see Section 25.3.4).

Recovery treats the WAL archive as read-only, so once a WAL file has been copied to the standby system it can be copied to tape at the same time as it is being read by the standby database server. Thus, running a standby server for high availability can be performed at the same time as files are stored for longer term disaster recovery purposes.

For testing purposes, it is possible to run both primary and standby servers on the same system. This does not provide any worthwhile improvement in server robustness, nor would it be described as HA.

26.4.2. Record-Based Log Shipping

It is also possible to implement record-based log shipping using this alternative method, though this requires custom development, and changes will still only become visible to hot standby queries after a full WAL file has been shipped.

An external program can call the `pg_walfile_name_offset()` function (see Section 9.26) to find out the file name and the exact byte offset within it of the current end of WAL. It can then access the WAL file directly and copy the data from the last known end of WAL through the current end over to the standby servers. With this approach, the window for data loss is the polling cycle time of the copying program, which can be very small, and there is no wasted bandwidth from forcing partially-used segment files to be archived. Note that the standby servers' `restore_command` scripts can only deal with whole WAL files, so the incrementally copied data is not ordinarily made available to the standby servers. It is of use only when the primary dies — then the last partial WAL file is fed to the standby before allowing it to come up. The correct implementation of this process requires cooperation of the `restore_command` script with the data copying program.

Starting with PostgreSQL version 9.0, you can use streaming replication (see Section 26.2.5) to achieve the same benefits with less effort.

26.5. Hot Standby

Hot Standby is the term used to describe the ability to connect to the server and run read-only queries while the server is in archive recovery or standby mode. This is useful both for replication purposes and for restoring a backup to a desired state with great precision. The term Hot Standby also refers to the ability of the server to move from recovery through to normal operation while users continue running queries and/or keep their connections open.

Running queries in hot standby mode is similar to normal query operation, though there are several usage and administrative differences explained below.

26.5.1. User's Overview

When the `hot_standby` parameter is set to `true` on a standby server, it will begin accepting connections once the recovery has brought the system to a consistent state. All such connections are strictly read-only; not even temporary tables may be written.

The data on the standby takes some time to arrive from the primary server so there will be a measurable delay between primary and standby. Running the same query nearly simultaneously on both primary and standby might therefore return differing results. We say that data on the standby is *eventually consistent* with the primary. Once the commit record for a transaction is replayed on the standby, the changes made by that transaction will be visible to any new snapshots taken on the standby. Snapshots may be taken at the start of each query or at the start of each transaction, depending on the current transaction isolation level. For more details, see Section 13.2.

Transactions started during hot standby may issue the following commands:

- Query access - `SELECT`, `COPY TO`
- Cursor commands - `DECLARE`, `FETCH`, `CLOSE`
- Parameters - `SHOW`, `SET`, `RESET`
- Transaction management commands
 - `BEGIN`, `END`, `ABORT`, `START TRANSACTION`
 - `SAVEPOINT`, `RELEASE`, `ROLLBACK TO SAVEPOINT`
 - `EXCEPTION` blocks and other internal subtransactions
- `LOCK TABLE`, though only when explicitly in one of these modes: `ACCESS SHARE`, `ROW SHARE` or `ROW EXCLUSIVE`.
- Plans and resources - `PREPARE`, `EXECUTE`, `DEALLOCATE`, `DISCARD`
- Plugins and extensions - `LOAD`
- `UNLISTEN`

Transactions started during hot standby will never be assigned a transaction ID and cannot write to the system write-ahead log. Therefore, the following actions will produce error messages:

- Data Manipulation Language (DML) - `INSERT`, `UPDATE`, `DELETE`, `COPY FROM`, `TRUNCATE`. Note that there are no allowed actions that result in a trigger being executed during recovery. This restriction applies even to temporary tables, because table rows cannot be read or written without assigning a transaction ID, which is currently not possible in a Hot Standby environment.
- Data Definition Language (DDL) - `CREATE`, `DROP`, `ALTER`, `COMMENT`. This restriction applies even to temporary tables, because carrying out these operations would require updating the system catalog tables.
- `SELECT ... FOR SHARE | UPDATE`, because row locks cannot be taken without updating the underlying data files.
- Rules on `SELECT` statements that generate DML commands.
- `LOCK` that explicitly requests a mode higher than `ROW EXCLUSIVE MODE`.
- `LOCK` in short default form, since it requests `ACCESS EXCLUSIVE MODE`.
- Transaction management commands that explicitly set non-read-only state:
 - `BEGIN READ WRITE`, `START TRANSACTION READ WRITE`

- `SET TRANSACTION READ WRITE, SET SESSION CHARACTERISTICS AS TRANSACTION READ WRITE`
- `SET transaction_read_only = off`
- Two-phase commit commands - `PREPARE TRANSACTION, COMMIT PREPARED, ROLLBACK PREPARED` because even read-only transactions need to write WAL in the prepare phase (the first phase of two phase commit).
- Sequence updates - `nextval()`, `setval()`
- `LISTEN, NOTIFY`

In normal operation, “read-only” transactions are allowed to use `LISTEN` and `NOTIFY`, so Hot Standby sessions operate under slightly tighter restrictions than ordinary read-only sessions. It is possible that some of these restrictions might be loosened in a future release.

During hot standby, the parameter `transaction_read_only` is always true and may not be changed. But as long as no attempt is made to modify the database, connections during hot standby will act much like any other database connection. If failover or switchover occurs, the database will switch to normal processing mode. Sessions will remain connected while the server changes mode. Once hot standby finishes, it will be possible to initiate read-write transactions (even from a session begun during hot standby).

Users will be able to tell whether their session is read-only by issuing `SHOW transaction_read_only`. In addition, a set of functions (Table 9.85) allow users to access information about the standby server. These allow you to write programs that are aware of the current state of the database. These can be used to monitor the progress of recovery, or to allow you to write complex programs that restore the database to particular states.

26.5.2. Handling Query Conflicts

The primary and standby servers are in many ways loosely connected. Actions on the primary will have an effect on the standby. As a result, there is potential for negative interactions or conflicts between them. The easiest conflict to understand is performance: if a huge data load is taking place on the primary then this will generate a similar stream of WAL records on the standby, so standby queries may contend for system resources, such as I/O.

There are also additional types of conflict that can occur with Hot Standby. These conflicts are *hard conflicts* in the sense that queries might need to be canceled and, in some cases, sessions disconnected to resolve them. The user is provided with several ways to handle these conflicts. Conflict cases include:

- Access Exclusive locks taken on the primary server, including both explicit `LOCK` commands and various DDL actions, conflict with table accesses in standby queries.
- Dropping a tablespace on the primary conflicts with standby queries using that tablespace for temporary work files.
- Dropping a database on the primary conflicts with sessions connected to that database on the standby.
- Application of a vacuum cleanup record from WAL conflicts with standby transactions whose snapshots can still “see” any of the rows to be removed.
- Application of a vacuum cleanup record from WAL conflicts with queries accessing the target page on the standby, whether or not the data to be removed is visible.

On the primary server, these cases simply result in waiting; and the user might choose to cancel either of the conflicting actions. However, on the standby there is no choice: the WAL-logged action already

occurred on the primary so the standby must not fail to apply it. Furthermore, allowing WAL application to wait indefinitely may be very undesirable, because the standby's state will become increasingly far behind the primary's. Therefore, a mechanism is provided to forcibly cancel standby queries that conflict with to-be-applied WAL records.

An example of the problem situation is an administrator on the primary server running `DROP TABLE` on a table that is currently being queried on the standby server. Clearly the standby query cannot continue if the `DROP TABLE` is applied on the standby. If this situation occurred on the primary, the `DROP TABLE` would wait until the other query had finished. But when `DROP TABLE` is run on the primary, the primary doesn't have information about what queries are running on the standby, so it will not wait for any such standby queries. The WAL change records come through to the standby while the standby query is still running, causing a conflict. The standby server must either delay application of the WAL records (and everything after them, too) or else cancel the conflicting query so that the `DROP TABLE` can be applied.

When a conflicting query is short, it's typically desirable to allow it to complete by delaying WAL application for a little bit; but a long delay in WAL application is usually not desirable. So the cancel mechanism has parameters, `max_standby_archive_delay` and `max_standby_streaming_delay`, that define the maximum allowed delay in WAL application. Conflicting queries will be canceled once it has taken longer than the relevant delay setting to apply any newly-received WAL data. There are two parameters so that different delay values can be specified for the case of reading WAL data from an archive (i.e., initial recovery from a base backup or “catching up” a standby server that has fallen far behind) versus reading WAL data via streaming replication.

In a standby server that exists primarily for high availability, it's best to set the delay parameters relatively short, so that the server cannot fall far behind the primary due to delays caused by standby queries. However, if the standby server is meant for executing long-running queries, then a high or even infinite delay value may be preferable. Keep in mind however that a long-running query could cause other sessions on the standby server to not see recent changes on the primary, if it delays application of WAL records.

Once the delay specified by `max_standby_archive_delay` or `max_standby_streaming_delay` has been exceeded, conflicting queries will be canceled. This usually results just in a cancellation error, although in the case of replaying a `DROP DATABASE` the entire conflicting session will be terminated. Also, if the conflict is over a lock held by an idle transaction, the conflicting session is terminated (this behavior might change in the future).

Canceled queries may be retried immediately (after beginning a new transaction, of course). Since query cancellation depends on the nature of the WAL records being replayed, a query that was canceled may well succeed if it is executed again.

Keep in mind that the delay parameters are compared to the elapsed time since the WAL data was received by the standby server. Thus, the grace period allowed to any one query on the standby is never more than the delay parameter, and could be considerably less if the standby has already fallen behind as a result of waiting for previous queries to complete, or as a result of being unable to keep up with a heavy update load.

The most common reason for conflict between standby queries and WAL replay is “early cleanup”. Normally, PostgreSQL allows cleanup of old row versions when there are no transactions that need to see them to ensure correct visibility of data according to MVCC rules. However, this rule can only be applied for transactions executing on the master. So it is possible that cleanup on the master will remove row versions that are still visible to a transaction on the standby.

Experienced users should note that both row version cleanup and row version freezing will potentially conflict with standby queries. Running a manual `VACUUM FREEZE` is likely to cause conflicts even on tables with no updated or deleted rows.

Users should be clear that tables that are regularly and heavily updated on the primary server will quickly cause cancellation of longer running queries on the standby. In such cases the setting of a

finite value for `max_standby_archive_delay` or `max_standby_streaming_delay` can be considered similar to setting `statement_timeout`.

Remedial possibilities exist if the number of standby-query cancellations is found to be unacceptable. The first option is to set the parameter `hot_standby_feedback`, which prevents `VACUUM` from removing recently-dead rows and so cleanup conflicts do not occur. If you do this, you should note that this will delay cleanup of dead rows on the primary, which may result in undesirable table bloat. However, the cleanup situation will be no worse than if the standby queries were running directly on the primary server, and you are still getting the benefit of off-loading execution onto the standby. If standby servers connect and disconnect frequently, you might want to make adjustments to handle the period when `hot_standby_feedback` feedback is not being provided. For example, consider increasing `max_standby_archive_delay` so that queries are not rapidly canceled by conflicts in WAL archive files during disconnected periods. You should also consider increasing `max_standby_streaming_delay` to avoid rapid cancellations by newly-arrived streaming WAL entries after reconnection.

Another option is to increase `vacuum_defer_cleanup_age` on the primary server, so that dead rows will not be cleaned up as quickly as they normally would be. This will allow more time for queries to execute before they are canceled on the standby, without having to set a high `max_standby_streaming_delay`. However it is difficult to guarantee any specific execution-time window with this approach, since `vacuum_defer_cleanup_age` is measured in transactions executed on the primary server.

The number of query cancels and the reason for them can be viewed using the `pg_stat_database_conflicts` system view on the standby server. The `pg_stat_database` system view also contains summary information.

26.5.3. Administrator's Overview

If `hot_standby` is on in `postgresql.conf` (the default value) and there is a `standby.signal` file present, the server will run in Hot Standby mode. However, it may take some time for Hot Standby connections to be allowed, because the server will not accept connections until it has completed sufficient recovery to provide a consistent state against which queries can run. During this period, clients that attempt to connect will be refused with an error message. To confirm the server has come up, either loop trying to connect from the application, or look for these messages in the server logs:

```
LOG:  entering standby mode
```

```
... then some time later ...
```

```
LOG:  consistent recovery state reached
```

```
LOG:  database system is ready to accept read only connections
```

Consistency information is recorded once per checkpoint on the primary. It is not possible to enable hot standby when reading WAL written during a period when `wal_level` was not set to `replica` or `logical` on the primary. Reaching a consistent state can also be delayed in the presence of both of these conditions:

- A write transaction has more than 64 subtransactions
- Very long-lived write transactions

If you are running file-based log shipping ("warm standby"), you might need to wait until the next WAL file arrives, which could be as long as the `archive_timeout` setting on the primary.

The setting of some parameters on the standby will need reconfiguration if they have been changed on the primary. For these parameters, the value on the standby must be equal to or greater than the value on the primary. Therefore, if you want to increase these values, you should do so on all standby

servers first, before applying the changes to the primary server. Conversely, if you want to decrease these values, you should do so on the primary server first, before applying the changes to all standby servers. If these parameters are not set high enough then the standby will refuse to start. Higher values can then be supplied and the server restarted to begin recovery again. These parameters are:

- `max_connections`
- `max_prepared_transactions`
- `max_locks_per_transaction`
- `max_wal_senders`
- `max_worker_processes`

It is important that the administrator select appropriate settings for `max_standby_archive_delay` and `max_standby_streaming_delay`. The best choices vary depending on business priorities. For example if the server is primarily tasked as a High Availability server, then you will want low delay settings, perhaps even zero, though that is a very aggressive setting. If the standby server is tasked as an additional server for decision support queries then it might be acceptable to set the maximum delay values to many hours, or even -1 which means wait forever for queries to complete.

Transaction status "hint bits" written on the primary are not WAL-logged, so data on the standby will likely re-write the hints again on the standby. Thus, the standby server will still perform disk writes even though all users are read-only; no changes occur to the data values themselves. Users will still write large sort temporary files and re-generate relcache info files, so no part of the database is truly read-only during hot standby mode. Note also that writes to remote databases using dblink module, and other operations outside the database using PL functions will still be possible, even though the transaction is read-only locally.

The following types of administration commands are not accepted during recovery mode:

- Data Definition Language (DDL) - e.g. `CREATE INDEX`
- Privilege and Ownership - `GRANT`, `REVOKE`, `REASSIGN`
- Maintenance commands - `ANALYZE`, `VACUUM`, `CLUSTER`, `REINDEX`

Again, note that some of these commands are actually allowed during "read only" mode transactions on the primary.

As a result, you cannot create additional indexes that exist solely on the standby, nor statistics that exist solely on the standby. If these administration commands are needed, they should be executed on the primary, and eventually those changes will propagate to the standby.

`pg_cancel_backend()` and `pg_terminate_backend()` will work on user backends, but not the Startup process, which performs recovery. `pg_stat_activity` does not show recovering transactions as active. As a result, `pg_prepared_xacts` is always empty during recovery. If you wish to resolve in-doubt prepared transactions, view `pg_prepared_xacts` on the primary and issue commands to resolve transactions there or resolve them after the end of recovery.

`pg_locks` will show locks held by backends, as normal. `pg_locks` also shows a virtual transaction managed by the Startup process that owns all `AccessExclusiveLocks` held by transactions being replayed by recovery. Note that the Startup process does not acquire locks to make database changes, and thus locks other than `AccessExclusiveLocks` do not show in `pg_locks` for the Startup process; they are just presumed to exist.

The Nagios plugin `check_pgsql` will work, because the simple information it checks for exists. The `check_postgres` monitoring script will also work, though some reported values could give different or confusing results. For example, last vacuum time will not be maintained, since no vacuum occurs on the standby. Vacuums running on the primary do still send their changes to the standby.

WAL file control commands will not work during recovery, e.g. `pg_start_backup`, `pg_switch_wal` etc.

Dynamically loadable modules work, including `pg_stat_statements`.

Advisory locks work normally in recovery, including deadlock detection. Note that advisory locks are never WAL logged, so it is impossible for an advisory lock on either the primary or the standby to conflict with WAL replay. Nor is it possible to acquire an advisory lock on the primary and have it initiate a similar advisory lock on the standby. Advisory locks relate only to the server on which they are acquired.

Trigger-based replication systems such as Slony, Londiste and Bucardo won't run on the standby at all, though they will run happily on the primary server as long as the changes are not sent to standby servers to be applied. WAL replay is not trigger-based so you cannot relay from the standby to any system that requires additional database writes or relies on the use of triggers.

New OIDs cannot be assigned, though some UUID generators may still work as long as they do not rely on writing new status to the database.

Currently, temporary table creation is not allowed during read only transactions, so in some cases existing scripts will not run correctly. This restriction might be relaxed in a later release. This is both a SQL Standard compliance issue and a technical issue.

`DROP TABLESPACE` can only succeed if the tablespace is empty. Some standby users may be actively using the tablespace via their `temp_tablespaces` parameter. If there are temporary files in the tablespace, all active queries are canceled to ensure that temporary files are removed, so the tablespace can be removed and WAL replay can continue.

Running `DROP DATABASE` or `ALTER DATABASE ... SET TABLESPACE` on the primary will generate a WAL entry that will cause all users connected to that database on the standby to be forcibly disconnected. This action occurs immediately, whatever the setting of `max_standby_streaming_delay`. Note that `ALTER DATABASE ... RENAME` does not disconnect users, which in most cases will go unnoticed, though might in some cases cause a program confusion if it depends in some way upon database name.

In normal (non-recovery) mode, if you issue `DROP USER` or `DROP ROLE` for a role with login capability while that user is still connected then nothing happens to the connected user - they remain connected. The user cannot reconnect however. This behavior applies in recovery also, so a `DROP USER` on the primary does not disconnect that user on the standby.

The statistics collector is active during recovery. All scans, reads, blocks, index usage, etc., will be recorded normally on the standby. Replayed actions will not duplicate their effects on primary, so replaying an insert will not increment the Inserts column of `pg_stat_user_tables`. The stats file is deleted at the start of recovery, so stats from primary and standby will differ; this is considered a feature, not a bug.

Autovacuum is not active during recovery. It will start normally at the end of recovery.

The background writer is active during recovery and will perform restartpoints (similar to checkpoints on the primary) and normal block cleaning activities. This can include updates of the hint bit information stored on the standby server. The `CHECKPOINT` command is accepted during recovery, though it performs a restartpoint rather than a new checkpoint.

26.5.4. Hot Standby Parameter Reference

Various parameters have been mentioned above in Section 26.5.2 and Section 26.5.3.

On the primary, parameters `wal_level` and `vacuum_defer_cleanup_age` can be used. `max_standby_archive_delay` and `max_standby_streaming_delay` have no effect if set on the primary.

On the standby, parameters `hot_standby`, `max_standby_archive_delay` and `max_standby_streaming_delay` can be used. `vacuum_defer_cleanup_age` has no effect as long as the server remains in standby mode, though it will become relevant if the standby becomes primary.

26.5.5. Caveats

There are several limitations of Hot Standby. These can and probably will be fixed in future releases:

- Full knowledge of running transactions is required before snapshots can be taken. Transactions that use large numbers of subtransactions (currently greater than 64) will delay the start of read only connections until the completion of the longest running write transaction. If this situation occurs, explanatory messages will be sent to the server log.
- Valid starting points for standby queries are generated at each checkpoint on the master. If the standby is shut down while the master is in a shutdown state, it might not be possible to re-enter Hot Standby until the primary is started up, so that it generates further starting points in the WAL logs. This situation isn't a problem in the most common situations where it might happen. Generally, if the primary is shut down and not available anymore, that's likely due to a serious failure that requires the standby being converted to operate as the new primary anyway. And in situations where the primary is being intentionally taken down, coordinating to make sure the standby becomes the new primary smoothly is also standard procedure.
- At the end of recovery, `AccessExclusiveLocks` held by prepared transactions will require twice the normal number of lock table entries. If you plan on running either a large number of concurrent prepared transactions that normally take `AccessExclusiveLocks`, or you plan on having one large transaction that takes many `AccessExclusiveLocks`, you are advised to select a larger value of `max_locks_per_transaction`, perhaps as much as twice the value of the parameter on the primary server. You need not consider this at all if your setting of `max_prepared_transactions` is 0.
- The Serializable transaction isolation level is not yet available in hot standby. (See Section 13.2.3 and Section 13.4.1 for details.) An attempt to set a transaction to the serializable isolation level in hot standby mode will generate an error.

Chapter 27. Monitoring Database Activity

A database administrator frequently wonders, “What is the system doing right now?” This chapter discusses how to find that out.

Several tools are available for monitoring database activity and analyzing performance. Most of this chapter is devoted to describing PostgreSQL's statistics collector, but one should not neglect regular Unix monitoring programs such as `ps`, `top`, `iostat`, and `vmstat`. Also, once one has identified a poorly-performing query, further investigation might be needed using PostgreSQL's `EXPLAIN` command. Section 14.1 discusses `EXPLAIN` and other methods for understanding the behavior of an individual query.

27.1. Standard Unix Tools

On most Unix platforms, PostgreSQL modifies its command title as reported by `ps`, so that individual server processes can readily be identified. A sample display is

```
$ ps auxww | grep ^postgres
postgres 15551 0.0 0.1 57536 7132 pts/0 S 18:02 0:00
postgres -i
postgres 15554 0.0 0.0 57536 1184 ? Ss 18:02 0:00
postgres: background writer
postgres 15555 0.0 0.0 57536 916 ? Ss 18:02 0:00
postgres: checkpointer
postgres 15556 0.0 0.0 57536 916 ? Ss 18:02 0:00
postgres: walwriter
postgres 15557 0.0 0.0 58504 2244 ? Ss 18:02 0:00
postgres: autovacuum launcher
postgres 15558 0.0 0.0 17512 1068 ? Ss 18:02 0:00
postgres: stats collector
postgres 15582 0.0 0.0 58772 3080 ? Ss 18:04 0:00
postgres: joe runbug 127.0.0.1 idle
postgres 15606 0.0 0.0 58772 3052 ? Ss 18:07 0:00
postgres: tgl regression [local] SELECT waiting
postgres 15610 0.0 0.0 58772 3056 ? Ss 18:07 0:00
postgres: tgl regression [local] idle in transaction
```

(The appropriate invocation of `ps` varies across different platforms, as do the details of what is shown. This example is from a recent Linux system.) The first process listed here is the master server process. The command arguments shown for it are the same ones used when it was launched. The next five processes are background worker processes automatically launched by the master process. (The “stats collector” process will not be present if you have set the system not to start the statistics collector; likewise the “autovacuum launcher” process can be disabled.) Each of the remaining processes is a server process handling one client connection. Each such process sets its command line display in the form

```
postgres: user database host activity
```

The user, database, and (client) host items remain the same for the life of the client connection, but the activity indicator changes. The activity can be `idle` (i.e., waiting for a client command), `idle in transaction` (waiting for client inside a `BEGIN` block), or a command type name such as `SELECT`. Also, `waiting` is appended if the server process is presently waiting on a lock held by another session. In the above example we can infer that process 15606 is waiting for process 15610 to

complete its transaction and thereby release some lock. (Process 15610 must be the blocker, because there is no other active session. In more complicated cases it would be necessary to look into the `pg_locks` system view to determine who is blocking whom.)

If `cluster_name` has been configured the cluster name will also be shown in `ps` output:

```
$ psql -c 'SHOW cluster_name'
 cluster_name
-----
 server1
(1 row)

$ ps aux|grep server1
postgres 27093 0.0 0.0 30096 2752 ?          Ss   11:34   0:00
 postgres: server1: background writer
...
```

If you have turned off `update_process_title` then the activity indicator is not updated; the process title is set only once when a new process is launched. On some platforms this saves a measurable amount of per-command overhead; on others it's insignificant.

Tip

Solaris requires special handling. You must use `/usr/ucb/ps`, rather than `/bin/ps`. You also must use two `w` flags, not just one. In addition, your original invocation of the `postgres` command must have a shorter `ps` status display than that provided by each server process. If you fail to do all three things, the `ps` output for each server process will be the original `postgres` command line.

27.2. The Statistics Collector

PostgreSQL's *statistics collector* is a subsystem that supports collection and reporting of information about server activity. Presently, the collector can count accesses to tables and indexes in both disk-block and individual-row terms. It also tracks the total number of rows in each table, and information about vacuum and analyze actions for each table. It can also count calls to user-defined functions and the total time spent in each one.

PostgreSQL also supports reporting dynamic information about exactly what is going on in the system right now, such as the exact command currently being executed by other server processes, and which other connections exist in the system. This facility is independent of the collector process.

27.2.1. Statistics Collection Configuration

Since collection of statistics adds some overhead to query execution, the system can be configured to collect or not collect information. This is controlled by configuration parameters that are normally set in `postgresql.conf`. (See Chapter 19 for details about setting configuration parameters.)

The parameter `track_activities` enables monitoring of the current command being executed by any server process.

The parameter `track_counts` controls whether statistics are collected about table and index accesses.

The parameter `track_functions` enables tracking of usage of user-defined functions.

The parameter `track_io_timing` enables monitoring of block read and write times.

Normally these parameters are set in `postgresql.conf` so that they apply to all server processes, but it is possible to turn them on or off in individual sessions using the `SET` command. (To prevent

ordinary users from hiding their activity from the administrator, only superusers are allowed to change these parameters with `SET`.)

The statistics collector transmits the collected information to other PostgreSQL processes through temporary files. These files are stored in the directory named by the `stats_temp_directory` parameter, `pg_stat_tmp` by default. For better performance, `stats_temp_directory` can be pointed at a RAM-based file system, decreasing physical I/O requirements. When the server shuts down cleanly, a permanent copy of the statistics data is stored in the `pg_stat` subdirectory, so that statistics can be retained across server restarts. When recovery is performed at server start (e.g. after immediate shutdown, server crash, and point-in-time recovery), all statistics counters are reset.

27.2.2. Viewing Statistics

Several predefined views, listed in Table 27.1, are available to show the current state of the system. There are also several other views, listed in Table 27.2, available to show the results of statistics collection. Alternatively, one can build custom views using the underlying statistics functions, as discussed in Section 27.2.3.

When using the statistics to monitor collected data, it is important to realize that the information does not update instantaneously. Each individual server process transmits new statistical counts to the collector just before going idle; so a query or transaction still in progress does not affect the displayed totals. Also, the collector itself emits a new report at most once per `PGSTAT_STAT_INTERVAL` milliseconds (500 ms unless altered while building the server). So the displayed information lags behind actual activity. However, current-query information collected by `track_activities` is always up-to-date.

Another important point is that when a server process is asked to display any of these statistics, it first fetches the most recent report emitted by the collector process and then continues to use this snapshot for all statistical views and functions until the end of its current transaction. So the statistics will show static information as long as you continue the current transaction. Similarly, information about the current queries of all sessions is collected when any such information is first requested within a transaction, and the same information will be displayed throughout the transaction. This is a feature, not a bug, because it allows you to perform several queries on the statistics and correlate the results without worrying that the numbers are changing underneath you. But if you want to see new results with each query, be sure to do the queries outside any transaction block. Alternatively, you can invoke `pg_stat_clear_snapshot()`, which will discard the current transaction's statistics snapshot (if any). The next use of statistical information will cause a new snapshot to be fetched.

A transaction can also see its own statistics (as yet untransmitted to the collector) in the views `pg_stat_xact_all_tables`, `pg_stat_xact_sys_tables`, `pg_stat_xact_user_tables`, and `pg_stat_xact_user_functions`. These numbers do not act as stated above; instead they update continuously throughout the transaction.

Some of the information in the dynamic statistics views shown in Table 27.1 is security restricted. Ordinary users can only see all the information about their own sessions (sessions belonging to a role that they are a member of). In rows about other sessions, many columns will be null. Note, however, that the existence of a session and its general properties such as its sessions user and database are visible to all users. Superusers and members of the built-in role `pg_read_all_stats` (see also Section 21.5) can see all the information about all sessions.

Table 27.1. Dynamic Statistics Views

View Name	Description
<code>pg_stat_activity</code>	One row per server process, showing information related to the current activity of that process, such as state and current query. See <code>pg_stat_activity</code> for details.
<code>pg_stat_replication</code>	One row per WAL sender process, showing statistics about replication to that sender's connect-

View Name	Description
	ed standby server. See <code>pg_stat_replication</code> for details.
<code>pg_stat_wal_receiver</code>	Only one row, showing statistics about the WAL receiver from that receiver's connected server. See <code>pg_stat_wal_receiver</code> for details.
<code>pg_stat_subscription</code>	At least one row per subscription, showing information about the subscription workers. See <code>pg_stat_subscription</code> for details.
<code>pg_stat_ssl</code>	One row per connection (regular and replication), showing information about SSL used on this connection. See <code>pg_stat_ssl</code> for details.
<code>pg_stat_gssapi</code>	One row per connection (regular and replication), showing information about GSSAPI authentication and encryption used on this connection. See <code>pg_stat_gssapi</code> for details.
<code>pg_stat_progress_create_index</code>	One row for each backend running <code>CREATE INDEX</code> or <code>REINDEX</code> , showing current progress. See Section 27.4.1.
<code>pg_stat_progress_vacuum</code>	One row for each backend (including autovacuum worker processes) running <code>VACUUM</code> , showing current progress. See Section 27.4.2.
<code>pg_stat_progress_cluster</code>	One row for each backend running <code>CLUSTER</code> or <code>VACUUM FULL</code> , showing current progress. See Section 27.4.3.

Table 27.2. Collected Statistics Views

View Name	Description
<code>pg_stat_archiver</code>	One row only, showing statistics about the WAL archiver process's activity. See <code>pg_stat_archiver</code> for details.
<code>pg_stat_bgwriter</code>	One row only, showing statistics about the background writer process's activity. See <code>pg_stat_bgwriter</code> for details.
<code>pg_stat_database</code>	One row per database, showing database-wide statistics. See <code>pg_stat_database</code> for details.
<code>pg_stat_database_conflicts</code>	One row per database, showing database-wide statistics about query cancels due to conflict with recovery on standby servers. See <code>pg_stat_database_conflicts</code> for details.
<code>pg_stat_all_tables</code>	One row for each table in the current database, showing statistics about accesses to that specific table. See <code>pg_stat_all_tables</code> for details.
<code>pg_stat_sys_tables</code>	Same as <code>pg_stat_all_tables</code> , except that only system tables are shown.
<code>pg_stat_user_tables</code>	Same as <code>pg_stat_all_tables</code> , except that only user tables are shown.
<code>pg_stat_xact_all_tables</code>	Similar to <code>pg_stat_all_tables</code> , but counts actions taken so far within the current transaction (which are <i>not</i> yet included in <code>pg_stat_all_tables</code> and related views). The columns for

View Name	Description
	numbers of live and dead rows and vacuum and analyze actions are not present in this view.
<code>pg_stat_xact_sys_tables</code>	Same as <code>pg_stat_xact_all_tables</code> , except that only system tables are shown.
<code>pg_stat_xact_user_tables</code>	Same as <code>pg_stat_xact_all_tables</code> , except that only user tables are shown.
<code>pg_stat_all_indexes</code>	One row for each index in the current database, showing statistics about accesses to that specific index. See <code>pg_stat_all_indexes</code> for details.
<code>pg_stat_sys_indexes</code>	Same as <code>pg_stat_all_indexes</code> , except that only indexes on system tables are shown.
<code>pg_stat_user_indexes</code>	Same as <code>pg_stat_all_indexes</code> , except that only indexes on user tables are shown.
<code>pg_statio_all_tables</code>	One row for each table in the current database, showing statistics about I/O on that specific table. See <code>pg_statio_all_tables</code> for details.
<code>pg_statio_sys_tables</code>	Same as <code>pg_statio_all_tables</code> , except that only system tables are shown.
<code>pg_statio_user_tables</code>	Same as <code>pg_statio_all_tables</code> , except that only user tables are shown.
<code>pg_statio_all_indexes</code>	One row for each index in the current database, showing statistics about I/O on that specific index. See <code>pg_statio_all_indexes</code> for details.
<code>pg_statio_sys_indexes</code>	Same as <code>pg_statio_all_indexes</code> , except that only indexes on system tables are shown.
<code>pg_statio_user_indexes</code>	Same as <code>pg_statio_all_indexes</code> , except that only indexes on user tables are shown.
<code>pg_statio_all_sequences</code>	One row for each sequence in the current database, showing statistics about I/O on that specific sequence. See <code>pg_statio_all_sequences</code> for details.
<code>pg_statio_sys_sequences</code>	Same as <code>pg_statio_all_sequences</code> , except that only system sequences are shown. (Presently, no system sequences are defined, so this view is always empty.)
<code>pg_statio_user_sequences</code>	Same as <code>pg_statio_all_sequences</code> , except that only user sequences are shown.
<code>pg_stat_user_functions</code>	One row for each tracked function, showing statistics about executions of that function. See <code>pg_stat_user_functions</code> for details.
<code>pg_stat_xact_user_functions</code>	Similar to <code>pg_stat_user_functions</code> , but counts only calls during the current transaction (which are <i>not</i> yet included in <code>pg_stat_user_functions</code>).

The per-index statistics are particularly useful to determine which indexes are being used and how effective they are.

The `pg_statio_` views are primarily useful to determine the effectiveness of the buffer cache. When the number of actual disk reads is much smaller than the number of buffer hits, then the cache is satisfying most read requests without invoking a kernel call. However, these statistics do not give the

entire story: due to the way in which PostgreSQL handles disk I/O, data that is not in the PostgreSQL buffer cache might still reside in the kernel's I/O cache, and might therefore still be fetched without requiring a physical read. Users interested in obtaining more detailed information on PostgreSQL I/O behavior are advised to use the PostgreSQL statistics collector in combination with operating system utilities that allow insight into the kernel's handling of I/O.

Table 27.3. pg_stat_activity View

Column	Type	Description
datid	oid	OID of the database this backend is connected to
datname	name	Name of the database this backend is connected to
pid	integer	Process ID of this backend
usesysid	oid	OID of the user logged into this backend
username	name	Name of the user logged into this backend
application_name	text	Name of the application that is connected to this backend
client_addr	inet	IP address of the client connected to this backend. If this field is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum.
client_hostname	text	Host name of the connected client, as reported by a reverse DNS lookup of <code>client_addr</code> . This field will only be non-null for IP connections, and only when <code>log_hostname</code> is enabled.
client_port	integer	TCP port number that the client is using for communication with this backend, or -1 if a Unix socket is used
backend_start	timestamp with time zone	Time when this process was started. For client backends, this is the time the client connected to the server.
xact_start	timestamp with time zone	Time when this process' current transaction was started, or null if no transaction is active. If the current query is the first of its transaction, this column is equal to the <code>query_start</code> column.
query_start	timestamp with time zone	Time when the currently active query was started, or if <code>state</code> is not active, when the last query was started
state_change	timestamp with time zone	Time when the state was last changed

Column	Type	Description
wait_event_type	text	<p>The type of event for which the backend is waiting, if any; otherwise NULL. Possible values are:</p> <ul style="list-style-type: none"> • LWLock: The backend is waiting for a lightweight lock. Each such lock protects a particular data structure in shared memory. <code>wait_event</code> will contain a name identifying the purpose of the lightweight lock. (Some locks have specific names; others are part of a group of locks each with a similar purpose.) • Lock: The backend is waiting for a heavyweight lock. Heavyweight locks, also known as lock manager locks or simply locks, primarily protect SQL-visible objects such as tables. However, they are also used to ensure mutual exclusion for certain internal operations such as relation extension. <code>wait_event</code> will identify the type of lock awaited. • BufferPin: The server process is waiting to access to a data buffer during a period when no other process can be examining that buffer. Buffer pin waits can be protracted if another process holds an open cursor which last read data from the buffer in question. • Activity: The server process is idle. This is used by system processes waiting for activity in their main processing loop. <code>wait_event</code> will identify the specific wait point. • Extension: The server process is waiting for activity in an extension module. This category is useful for modules to track custom waiting points. • Client: The server process is waiting for some activ-

Column	Type	Description
		<p>ity on a socket from user applications, and that the server expects something to happen that is independent from its internal processes. <code>wait_event</code> will identify the specific wait point.</p> <ul style="list-style-type: none"> • IPC: The server process is waiting for some activity from another process in the server. <code>wait_event</code> will identify the specific wait point. • Timeout: The server process is waiting for a timeout to expire. <code>wait_event</code> will identify the specific wait point. • IO: The server process is waiting for a IO to complete. <code>wait_event</code> will identify the specific wait point.
<code>wait_event</code>	text	Wait event name if backend is currently waiting, otherwise NULL. See Table 27.4 for details.
<code>state</code>	text	<p>Current overall state of this backend. Possible values are:</p> <ul style="list-style-type: none"> • active: The backend is executing a query. • idle: The backend is waiting for a new client command. • idle in transaction: The backend is in a transaction, but is not currently executing a query. • idle in transaction (aborted): This state is similar to <code>idle in transaction</code>, except one of the statements in the transaction caused an error. • fastpath function call: The backend is executing a fast-path function. • disabled: This state is reported if <code>track_activities</code> is disabled in this backend.

Column	Type	Description
backend_xid	xid	Top-level transaction identifier of this backend, if any.
backend_xmin	xid	The current backend's xmin horizon.
query	text	Text of this backend's most recent query. If state is active this field shows the currently executing query. In all other states, it shows the last query that was executed. By default the query text is truncated at 1024 characters; this value can be changed via the parameter track_activity_query_size.
backend_type	text	Type of current backend. Possible types are autovacuum launcher, autovacuum worker, logical replication launcher, logical replication worker, parallel worker, background writer, client backend, checkpoint, startup, walreceiver, walsender and walwriter. In addition, background workers registered by extensions may have additional types.

The `pg_stat_activity` view will have one row per server process, showing information related to the current activity of that process.

Note

The `wait_event` and `state` columns are independent. If a backend is in the active state, it may or may not be waiting on some event. If the state is active and `wait_event` is non-null, it means that a query is being executed, but is being blocked somewhere in the system.

Table 27.4. `wait_event` Description

Wait Event Type	Wait Event Name	Description
LWLock	ShmemIndexLock	Waiting to find or allocate space in shared memory.
	OidGenLock	Waiting to allocate or assign an OID.
	XidGenLock	Waiting to allocate or assign a transaction id.
	ProcArrayLock	Waiting to get a snapshot or clearing a transaction id at transaction end.

Wait Event Type	Wait Event Name	Description
	SInvalReadLock	Waiting to retrieve or remove messages from shared invalidation queue.
	SInvalWriteLock	Waiting to add a message in shared invalidation queue.
	WALBufMappingLock	Waiting to replace a page in WAL buffers.
	WALWriteLock	Waiting for WAL buffers to be written to disk.
	ControlFileLock	Waiting to read or update the control file or creation of a new WAL file.
	CheckpointLock	Waiting to perform checkpoint.
	CLogControlLock	Waiting to read or update transaction status.
	SubtransControlLock	Waiting to read or update subtransaction information.
	MultiXactGenLock	Waiting to read or update shared multixact state.
	MultiXactOffsetControlLock	Waiting to read or update multixact offset mappings.
	MultiXactMemberControlLock	Waiting to read or update multixact member mappings.
	RelCacheInitLock	Waiting to read or write relation cache initialization file.
	CheckpointerCommLock	Waiting to manage fsync requests.
	TwoPhaseStateLock	Waiting to read or update the state of prepared transactions.
	TablespaceCreateLock	Waiting to create or drop the tablespace.
	BtreeVacuumLock	Waiting to read or update vacuum-related information for a B-tree index.
	AddinShmemInitLock	Waiting to manage space allocation in shared memory.
	AutovacuumLock	Autovacuum worker or launcher waiting to update or read the current state of autovacuum workers.
	AutovacuumScheduleLock	Waiting to ensure that the table it has selected for a vacuum still needs vacuuming.
	SyncScanLock	Waiting to get the start location of a scan on a table for synchronized scans.

Wait Event Type	Wait Event Name	Description
	RelationMappingLock	Waiting to update the relation map file used to store catalog to filenode mapping.
	AsyncCtlLock	Waiting to read or update shared notification state.
	AsyncQueueLock	Waiting to read or update notification messages.
	SerializableExactHashLock	Waiting to retrieve or store information about serializable transactions.
	SerializableFinishedListLock	Waiting to access the list of finished serializable transactions.
	SerializablePredicateLockListLock	Waiting to perform an operation on a list of locks held by serializable transactions.
	OldSerXidLock	Waiting to read or record conflicting serializable transactions.
	SyncRepLock	Waiting to read or update information about synchronous replicas.
	BackgroundWorkerLock	Waiting to read or update background worker state.
	DynamicSharedMemoryControlLock	Waiting to read or update dynamic shared memory state.
	AutoFileLock	Waiting to update the postgresql.auto.conf file.
	ReplicationSlotAllocationLock	Waiting to allocate or free a replication slot.
	ReplicationSlotControlLock	Waiting to read or update replication slot state.
	CommitTsControlLock	Waiting to read or update transaction commit timestamps.
	CommitTsLock	Waiting to read or update the last value set for the transaction timestamp.
	ReplicationOriginLock	Waiting to setup, drop or use replication origin.
	MultiXactTruncationLock	Waiting to read or truncate multixact information.
	OldSnapshotTimeMapLock	Waiting to read or update old snapshot control information.
	LogicalRepWorkerLock	Waiting for action on logical replication worker to finish.
	CLogTruncationLock	Waiting to execute txid_status or update the oldest transaction id available to it.
	clog	Waiting for I/O on a clog (transaction status) buffer.

Wait Event Type	Wait Event Name	Description
	commit_timestamp	Waiting for I/O on commit timestamp buffer.
	subtrans	Waiting for I/O a subtransaction buffer.
	multixact_offset	Waiting for I/O on a multixact offset buffer.
	multixact_member	Waiting for I/O on a multixact_member buffer.
	async	Waiting for I/O on an async (notify) buffer.
	oldserxid	Waiting for I/O on an oldserxid buffer.
	wal_insert	Waiting to insert WAL into a memory buffer.
	buffer_content	Waiting to read or write a data page in memory.
	buffer_io	Waiting for I/O on a data page.
	replication_origin	Waiting to read or update the replication progress.
	replication_slot_io	Waiting for I/O on a replication slot.
	proc	Waiting to read or update the fast-path lock information.
	buffer_mapping	Waiting to associate a data block with a buffer in the buffer pool.
	lock_manager	Waiting to add or examine locks for backends, or waiting to join or exit a locking group (used by parallel query).
	predicate_lock_manager	Waiting to add or examine predicate lock information.
	serializable_xact	Waiting to perform an operation on a serializable transaction in a parallel query.
	parallel_query_dsa	Waiting for parallel query dynamic shared memory allocation lock.
	tbm	Waiting for TBM shared iterator lock.
	parallel_append	Waiting to choose the next subplan during Parallel Append plan execution.
	parallel_hash_join	Waiting to allocate or exchange a chunk of memory or update counters during Parallel Hash plan execution.
Lock	relation	Waiting to acquire a lock on a relation.

Wait Event Type	Wait Event Name	Description
	extend	Waiting to extend a relation.
	page	Waiting to acquire a lock on page of a relation.
	tuple	Waiting to acquire a lock on a tuple.
	transactionid	Waiting for a transaction to finish.
	virtualxid	Waiting to acquire a virtual xid lock.
	speculative token	Waiting to acquire a speculative insertion lock.
	object	Waiting to acquire a lock on a non-relation database object.
	userlock	Waiting to acquire a user lock.
	advisory	Waiting to acquire an advisory user lock.
BufferPin	BufferPin	Waiting to acquire a pin on a buffer.
Activity	ArchiverMain	Waiting in main loop of the archiver process.
	AutoVacuumMain	Waiting in main loop of autovacuum launcher process.
	BgWriterHibernate	Waiting in background writer process, hibernating.
	BgWriterMain	Waiting in main loop of background writer process background worker.
	CheckpointMain	Waiting in main loop of checkpoint process.
	LogicalApplyMain	Waiting in main loop of logical apply process.
	LogicalLauncherMain	Waiting in main loop of logical launcher process.
	PgStatMain	Waiting in main loop of the statistics collector process.
	RecoveryWalAll	Waiting for WAL from any kind of source (local, archive or stream) at recovery.
	RecoveryWalStream	Waiting for WAL from a stream at recovery.
	SysLoggerMain	Waiting in main loop of sysloger process.
	WalReceiverMain	Waiting in main loop of WAL receiver process.
	WalSenderMain	Waiting in main loop of WAL sender process.

Wait Event Type	Wait Event Name	Description
	WalWriterMain	Waiting in main loop of WAL writer process.
Client	ClientRead	Waiting to read data from the client.
	ClientWrite	Waiting to write data to the client.
	LibPQWalReceiverConnect	Waiting in WAL receiver to establish connection to remote server.
	LibPQWalReceiverReceive	Waiting in WAL receiver to receive data from remote server.
	SSLOpenServer	Waiting for SSL while attempting connection.
	WalReceiverWaitStart	Waiting for startup process to send initial data for streaming replication.
	WalSenderWaitForWAL	Waiting for WAL to be flushed in WAL sender process.
	WalSenderWriteData	Waiting for any activity when processing replies from WAL receiver in WAL sender process.
Extension	Extension	Waiting in an extension.
IPC	BgWorkerShutdown	Waiting for background worker to shut down.
	BgWorkerStartup	Waiting for background worker to start up.
	BtreePage	Waiting for the page number needed to continue a parallel B-tree scan to become available.
	CheckpointDone	Waiting for a checkpoint to complete.
	CheckpointStart	Waiting for a checkpoint to start.
	ClogGroupUpdate	Waiting for group leader to update transaction status at transaction end.
	ExecuteGather	Waiting for activity from child process when executing Gather node.
	Hash/Batch/Allocating	Waiting for an elected Parallel Hash participant to allocate a hash table.
	Hash/Batch/Electing	Electing a Parallel Hash participant to allocate a hash table.
	Hash/Batch/Loading	Waiting for other Parallel Hash participants to finish loading a hash table.

Wait Event Type	Wait Event Name	Description
	Hash/Build/Allocating	Waiting for an elected Parallel Hash participant to allocate the initial hash table.
	Hash/Build/Electing	Electing a Parallel Hash participant to allocate the initial hash table.
	Hash/Build/HashingInner	Waiting for other Parallel Hash participants to finish hashing the inner relation.
	Hash/Build/HashingOuter	Waiting for other Parallel Hash participants to finish partitioning the outer relation.
	Hash/GrowBatches/Allocating	Waiting for an elected Parallel Hash participant to allocate more batches.
	Hash/GrowBatches/Deciding	Electing a Parallel Hash participant to decide on future batch growth.
	Hash/GrowBatches/Electing	Electing a Parallel Hash participant to allocate more batches.
	Hash/GrowBatches/Finishing	Waiting for an elected Parallel Hash participant to decide on future batch growth.
	Hash/GrowBatches/Repartitioning	Waiting for other Parallel Hash participants to finishing repartitioning.
	Hash/GrowBuckets/Allocating	Waiting for an elected Parallel Hash participant to finish allocating more buckets.
	Hash/GrowBuckets/Electing	Electing a Parallel Hash participant to allocate more buckets.
	Hash/GrowBuckets/Reinserting	Waiting for other Parallel Hash participants to finish inserting tuples into new buckets.
	LogicalSyncData	Waiting for logical replication remote server to send data for initial table synchronization.
	LogicalSyncStateChange	Waiting for logical replication remote server to change state.
	MessageQueueInternal	Waiting for other process to be attached in shared message queue.
	MessageQueuePutMessage	Waiting to write a protocol message to a shared message queue.
	MessageQueueReceive	Waiting to receive bytes from a shared message queue.
	MessageQueueSend	Waiting to send bytes to a shared message queue.

Wait Event Type	Wait Event Name	Description
	ParallelBitmapScan	Waiting for parallel bitmap scan to become initialized.
	ParallelCreateIndexScan	Waiting for parallel CREATE INDEX workers to finish heap scan.
	ParallelFinish	Waiting for parallel workers to finish computing.
	ProcArrayGroupUpdate	Waiting for group leader to clear transaction id at transaction end.
	Promote	Waiting for standby promotion.
	ReplicationOriginDrop	Waiting for a replication origin to become inactive to be dropped.
	ReplicationSlotDrop	Waiting for a replication slot to become inactive to be dropped.
	SafeSnapshot	Waiting for a snapshot for a READ ONLY DEFERRABLE transaction.
	SyncRep	Waiting for confirmation from remote server during synchronous replication.
Timeout	BaseBackupThrottle	Waiting during base backup when throttling activity.
	PgSleep	Waiting in process that called pg_sleep.
	RecoveryApplyDelay	Waiting to apply WAL at recovery because it is delayed.
IO	BufFileRead	Waiting for a read from a buffered file.
	BufFileWrite	Waiting for a write to a buffered file.
	ControlFileRead	Waiting for a read from the control file.
	ControlFileSync	Waiting for the control file to reach stable storage.
	ControlFileSyncUpdate	Waiting for an update to the control file to reach stable storage.
	ControlFileWrite	Waiting for a write to the control file.
	ControlFileWriteUpdate	Waiting for a write to update the control file.
	CopyFileRead	Waiting for a read during a file copy operation.
	CopyFileWrite	Waiting for a write during a file copy operation.
	DataFileExtend	Waiting for a relation data file to be extended.

Wait Event Type	Wait Event Name	Description
	DataFileFlush	Waiting for a relation data file to reach stable storage.
	DataFileImmediateSync	Waiting for an immediate synchronization of a relation data file to stable storage.
	DataFilePrefetch	Waiting for an asynchronous prefetch from a relation data file.
	DataFileRead	Waiting for a read from a relation data file.
	DataFileSync	Waiting for changes to a relation data file to reach stable storage.
	DataFileTruncate	Waiting for a relation data file to be truncated.
	DataFileWrite	Waiting for a write to a relation data file.
	DSMFillZeroWrite	Waiting to write zero bytes to a dynamic shared memory backing file.
	LockFileAddTo-DataDirRead	Waiting for a read while adding a line to the data directory lock file.
	LockFileAddTo-DataDirSync	Waiting for data to reach stable storage while adding a line to the data directory lock file.
	LockFileAddTo-DataDirWrite	Waiting for a write while adding a line to the data directory lock file.
	LockFileCreateRead	Waiting to read while creating the data directory lock file.
	LockFileCreateSync	Waiting for data to reach stable storage while creating the data directory lock file.
	LockFileCreateWrite	Waiting for a write while creating the data directory lock file.
	LockFileReCheck-DataDirRead	Waiting for a read during recheck of the data directory lock file.
	LogicalRewriteCheckpointSync	Waiting for logical rewrite mappings to reach stable storage during a checkpoint.
	LogicalRewriteMappingSync	Waiting for mapping data to reach stable storage during a logical rewrite.
	LogicalRewriteMappingWrite	Waiting for a write of mapping data during a logical rewrite.
	LogicalRewriteSync	Waiting for logical rewrite mappings to reach stable storage.
	LogicalRewriteWrite	Waiting for a write of logical rewrite mappings.

Wait Event Type	Wait Event Name	Description
	RelationMapRead	Waiting for a read of the relation map file.
	RelationMapSync	Waiting for the relation map file to reach stable storage.
	RelationMapWrite	Waiting for a write to the relation map file.
	ReorderBufferRead	Waiting for a read during reorder buffer management.
	ReorderBufferWrite	Waiting for a write during reorder buffer management.
	ReorderLogicalMappingRead	Waiting for a read of a logical mapping during reorder buffer management.
	ReplicationSlotRead	Waiting for a read from a replication slot control file.
	ReplicationSlotRestoreSync	Waiting for a replication slot control file to reach stable storage while restoring it to memory.
	ReplicationSlotSync	Waiting for a replication slot control file to reach stable storage.
	ReplicationSlotWrite	Waiting for a write to a replication slot control file.
	SLRUFlushSync	Waiting for SLRU data to reach stable storage during a checkpoint or database shutdown.
	SLRURead	Waiting for a read of an SLRU page.
	SLRUSync	Waiting for SLRU data to reach stable storage following a page write.
	SLRUWrite	Waiting for a write of an SLRU page.
	SnapbuildRead	Waiting for a read of a serialized historical catalog snapshot.
	SnapbuildSync	Waiting for a serialized historical catalog snapshot to reach stable storage.
	SnapbuildWrite	Waiting for a write of a serialized historical catalog snapshot.
	TimelineHistoryFileSync	Waiting for a timeline history file received via streaming replication to reach stable storage.
	TimelineHistoryFileWrite	Waiting for a write of a timeline history file received via streaming replication.
	TimelineHistoryRead	Waiting for a read of a timeline history file.

Wait Event Type	Wait Event Name	Description
	TimelineHistorySync	Waiting for a newly created timeline history file to reach stable storage.
	TimelineHistoryWrite	Waiting for a write of a newly created timeline history file.
	TwophaseFileRead	Waiting for a read of a two phase state file.
	TwophaseFileSync	Waiting for a two phase state file to reach stable storage.
	TwophaseFileWrite	Waiting for a write of a two phase state file.
	WALBootstrapSync	Waiting for WAL to reach stable storage during bootstrapping.
	WALBootstrapWrite	Waiting for a write of a WAL page during bootstrapping.
	WALCopyRead	Waiting for a read when creating a new WAL segment by copying an existing one.
	WALCopySync	Waiting a new WAL segment created by copying an existing one to reach stable storage.
	WALCopyWrite	Waiting for a write when creating a new WAL segment by copying an existing one.
	WALInitSync	Waiting for a newly initialized WAL file to reach stable storage.
	WALInitWrite	Waiting for a write while initializing a new WAL file.
	WALRead	Waiting for a read from a WAL file.
	WALSenderTimelineHistoryRead	Waiting for a read from a timeline history file during walsender timeline command.
	WALSync	Waiting for a WAL file to reach stable storage.
	WALSyncMethodAssign	Waiting for data to reach stable storage while assigning WAL sync method.
	WALWrite	Waiting for a write to a WAL file.

Note

For tranches registered by extensions, the name is specified by extension and this will be displayed as `wait_event`. It is quite possible that user has registered the tranche in one of the backends (by having allocation in dynamic shared memory) in which case other backends won't have that information, so we display `extension` for such cases.

Here is an example of how wait events can be viewed

```
SELECT pid, wait_event_type, wait_event FROM pg_stat_activity WHERE
wait_event is NOT NULL;
pid | wait_event_type | wait_event
-----+-----+-----
2540 | Lock            | relation
6644 | LWLock         | ProcArrayLock
(2 rows)
```

Table 27.5. pg_stat_replication View

Column	Type	Description
pid	integer	Process ID of a WAL sender process
usesysid	oid	OID of the user logged into this WAL sender process
username	name	Name of the user logged into this WAL sender process
application_name	text	Name of the application that is connected to this WAL sender
client_addr	inet	IP address of the client connected to this WAL sender. If this field is null, it indicates that the client is connected via a Unix socket on the server machine.
client_hostname	text	Host name of the connected client, as reported by a reverse DNS lookup of <code>client_addr</code> . This field will only be non-null for IP connections, and only when <code>log_hostname</code> is enabled.
client_port	integer	TCP port number that the client is using for communication with this WAL sender, or -1 if a Unix socket is used
backend_start	timestamp with time zone	Time when this process was started, i.e., when the client connected to this WAL sender
backend_xmin	xid	This standby's xmin horizon reported by <code>hot_standby_feedback</code> .
state	text	Current WAL sender state. Possible values are: <ul style="list-style-type: none"> • <code>startup</code>: This WAL sender is starting up. • <code>catchup</code>: This WAL sender's connected standby is catching up with the primary. • <code>streaming</code>: This WAL sender is streaming changes after its connected standby

Column	Type	Description
		<p>server has caught up with the primary.</p> <ul style="list-style-type: none"> • <code>backup</code>: This WAL sender is sending a backup. • <code>stopping</code>: This WAL sender is stopping.
<code>sent_lsn</code>	<code>pg_lsn</code>	Last write-ahead log location sent on this connection
<code>write_lsn</code>	<code>pg_lsn</code>	Last write-ahead log location written to disk by this standby server
<code>flush_lsn</code>	<code>pg_lsn</code>	Last write-ahead log location flushed to disk by this standby server
<code>replay_lsn</code>	<code>pg_lsn</code>	Last write-ahead log location replayed into the database on this standby server
<code>write_lag</code>	<code>interval</code>	Time elapsed between flushing recent WAL locally and receiving notification that this standby server has written it (but not yet flushed it or applied it). This can be used to gauge the delay that <code>synchronous_commit</code> level <code>remote_write</code> incurred while committing if this server was configured as a synchronous standby.
<code>flush_lag</code>	<code>interval</code>	Time elapsed between flushing recent WAL locally and receiving notification that this standby server has written and flushed it (but not yet applied it). This can be used to gauge the delay that <code>synchronous_commit</code> level on incurred while committing if this server was configured as a synchronous standby.
<code>replay_lag</code>	<code>interval</code>	Time elapsed between flushing recent WAL locally and receiving notification that this standby server has written, flushed and applied it. This can be used to gauge the delay that <code>synchronous_commit</code> level <code>remote_apply</code> incurred while committing if this server was configured as a synchronous standby.
<code>sync_priority</code>	<code>integer</code>	Priority of this standby server for being chosen as the synchronous standby in a priority-based syn-

Column	Type	Description
		chronous replication. This has no effect in a quorum-based synchronous replication.
sync_state	text	Synchronous state of this standby server. Possible values are: <ul style="list-style-type: none"> • <code>async</code>: This standby server is asynchronous. • <code>potential</code>: This standby server is now asynchronous, but can potentially become synchronous if one of current synchronous ones fails. • <code>sync</code>: This standby server is synchronous. • <code>quorum</code>: This standby server is considered as a candidate for quorum standbys.
reply_time	timestamp with time zone	Send time of last reply message received from standby server

The `pg_stat_replication` view will contain one row per WAL sender process, showing statistics about replication to that sender's connected standby server. Only directly connected standbys are listed; no information is available about downstream standby servers.

The lag times reported in the `pg_stat_replication` view are measurements of the time taken for recent WAL to be written, flushed and replayed and for the sender to know about it. These times represent the commit delay that was (or would have been) introduced by each synchronous commit level, if the remote server was configured as a synchronous standby. For an asynchronous standby, the `reply_lag` column approximates the delay before recent transactions became visible to queries. If the standby server has entirely caught up with the sending server and there is no more WAL activity, the most recently measured lag times will continue to be displayed for a short time and then show NULL.

Lag times work automatically for physical replication. Logical decoding plugins may optionally emit tracking messages; if they do not, the tracking mechanism will simply display NULL lag.

Note

The reported lag times are not predictions of how long it will take for the standby to catch up with the sending server assuming the current rate of replay. Such a system would show similar times while new WAL is being generated, but would differ when the sender becomes idle. In particular, when the standby has caught up completely, `pg_stat_replication` shows the time taken to write, flush and replay the most recent reported WAL location rather than zero as some users might expect. This is consistent with the goal of measuring synchronous commit and transaction visibility delays for recent write transactions. To reduce confusion for users expecting a different model of lag, the lag columns revert to NULL after a short time on a fully replayed idle system. Monitoring systems should choose whether to represent this as missing data, zero or continue to display the last known value.

Table 27.6. pg_stat_wal_receiver View

Column	Type	Description
pid	integer	Process ID of the WAL receiver process
status	text	Activity status of the WAL receiver process
receive_start_lsn	pg_lsn	First write-ahead log location used when WAL receiver is started
receive_start_tli	integer	First timeline number used when WAL receiver is started
received_lsn	pg_lsn	Last write-ahead log location already received and flushed to disk, the initial value of this field being the first log location used when WAL receiver is started
received_tli	integer	Timeline number of last write-ahead log location received and flushed to disk, the initial value of this field being the timeline number of the first log location used when WAL receiver is started
last_msg_send_time	timestamp with time zone	Send time of last message received from origin WAL sender
last_msg_receipt_time	timestamp with time zone	Receipt time of last message received from origin WAL sender
latest_end_lsn	pg_lsn	Last write-ahead log location reported to origin WAL sender
latest_end_time	timestamp with time zone	Time of last write-ahead log location reported to origin WAL sender
slot_name	text	Replication slot name used by this WAL receiver
sender_host	text	Host of the PostgreSQL instance this WAL receiver is connected to. This can be a host name, an IP address, or a directory path if the connection is via Unix socket. (The path case can be distinguished because it will always be an absolute path, beginning with /.)
sender_port	integer	Port number of the PostgreSQL instance this WAL receiver is connected to.
conninfo	text	Connection string used by this WAL receiver, with security-sensitive fields obfuscated.

The `pg_stat_wal_receiver` view will contain only one row, showing statistics about the WAL receiver from that receiver's connected server.

Table 27.7. pg_stat_subscription View

Column	Type	Description
subid	oid	OID of the subscription
subname	text	Name of the subscription
pid	integer	Process ID of the subscription worker process
relid	Oid	OID of the relation that the worker is synchronizing; null for the main apply worker
received_lsn	pg_lsn	Last write-ahead log location received, the initial value of this field being 0
last_msg_send_time	timestamp with time zone	Send time of last message received from origin WAL sender
last_msg_receipt_time	timestamp with time zone	Receipt time of last message received from origin WAL sender
latest_end_lsn	pg_lsn	Last write-ahead log location reported to origin WAL sender
latest_end_time	timestamp with time zone	Time of last write-ahead log location reported to origin WAL sender

The `pg_stat_subscription` view will contain one row per subscription for main worker (with null PID if the worker is not running), and additional rows for workers handling the initial data copy of the subscribed tables.

Table 27.8. pg_stat_ssl View

Column	Type	Description
pid	integer	Process ID of a backend or WAL sender process
ssl	boolean	True if SSL is used on this connection
version	text	Version of SSL in use, or NULL if SSL is not in use on this connection
cipher	text	Name of SSL cipher in use, or NULL if SSL is not in use on this connection
bits	integer	Number of bits in the encryption algorithm used, or NULL if SSL is not used on this connection
compression	boolean	True if SSL compression is in use, false if not, or NULL if SSL is not in use on this connection
client_dn	text	Distinguished Name (DN) field from the client certificate used, or NULL if no client certificate was supplied or if SSL is not in use on this connection. This field is truncated if the DN field is

Column	Type	Description
		longer than NAMEDATALEN (64 characters in a standard build).
client_serial	numeric	Serial number of the client certificate, or NULL if no client certificate was supplied or if SSL is not in use on this connection. The combination of certificate serial number and certificate issuer uniquely identifies a certificate (unless the issuer erroneously reuses serial numbers).
issuer_dn	text	DN of the issuer of the client certificate, or NULL if no client certificate was supplied or if SSL is not in use on this connection. This field is truncated like client_dn.

The `pg_stat_ssl` view will contain one row per backend or WAL sender process, showing statistics about SSL usage on this connection. It can be joined to `pg_stat_activity` or `pg_stat_replication` on the `pid` column to get more details about the connection.

Table 27.9. `pg_stat_gssapi` View

Column	Type	Description
pid	integer	Process ID of a backend
gss_authenticated	boolean	True if GSSAPI authentication was used for this connection
principal	text	Principal used to authenticate this connection, or NULL if GSSAPI was not used to authenticate this connection. This field is truncated if the principal is longer than NAMEDATALEN (64 characters in a standard build).
encrypted	boolean	True if GSSAPI encryption is in use on this connection

The `pg_stat_gssapi` view will contain one row per backend, showing information about GSSAPI usage on this connection. It can be joined to `pg_stat_activity` or `pg_stat_replication` on the `pid` column to get more details about the connection.

Table 27.10. `pg_stat_archiver` View

Column	Type	Description
archived_count	bigint	Number of WAL files that have been successfully archived
last_archived_wal	text	Name of the last WAL file successfully archived
last_archived_time	timestamp with time zone	Time of the last successful archive operation
failed_count	bigint	Number of failed attempts for archiving WAL files

Column	Type	Description
last_failed_wal	text	Name of the WAL file of the last failed archival operation
last_failed_time	timestamp with time zone	Time of the last failed archival operation
stats_reset	timestamp with time zone	Time at which these statistics were last reset

The `pg_stat_archiver` view will always have a single row, containing data about the archiver process of the cluster.

Table 27.11. `pg_stat_bgwriter` View

Column	Type	Description
checkpoints_timed	bigint	Number of scheduled checkpoints that have been performed
checkpoints_req	bigint	Number of requested checkpoints that have been performed
checkpoint_write_time	double precision	Total amount of time that has been spent in the portion of checkpoint processing where files are written to disk, in milliseconds
checkpoint_sync_time	double precision	Total amount of time that has been spent in the portion of checkpoint processing where files are synchronized to disk, in milliseconds
buffers_checkpoint	bigint	Number of buffers written during checkpoints
buffers_clean	bigint	Number of buffers written by the background writer
maxwritten_clean	bigint	Number of times the background writer stopped a cleaning scan because it had written too many buffers
buffers_backend	bigint	Number of buffers written directly by a backend
buffers_backend_fsync	bigint	Number of times a backend had to execute its own <code>fsync</code> call (normally the background writer handles those even when the backend does its own write)
buffers_alloc	bigint	Number of buffers allocated
stats_reset	timestamp with time zone	Time at which these statistics were last reset

The `pg_stat_bgwriter` view will always have a single row, containing global data for the cluster.

Table 27.12. pg_stat_database View

Column	Type	Description
datid	oid	OID of this database, or 0 for objects belonging to a shared relation
datname	name	Name of this database, or NULL for the shared objects.
numbackends	integer	Number of backends currently connected to this database, or NULL for the shared objects. This is the only column in this view that returns a value reflecting current state; all other columns return the accumulated values since the last reset.
xact_commit	bigint	Number of transactions in this database that have been committed
xact_rollback	bigint	Number of transactions in this database that have been rolled back
blks_read	bigint	Number of disk blocks read in this database
blks_hit	bigint	Number of times disk blocks were found already in the buffer cache, so that a read was not necessary (this only includes hits in the PostgreSQL buffer cache, not the operating system's file system cache)
tup_returned	bigint	Number of rows returned by queries in this database
tup_fetched	bigint	Number of rows fetched by queries in this database
tup_inserted	bigint	Number of rows inserted by queries in this database
tup_updated	bigint	Number of rows updated by queries in this database
tup_deleted	bigint	Number of rows deleted by queries in this database
conflicts	bigint	Number of queries canceled due to conflicts with recovery in this database. (Conflicts occur only on standby servers; see <code>pg_stat_database_conflicts</code> for details.)
temp_files	bigint	Number of temporary files created by queries in this database. All temporary files are counted, regardless of why the temporary file was created (e.g., sorting or

Column	Type	Description
		hashing), and regardless of the log_temp_files setting.
temp_bytes	bigint	Total amount of data written to temporary files by queries in this database. All temporary files are counted, regardless of why the temporary file was created, and regardless of the log_temp_files setting.
deadlocks	bigint	Number of deadlocks detected in this database
checksum_failures	bigint	Number of data page checksum failures detected in this database (or on a shared object), or NULL if data checksums are not enabled.
checksum_last_failure	timestamp with time zone	Time at which the last data page checksum failure was detected in this database (or on a shared object), or NULL if data checksums are not enabled.
blk_read_time	double precision	Time spent reading data file blocks by backends in this database, in milliseconds
blk_write_time	double precision	Time spent writing data file blocks by backends in this database, in milliseconds
stats_reset	timestamp with time zone	Time at which these statistics were last reset

The `pg_stat_database` view will contain one row for each database in the cluster, plus one for the shared objects, showing database-wide statistics.

Table 27.13. `pg_stat_database_conflicts` View

Column	Type	Description
datid	oid	OID of a database
datname	name	Name of this database
confl_tablespace	bigint	Number of queries in this database that have been canceled due to dropped tablespaces
confl_lock	bigint	Number of queries in this database that have been canceled due to lock timeouts
confl_snapshot	bigint	Number of queries in this database that have been canceled due to old snapshots
confl_bufferpin	bigint	Number of queries in this database that have been canceled due to pinned buffers

Column	Type	Description
confl_deadlock	bigint	Number of queries in this database that have been canceled due to deadlocks

The `pg_stat_database_conflicts` view will contain one row per database, showing database-wide statistics about query cancels occurring due to conflicts with recovery on standby servers. This view will only contain information on standby servers, since conflicts do not occur on master servers.

Table 27.14. `pg_stat_all_tables` View

Column	Type	Description
relid	oid	OID of a table
schemaname	name	Name of the schema that this table is in
relname	name	Name of this table
seq_scan	bigint	Number of sequential scans initiated on this table
seq_tup_read	bigint	Number of live rows fetched by sequential scans
idx_scan	bigint	Number of index scans initiated on this table
idx_tup_fetch	bigint	Number of live rows fetched by index scans
n_tup_ins	bigint	Number of rows inserted
n_tup_upd	bigint	Number of rows updated (includes HOT updated rows)
n_tup_del	bigint	Number of rows deleted
n_tup_hot_upd	bigint	Number of rows HOT updated (i.e., with no separate index update required)
n_live_tup	bigint	Estimated number of live rows
n_dead_tup	bigint	Estimated number of dead rows
n_mod_since_analyze	bigint	Estimated number of rows modified since this table was last analyzed
last_vacuum	timestamp with time zone	Last time at which this table was manually vacuumed (not counting <code>VACUUM FULL</code>)
last_autovacuum	timestamp with time zone	Last time at which this table was vacuumed by the autovacuum daemon
last_analyze	timestamp with time zone	Last time at which this table was manually analyzed
last_autoanalyze	timestamp with time zone	Last time at which this table was analyzed by the autovacuum daemon

Column	Type	Description
vacuum_count	bigint	Number of times this table has been manually vacuumed (not counting VACUUM FULL)
autovacuum_count	bigint	Number of times this table has been vacuumed by the autovacuum daemon
analyze_count	bigint	Number of times this table has been manually analyzed
autoanalyze_count	bigint	Number of times this table has been analyzed by the autovacuum daemon

The `pg_stat_all_tables` view will contain one row for each table in the current database (including TOAST tables), showing statistics about accesses to that specific table. The `pg_stat_user_tables` and `pg_stat_sys_tables` views contain the same information, but filtered to only show user and system tables respectively.

Table 27.15. `pg_stat_all_indexes` View

Column	Type	Description
relid	oid	OID of the table for this index
indexrelid	oid	OID of this index
schemaname	name	Name of the schema this index is in
relname	name	Name of the table for this index
indexrelname	name	Name of this index
idx_scan	bigint	Number of index scans initiated on this index
idx_tup_read	bigint	Number of index entries returned by scans on this index
idx_tup_fetch	bigint	Number of live table rows fetched by simple index scans using this index

The `pg_stat_all_indexes` view will contain one row for each index in the current database, showing statistics about accesses to that specific index. The `pg_stat_user_indexes` and `pg_stat_sys_indexes` views contain the same information, but filtered to only show user and system indexes respectively.

Indexes can be used by simple index scans, “bitmap” index scans, and the optimizer. In a bitmap scan the output of several indexes can be combined via AND or OR rules, so it is difficult to associate individual heap row fetches with specific indexes when a bitmap scan is used. Therefore, a bitmap scan increments the `pg_stat_all_indexes.idx_tup_read` count(s) for the index(es) it uses, and it increments the `pg_stat_all_tables.idx_tup_fetch` count for the table, but it does not affect `pg_stat_all_indexes.idx_tup_fetch`. The optimizer also accesses indexes to check for supplied constants whose values are outside the recorded range of the optimizer statistics because the optimizer statistics might be stale.

Note

The `idx_tup_read` and `idx_tup_fetch` counts can be different even without any use of bitmap scans, because `idx_tup_read` counts index entries retrieved from

the index while `idx_tup_fetch` counts live rows fetched from the table. The latter will be less if any dead or not-yet-committed rows are fetched using the index, or if any heap fetches are avoided by means of an index-only scan.

Table 27.16. `pg_statio_all_tables` View

Column	Type	Description
<code>relid</code>	<code>oid</code>	OID of a table
<code>schemaname</code>	<code>name</code>	Name of the schema that this table is in
<code>relname</code>	<code>name</code>	Name of this table
<code>heap_blks_read</code>	<code>bigint</code>	Number of disk blocks read from this table
<code>heap_blks_hit</code>	<code>bigint</code>	Number of buffer hits in this table
<code>idx_blks_read</code>	<code>bigint</code>	Number of disk blocks read from all indexes on this table
<code>idx_blks_hit</code>	<code>bigint</code>	Number of buffer hits in all indexes on this table
<code>toast_blks_read</code>	<code>bigint</code>	Number of disk blocks read from this table's TOAST table (if any)
<code>toast_blks_hit</code>	<code>bigint</code>	Number of buffer hits in this table's TOAST table (if any)
<code>tidx_blks_read</code>	<code>bigint</code>	Number of disk blocks read from this table's TOAST table indexes (if any)
<code>tidx_blks_hit</code>	<code>bigint</code>	Number of buffer hits in this table's TOAST table indexes (if any)

The `pg_statio_all_tables` view will contain one row for each table in the current database (including TOAST tables), showing statistics about I/O on that specific table. The `pg_statio_user_tables` and `pg_statio_sys_tables` views contain the same information, but filtered to only show user and system tables respectively.

Table 27.17. `pg_statio_all_indexes` View

Column	Type	Description
<code>relid</code>	<code>oid</code>	OID of the table for this index
<code>indexrelid</code>	<code>oid</code>	OID of this index
<code>schemaname</code>	<code>name</code>	Name of the schema this index is in
<code>relname</code>	<code>name</code>	Name of the table for this index
<code>indexrelname</code>	<code>name</code>	Name of this index
<code>idx_blks_read</code>	<code>bigint</code>	Number of disk blocks read from this index
<code>idx_blks_hit</code>	<code>bigint</code>	Number of buffer hits in this index

The `pg_statio_all_indexes` view will contain one row for each index in the current database, showing statistics about I/O on that specific index. The `pg_statio_user_indexes` and `pg_s-`

`tatio_sys_indexes` views contain the same information, but filtered to only show user and system indexes respectively.

Table 27.18. `pg_statio_all_sequences` View

Column	Type	Description
<code>relid</code>	<code>oid</code>	OID of a sequence
<code>schemaname</code>	<code>name</code>	Name of the schema this sequence is in
<code>relname</code>	<code>name</code>	Name of this sequence
<code>blks_read</code>	<code>bigint</code>	Number of disk blocks read from this sequence
<code>blks_hit</code>	<code>bigint</code>	Number of buffer hits in this sequence

The `pg_statio_all_sequences` view will contain one row for each sequence in the current database, showing statistics about I/O on that specific sequence.

Table 27.19. `pg_stat_user_functions` View

Column	Type	Description
<code>funcid</code>	<code>oid</code>	OID of a function
<code>schemaname</code>	<code>name</code>	Name of the schema this function is in
<code>funcname</code>	<code>name</code>	Name of this function
<code>calls</code>	<code>bigint</code>	Number of times this function has been called
<code>total_time</code>	<code>double precision</code>	Total time spent in this function and all other functions called by it, in milliseconds
<code>self_time</code>	<code>double precision</code>	Total time spent in this function itself, not including other functions called by it, in milliseconds

The `pg_stat_user_functions` view will contain one row for each tracked function, showing statistics about executions of that function. The `track_functions` parameter controls exactly which functions are tracked.

27.2.3. Statistics Functions

Other ways of looking at the statistics can be set up by writing queries that use the same underlying statistics access functions used by the standard views shown above. For details such as the functions' names, consult the definitions of the standard views. (For example, in `psql` you could issue `\d+ pg_stat_activity`.) The access functions for per-database statistics take a database OID as an argument to identify which database to report on. The per-table and per-index functions take a table or index OID. The functions for per-function statistics take a function OID. Note that only tables, indexes, and functions in the current database can be seen with these functions.

Additional functions related to statistics collection are listed in Table 27.20.

Table 27.20. Additional Statistics Functions

Function	Return Type	Description
<code>pg_backend_pid()</code>	<code>integer</code>	Process ID of the server process handling the current session

Function	Return Type	Description
<code>pg_stat_get_activity(integer)</code>	setof record	Returns a record of information about the backend with the specified PID, or one record for each active backend in the system if NULL is specified. The fields returned are a subset of those in the <code>pg_stat_activity</code> view.
<code>pg_stat_get_snapshot_timestamp()</code>	timestamp with time zone	Returns the timestamp of the current statistics snapshot
<code>pg_stat_clear_snapshot()</code>	void	Discard the current statistics snapshot
<code>pg_stat_reset()</code>	void	Reset all statistics counters for the current database to zero (requires superuser privileges by default, but EXECUTE for this function can be granted to others.)
<code>pg_stat_reset_shared(text)</code>	void	Reset some cluster-wide statistics counters to zero, depending on the argument (requires superuser privileges by default, but EXECUTE for this function can be granted to others). Calling <code>pg_stat_reset_shared('bgwriter')</code> will zero all the counters shown in the <code>pg_stat_bgwriter</code> view. Calling <code>pg_stat_reset_shared('archiver')</code> will zero all the counters shown in the <code>pg_stat_archiver</code> view.
<code>pg_stat_reset_single_table_counters(oid)</code>	void	Reset statistics for a single table or index in the current database to zero (requires superuser privileges by default, but EXECUTE for this function can be granted to others)
<code>pg_stat_reset_single_function_counters(oid)</code>	void	Reset statistics for a single function in the current database to zero (requires superuser privileges by default, but EXECUTE for this function can be granted to others)

`pg_stat_get_activity`, the underlying function of the `pg_stat_activity` view, returns a set of records containing all the available information about each backend process. Sometimes it may be more convenient to obtain just a subset of this information. In such cases, an older set of per-backend statistics access functions can be used; these are shown in Table 27.21. These access functions use a backend ID number, which ranges from one to the number of currently active backends. The function `pg_stat_get_backend_idset` provides a convenient way to generate one row for each active backend for invoking these functions. For example, to show the PIDs and current queries of all backends:

```
SELECT pg_stat_get_backend_pid(s.backendid) AS pid,
       pg_stat_get_backend_activity(s.backendid) AS query
FROM (SELECT pg_stat_get_backend_idset() AS backendid) AS s;
```

Table 27.21. Per-Backend Statistics Functions

Function	Return Type	Description
<code>pg_stat_get_backend_idset()</code>	setof integer	Set of currently active backend ID numbers (from 1 to the number of active backends)
<code>pg_stat_get_backend_activity(integer)</code>	text	Text of this backend's most recent query
<code>pg_stat_get_backend_activity_start(integer)</code>	timestamp with time zone	Time when the most recent query was started
<code>pg_stat_get_backend_client_addr(integer)</code>	inet	IP address of the client connected to this backend
<code>pg_stat_get_backend_client_port(integer)</code>	integer	TCP port number that the client is using for communication
<code>pg_stat_get_backend_dbid(integer)</code>	oid	OID of the database this backend is connected to
<code>pg_stat_get_backend_pid(integer)</code>	integer	Process ID of this backend
<code>pg_stat_get_backend_start(integer)</code>	timestamp with time zone	Time when this process was started
<code>pg_stat_get_backend_userid(integer)</code>	oid	OID of the user logged into this backend
<code>pg_stat_get_backend_wait_event_type(integer)</code>	text	Wait event type name if backend is currently waiting, otherwise NULL. See Table 27.4 for details.
<code>pg_stat_get_backend_wait_event(integer)</code>	text	Wait event name if backend is currently waiting, otherwise NULL. See Table 27.4 for details.
<code>pg_stat_get_backend_xact_start(integer)</code>	timestamp with time zone	Time when the current transaction was started

27.3. Viewing Locks

Another useful tool for monitoring database activity is the `pg_locks` system table. It allows the database administrator to view information about the outstanding locks in the lock manager. For example, this capability can be used to:

- View all the locks currently outstanding, all the locks on relations in a particular database, all the locks on a particular relation, or all the locks held by a particular PostgreSQL session.
- Determine the relation in the current database with the most ungranted locks (which might be a source of contention among database clients).

- Determine the effect of lock contention on overall database performance, as well as the extent to which contention varies with overall database traffic.

Details of the `pg_locks` view appear in Section 51.74. For more information on locking and managing concurrency with PostgreSQL, refer to Chapter 13.

27.4. Progress Reporting

PostgreSQL has the ability to report the progress of certain commands during command execution. Currently, the only commands which support progress reporting are `CREATE INDEX`, `VACUUM` and `CLUSTER`. This may be expanded in the future.

27.4.1. CREATE INDEX Progress Reporting

Whenever `CREATE INDEX` or `REINDEX` is running, the `pg_stat_progress_create_index` view will contain one row for each backend that is currently creating indexes. The tables below describe the information that will be reported and provide information about how to interpret it.

Table 27.22. `pg_stat_progress_create_index` View

Column	Type	Description
<code>pid</code>	<code>integer</code>	Process ID of backend.
<code>datid</code>	<code>oid</code>	OID of the database to which this backend is connected.
<code>datname</code>	<code>name</code>	Name of the database to which this backend is connected.
<code>relid</code>	<code>oid</code>	OID of the table on which the index is being created.
<code>index_relid</code>	<code>oid</code>	OID of the index being created or reindexed. During a non-concurrent <code>CREATE INDEX</code> , this is 0.
<code>command</code>	<code>text</code>	The command that is running: <code>CREATE INDEX</code> , <code>CREATE INDEX CONCURRENTLY</code> , <code>REINDEX</code> , or <code>REINDEX CONCURRENTLY</code> .
<code>phase</code>	<code>text</code>	Current processing phase of index creation. See Table 27.23.
<code>lockers_total</code>	<code>bigint</code>	Total number of lockers to wait for, when applicable.
<code>lockers_done</code>	<code>bigint</code>	Number of lockers already waited for.
<code>current_locker_pid</code>	<code>bigint</code>	Process ID of the locker currently being waited for.
<code>blocks_total</code>	<code>bigint</code>	Total number of blocks to be processed in the current phase.
<code>blocks_done</code>	<code>bigint</code>	Number of blocks already processed in the current phase.
<code>tuples_total</code>	<code>bigint</code>	Total number of tuples to be processed in the current phase.

Column	Type	Description
tuples_done	bigint	Number of tuples already processed in the current phase.
partitions_total	bigint	When creating an index on a partitioned table, this column is set to the total number of partitions on which the index is to be created.
partitions_done	bigint	When creating an index on a partitioned table, this column is set to the number of partitions on which the index has been completed.

Table 27.23. CREATE INDEX Phases

Phase	Description
initializing	CREATE INDEX or REINDEX is preparing to create the index. This phase is expected to be very brief.
waiting for writers before build	CREATE INDEX CONCURRENTLY or REINDEX CONCURRENTLY is waiting for transactions with write locks that can potentially see the table to finish. This phase is skipped when not in concurrent mode. Columns lockers_total, lockers_done and current_locker_pid contain the progress information for this phase.
building index	The index is being built by the access method-specific code. In this phase, access methods that support progress reporting fill in their own progress data, and the subphase is indicated in this column. Typically, blocks_total and blocks_done will contain progress data, as well as potentially tuples_total and tuples_done.
waiting for writers before validation	CREATE INDEX CONCURRENTLY or REINDEX CONCURRENTLY is waiting for transactions with write locks that can potentially write into the table to finish. This phase is skipped when not in concurrent mode. Columns lockers_total, lockers_done and current_locker_pid contain the progress information for this phase.
index validation: scanning index	CREATE INDEX CONCURRENTLY is scanning the index searching for tuples that need to be validated. This phase is skipped when not in concurrent mode. Columns blocks_total (set to the total size of the index) and blocks_done contain the progress information for this phase.
index validation: sorting tuples	CREATE INDEX CONCURRENTLY is sorting the output of the index scanning phase.
index validation: scanning table	CREATE INDEX CONCURRENTLY is scanning the table to validate the index tuples collected in the previous two phases. This phase is skipped

Phase	Description
	when not in concurrent mode. Columns <code>blocks_total</code> (set to the total size of the table) and <code>blocks_done</code> contain the progress information for this phase.
waiting for old snapshots	<code>CREATE INDEX CONCURRENTLY</code> or <code>REINDEX CONCURRENTLY</code> is waiting for transactions that can potentially see the table to release their snapshots. This phase is skipped when not in concurrent mode. Columns <code>lockers_total</code> , <code>lockers_done</code> and <code>current_locker_pid</code> contain the progress information for this phase.
waiting for readers before marking dead	<code>REINDEX CONCURRENTLY</code> is waiting for transactions with read locks on the table to finish, before marking the old index dead. This phase is skipped when not in concurrent mode. Columns <code>lockers_total</code> , <code>lockers_done</code> and <code>current_locker_pid</code> contain the progress information for this phase.
waiting for readers before dropping	<code>REINDEX CONCURRENTLY</code> is waiting for transactions with read locks on the table to finish, before dropping the old index. This phase is skipped when not in concurrent mode. Columns <code>lockers_total</code> , <code>lockers_done</code> and <code>current_locker_pid</code> contain the progress information for this phase.

27.4.2. VACUUM Progress Reporting

Whenever `VACUUM` is running, the `pg_stat_progress_vacuum` view will contain one row for each backend (including autovacuum worker processes) that is currently vacuuming. The tables below describe the information that will be reported and provide information about how to interpret it. Progress for `VACUUM FULL` commands is reported via `pg_stat_progress_cluster` because both `VACUUM FULL` and `CLUSTER` rewrite the table, while regular `VACUUM` only modifies it in place. See Section 27.4.3.

Table 27.24. `pg_stat_progress_vacuum` View

Column	Type	Description
<code>pid</code>	<code>integer</code>	Process ID of backend.
<code>datid</code>	<code>oid</code>	OID of the database to which this backend is connected.
<code>datname</code>	<code>name</code>	Name of the database to which this backend is connected.
<code>relid</code>	<code>oid</code>	OID of the table being vacuumed.
<code>phase</code>	<code>text</code>	Current processing phase of vacuum. See Table 27.25.
<code>heap_blks_total</code>	<code>bigint</code>	Total number of heap blocks in the table. This number is reported as of the beginning of the scan; blocks added later will not

Column	Type	Description
		be (and need not be) visited by this VACUUM.
heap_blks_scanned	bigint	Number of heap blocks scanned. Because the visibility map is used to optimize scans, some blocks will be skipped without inspection; skipped blocks are included in this total, so that this number will eventually become equal to heap_blks_total when the vacuum is complete. This counter only advances when the phase is scanning heap.
heap_blks_vacuumed	bigint	Number of heap blocks vacuumed. Unless the table has no indexes, this counter only advances when the phase is vacuuming heap. Blocks that contain no dead tuples are skipped, so the counter may sometimes skip forward in large increments.
index_vacuum_count	bigint	Number of completed index vacuum cycles.
max_dead_tuples	bigint	Number of dead tuples that we can store before needing to perform an index vacuum cycle, based on maintenance_work_mem.
num_dead_tuples	bigint	Number of dead tuples collected since the last index vacuum cycle.

Table 27.25. VACUUM Phases

Phase	Description
initializing	VACUUM is preparing to begin scanning the heap. This phase is expected to be very brief.
scanning heap	VACUUM is currently scanning the heap. It will prune and defragment each page if required, and possibly perform freezing activity. The heap_blks_scanned column can be used to monitor the progress of the scan.
vacuuming indexes	VACUUM is currently vacuuming the indexes. If a table has any indexes, this will happen at least once per vacuum, after the heap has been completely scanned. It may happen multiple times per vacuum if maintenance_work_mem is insufficient to store the number of dead tuples found.
vacuuming heap	VACUUM is currently vacuuming the heap. Vacuuming the heap is distinct from scanning the heap, and occurs after each instance of vacuuming indexes. If heap_blks_scanned is less than

Phase	Description
	heap_blks_total, the system will return to scanning the heap after this phase is completed; otherwise, it will begin cleaning up indexes after this phase is completed.
cleaning up indexes	VACUUM is currently cleaning up indexes. This occurs after the heap has been completely scanned and all vacuuming of the indexes and the heap has been completed.
truncating heap	VACUUM is currently truncating the heap so as to return empty pages at the end of the relation to the operating system. This occurs after cleaning up indexes.
performing final cleanup	VACUUM is performing final cleanup. During this phase, VACUUM will vacuum the free space map, update statistics in pg_class, and report statistics to the statistics collector. When this phase is completed, VACUUM will end.

27.4.3. CLUSTER Progress Reporting

Whenever CLUSTER or VACUUM FULL is running, the pg_stat_progress_cluster view will contain a row for each backend that is currently running either command. The tables below describe the information that will be reported and provide information about how to interpret it.

Table 27.26. pg_stat_progress_cluster View

Column	Type	Description
pid	integer	Process ID of backend.
datid	oid	OID of the database to which this backend is connected.
datname	name	Name of the database to which this backend is connected.
relid	oid	OID of the table being clustered.
command	text	The command that is running. Either CLUSTER or VACUUM FULL.
phase	text	Current processing phase. See Table 27.27.
cluster_index_relid	oid	If the table is being scanned using an index, this is the OID of the index being used; otherwise, it is zero.
heap_tuples_scanned	bigint	Number of heap tuples scanned. This counter only advances when the phase is seq scanning heap, index scanning heap or writing new heap.
heap_tuples_written	bigint	Number of heap tuples written. This counter only advances when the phase is seq scan-

Column	Type	Description
		ning heap, index scanning heap or writing new heap.
heap_blks_total	bigint	Total number of heap blocks in the table. This number is reported as of the beginning of seq scanning heap.
heap_blks_scanned	bigint	Number of heap blocks scanned. This counter only advances when the phase is seq scanning heap.
index_rebuild_count	bigint	Number of indexes rebuilt. This counter only advances when the phase is rebuilding index.

Table 27.27. CLUSTER and VACUUM FULL Phases

Phase	Description
initializing	The command is preparing to begin scanning the heap. This phase is expected to be very brief.
seq scanning heap	The command is currently scanning the table using a sequential scan.
index scanning heap	CLUSTER is currently scanning the table using an index scan.
sorting tuples	CLUSTER is currently sorting tuples.
writing new heap	CLUSTER is currently writing the new heap.
swapping relation files	The command is currently swapping newly-built files into place.
rebuilding index	The command is currently rebuilding an index.
performing final cleanup	The command is performing final cleanup. When this phase is completed, CLUSTER or VACUUM FULL will end.

27.5. Dynamic Tracing

PostgreSQL provides facilities to support dynamic tracing of the database server. This allows an external utility to be called at specific points in the code and thereby trace execution.

A number of probes or trace points are already inserted into the source code. These probes are intended to be used by database developers and administrators. By default the probes are not compiled into PostgreSQL; the user needs to explicitly tell the configure script to make the probes available.

Currently, the DTrace¹ utility is supported, which, at the time of this writing, is available on Solaris, macOS, FreeBSD, NetBSD, and Oracle Linux. The SystemTap² project for Linux provides a DTrace equivalent and can also be used. Supporting other dynamic tracing utilities is theoretically possible by changing the definitions for the macros in `src/include/utills/probes.h`.

¹ <https://en.wikipedia.org/wiki/DTrace>

² <http://sourceware.org/systemtap/>

27.5.1. Compiling for Dynamic Tracing

By default, probes are not available, so you will need to explicitly tell the configure script to make the probes available in PostgreSQL. To include DTrace support specify `--enable-dtrace` to configure. See Section 16.4 for further information.

27.5.2. Built-in Probes

A number of standard probes are provided in the source code, as shown in Table 27.28; Table 27.29 shows the types used in the probes. More probes can certainly be added to enhance PostgreSQL's observability.

Table 27.28. Built-in DTrace Probes

Name	Parameters	Description
<code>transaction-start</code>	<code>(LocalTransactionId)</code>	Probe that fires at the start of a new transaction. <code>arg0</code> is the transaction ID.
<code>transaction-commit</code>	<code>(LocalTransactionId)</code>	Probe that fires when a transaction completes successfully. <code>arg0</code> is the transaction ID.
<code>transaction-abort</code>	<code>(LocalTransactionId)</code>	Probe that fires when a transaction completes unsuccessfully. <code>arg0</code> is the transaction ID.
<code>query-start</code>	<code>(const char *)</code>	Probe that fires when the processing of a query is started. <code>arg0</code> is the query string.
<code>query-done</code>	<code>(const char *)</code>	Probe that fires when the processing of a query is complete. <code>arg0</code> is the query string.
<code>query-parse-start</code>	<code>(const char *)</code>	Probe that fires when the parsing of a query is started. <code>arg0</code> is the query string.
<code>query-parse-done</code>	<code>(const char *)</code>	Probe that fires when the parsing of a query is complete. <code>arg0</code> is the query string.
<code>query-rewrite-start</code>	<code>(const char *)</code>	Probe that fires when the rewriting of a query is started. <code>arg0</code> is the query string.
<code>query-rewrite-done</code>	<code>(const char *)</code>	Probe that fires when the rewriting of a query is complete. <code>arg0</code> is the query string.
<code>query-plan-start</code>	<code>()</code>	Probe that fires when the planning of a query is started.
<code>query-plan-done</code>	<code>()</code>	Probe that fires when the planning of a query is complete.
<code>query-execute-start</code>	<code>()</code>	Probe that fires when the execution of a query is started.
<code>query-execute-done</code>	<code>()</code>	Probe that fires when the execution of a query is complete.
<code>statement-status</code>	<code>(const char *)</code>	Probe that fires anytime the server process updates

Name	Parameters	Description
		its <code>pg_stat_activity.status</code> . <code>arg0</code> is the new status string.
<code>checkpoint-start</code>	<code>(int)</code>	Probe that fires when a checkpoint is started. <code>arg0</code> holds the bitwise flags used to distinguish different checkpoint types, such as shutdown, immediate or force.
<code>checkpoint-done</code>	<code>(int, int, int, int, int)</code>	Probe that fires when a checkpoint is complete. (The probes listed next fire in sequence during checkpoint processing.) <code>arg0</code> is the number of buffers written. <code>arg1</code> is the total number of buffers. <code>arg2</code> , <code>arg3</code> and <code>arg4</code> contain the number of WAL files added, removed and recycled respectively.
<code>clog-checkpoint-start</code>	<code>(bool)</code>	Probe that fires when the CLOG portion of a checkpoint is started. <code>arg0</code> is true for normal checkpoint, false for shutdown checkpoint.
<code>clog-checkpoint-done</code>	<code>(bool)</code>	Probe that fires when the CLOG portion of a checkpoint is complete. <code>arg0</code> has the same meaning as for <code>clog-checkpoint-start</code> .
<code>subtrans-checkpoint-start</code>	<code>(bool)</code>	Probe that fires when the SUBTRANS portion of a checkpoint is started. <code>arg0</code> is true for normal checkpoint, false for shutdown checkpoint.
<code>subtrans-checkpoint-done</code>	<code>(bool)</code>	Probe that fires when the SUBTRANS portion of a checkpoint is complete. <code>arg0</code> has the same meaning as for <code>subtrans-checkpoint-start</code> .
<code>multixact-checkpoint-start</code>	<code>(bool)</code>	Probe that fires when the MultiXact portion of a checkpoint is started. <code>arg0</code> is true for normal checkpoint, false for shutdown checkpoint.
<code>multixact-checkpoint-done</code>	<code>(bool)</code>	Probe that fires when the MultiXact portion of a checkpoint is complete. <code>arg0</code> has the same meaning as for <code>multixact-checkpoint-start</code> .
<code>buffer-checkpoint-start</code>	<code>(int)</code>	Probe that fires when the buffer-writing portion of a checkpoint is started. <code>arg0</code> holds the bitwise

Name	Parameters	Description
		flags used to distinguish different checkpoint types, such as shutdown, immediate or force.
buffer-sync-start	(int, int)	Probe that fires when we begin to write dirty buffers during checkpoint (after identifying which buffers must be written). arg0 is the total number of buffers. arg1 is the number that are currently dirty and need to be written.
buffer-sync-written	(int)	Probe that fires after each buffer is written during checkpoint. arg0 is the ID number of the buffer.
buffer-sync-done	(int, int, int)	Probe that fires when all dirty buffers have been written. arg0 is the total number of buffers. arg1 is the number of buffers actually written by the checkpoint process. arg2 is the number that were expected to be written (arg1 of buffer-sync-start); any difference reflects other processes flushing buffers during the checkpoint.
buffer-checkpoint-sync-start	()	Probe that fires after dirty buffers have been written to the kernel, and before starting to issue fsync requests.
buffer-checkpoint-done	()	Probe that fires when syncing of buffers to disk is complete.
twophase-checkpoint-start	()	Probe that fires when the two-phase portion of a checkpoint is started.
twophase-checkpoint-done	()	Probe that fires when the two-phase portion of a checkpoint is complete.
buffer-read-start	(ForkNumber, BlockNumber, Oid, Oid, int, bool)	Probe that fires when a buffer read is started. arg0 and arg1 contain the fork and block numbers of the page (but arg1 will be -1 if this is a relation extension request). arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is true for a relation extension request, false for normal read.

Name	Parameters	Description
buffer-read-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, bool, bool)	Probe that fires when a buffer read is complete. arg0 and arg1 contain the fork and block numbers of the page (if this is a relation extension request, arg1 now contains the block number of the newly added block). arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is true for a relation extension request, false for normal read. arg7 is true if the buffer was found in the pool, false if not.
buffer-flush-start	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires before issuing any write request for a shared buffer. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation.
buffer-flush-done	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a write request is complete. (Note that this just reflects the time to pass the data to the kernel; it's typically not actually been written to disk yet.) The arguments are the same as for buffer-flush-start.
buffer-write-dirty-start	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a server process begins to write a dirty buffer. (If this happens often, it implies that shared_buffers is too small or the background writer control parameters need adjustment.) arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation.
buffer-write-dirty-done	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a dirty-buffer write is complete. The arguments are the same as for buffer-write-dirty-start.
wal-buffer-write-dirty-start	()	Probe that fires when a server process begins to write a dirty

Name	Parameters	Description
		WAL buffer because no more WAL buffer space is available. (If this happens often, it implies that wal_buffers is too small.)
wal-buffer-write-dirty-done	()	Probe that fires when a dirty WAL buffer write is complete.
wal-insert	(unsigned char, unsigned char)	Probe that fires when a WAL record is inserted. arg0 is the resource manager (rmid) for the record. arg1 contains the info flags.
wal-switch	()	Probe that fires when a WAL segment switch is requested.
smgr-md-read-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int)	Probe that fires when beginning to read a block from a relation. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer.
smgr-md-read-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, int, int)	Probe that fires when a block read is complete. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is the number of bytes actually read, while arg7 is the number requested (if these are different it indicates trouble).
smgr-md-write-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int)	Probe that fires when beginning to write a block to a relation. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer.

Name	Parameters	Description
smgr-md-write-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, int, int)	Probe that fires when a block write is complete. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is the number of bytes actually written, while arg7 is the number requested (if these are different it indicates trouble).
sort-start	(int, bool, int, int, bool, int)	Probe that fires when a sort operation is started. arg0 indicates heap, index or datum sort. arg1 is true for unique-value enforcement. arg2 is the number of key columns. arg3 is the number of kilobytes of work memory allowed. arg4 is true if random access to the sort result is required. arg5 indicates serial when 0, parallel worker when 1, or parallel leader when 2.
sort-done	(bool, long)	Probe that fires when a sort is complete. arg0 is true for external sort, false for internal sort. arg1 is the number of disk blocks used for an external sort, or kilobytes of memory used for an internal sort.
lwlock-acquire	(char *, LWLockMode)	Probe that fires when an LWLock has been acquired. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-release	(char *)	Probe that fires when an LWLock has been released (but note that any released waiters have not yet been awakened). arg0 is the LWLock's tranche.
lwlock-wait-start	(char *, LWLockMode)	Probe that fires when an LWLock was not immediately available and a server process has begun to wait for the lock to become available. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.

Name	Parameters	Description
lwlock-wait-done	(char *, LWLockMode)	Probe that fires when a server process has been released from its wait for an LWLock (it does not actually have the lock yet). arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-condacquire	(char *, LWLockMode)	Probe that fires when an LWLock was successfully acquired when the caller specified no waiting. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lwlock-condacquire-fail	(char *, LWLockMode)	Probe that fires when an LWLock was not successfully acquired when the caller specified no waiting. arg0 is the LWLock's tranche. arg1 is the requested lock mode, either exclusive or shared.
lock-wait-start	(unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, LOCKMODE)	Probe that fires when a request for a heavyweight lock (lmgr lock) has begun to wait because the lock is not available. arg0 through arg3 are the tag fields identifying the object being locked. arg4 indicates the type of object being locked. arg5 indicates the lock type being requested.
lock-wait-done	(unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, LOCKMODE)	Probe that fires when a request for a heavyweight lock (lmgr lock) has finished waiting (i.e., has acquired the lock). The arguments are the same as for lock-wait-start.
deadlock-found	()	Probe that fires when a deadlock is found by the deadlock detector.

Table 27.29. Defined Types Used in Probe Parameters

Type	Definition
LocalTransactionId	unsigned int
LWLockMode	int
LOCKMODE	int
BlockNumber	unsigned int
Oid	unsigned int
ForkNumber	int
bool	unsigned char

27.5.3. Using Probes

The example below shows a DTrace script for analyzing transaction counts in the system, as an alternative to snapshotting `pg_stat_database` before and after a performance test:

```
#!/usr/sbin/dtrace -qs

postgresql$1:::transaction-start
{
    @start["Start"] = count();
    self->ts = timestamp;
}

postgresql$1:::transaction-abort
{
    @abort["Abort"] = count();
}

postgresql$1:::transaction-commit
/self->ts/
{
    @commit["Commit"] = count();
    @time["Total time (ns)"] = sum(timestamp - self->ts);
    self->ts=0;
}
```

When executed, the example D script gives output such as:

```
# ./txn_count.d `pgrep -n postgres` or ./txn_count.d <PID>
^C

Start                                71
Commit                                70
Total time (ns)                       2312105013
```

Note

SystemTap uses a different notation for trace scripts than DTrace does, even though the underlying trace points are compatible. One point worth noting is that at this writing, SystemTap scripts must reference probe names using double underscores in place of hyphens. This is expected to be fixed in future SystemTap releases.

You should remember that DTrace scripts need to be carefully written and debugged, otherwise the trace information collected might be meaningless. In most cases where problems are found it is the instrumentation that is at fault, not the underlying system. When discussing information found using dynamic tracing, be sure to enclose the script used to allow that too to be checked and discussed.

27.5.4. Defining New Probes

New probes can be defined within the code wherever the developer desires, though this will require a recompilation. Below are the steps for inserting new probes:

1. Decide on probe names and data to be made available through the probes
2. Add the probe definitions to `src/backend/utils/probes.d`

3. Include `pg_trace.h` if it is not already present in the module(s) containing the probe points, and insert `TRACE_POSTGRESQL` probe macros at the desired locations in the source code
4. Recompile and verify that the new probes are available

Example: Here is an example of how you would add a probe to trace all new transactions by transaction ID.

1. Decide that the probe will be named `transaction__start` and requires a parameter of type `LocalTransactionId`
2. Add the probe definition to `src/backend/utils/probes.d`:

```
probe transaction__start(LocalTransactionId);
```

Note the use of the double underline in the probe name. In a DTrace script using the probe, the double underline needs to be replaced with a hyphen, so `transaction-start` is the name to document for users.

3. At compile time, `transaction__start` is converted to a macro called `TRACE_POSTGRESQL_TRANSACTION_START` (notice the underscores are single here), which is available by including `pg_trace.h`. Add the macro call to the appropriate location in the source code. In this case, it looks like the following:

```
TRACE_POSTGRESQL_TRANSACTION_START(vxid.localTransactionId);
```

4. After recompiling and running the new binary, check that your newly added probe is available by executing the following DTrace command. You should see similar output:

```
# dtrace -ln transaction-start
  ID    PROVIDER      MODULE      FUNCTION NAME
18705 postgresql49878 postgres    StartTransactionCommand
transaction-start
18755 postgresql49877 postgres    StartTransactionCommand
transaction-start
18805 postgresql49876 postgres    StartTransactionCommand
transaction-start
18855 postgresql49875 postgres    StartTransactionCommand
transaction-start
18986 postgresql49873 postgres    StartTransactionCommand
transaction-start
```

There are a few things to be careful about when adding trace macros to the C code:

- You should take care that the data types specified for a probe's parameters match the data types of the variables used in the macro. Otherwise, you will get compilation errors.
- On most platforms, if PostgreSQL is built with `--enable-dtrace`, the arguments to a trace macro will be evaluated whenever control passes through the macro, *even if no tracing is being done*. This is usually not worth worrying about if you are just reporting the values of a few local variables. But beware of putting expensive function calls into the arguments. If you need to do that, consider protecting the macro with a check to see if the trace is actually enabled:

```
if (TRACE_POSTGRESQL_TRANSACTION_START_ENABLED())
    TRACE_POSTGRESQL_TRANSACTION_START(some_function(...));
```

Each trace macro has a corresponding `ENABLED` macro.

Chapter 28. Monitoring Disk Usage

This chapter discusses how to monitor the disk usage of a PostgreSQL database system.

28.1. Determining Disk Usage

Each table has a primary heap disk file where most of the data is stored. If the table has any columns with potentially-wide values, there also might be a TOAST file associated with the table, which is used to store values too wide to fit comfortably in the main table (see Section 68.2). There will be one valid index on the TOAST table, if present. There also might be indexes associated with the base table. Each table and index is stored in a separate disk file — possibly more than one file, if the file would exceed one gigabyte. Naming conventions for these files are described in Section 68.1.

You can monitor disk space in three ways: using the SQL functions listed in Table 9.89, using the `oid2name` module, or using manual inspection of the system catalogs. The SQL functions are the easiest to use and are generally recommended. The remainder of this section shows how to do it by inspection of the system catalogs.

Using `psql` on a recently vacuumed or analyzed database, you can issue queries to see the disk usage of any table:

```
SELECT pg_relation_filepath(oid), relpages FROM pg_class WHERE
relname = 'customer';
```

```
pg_relation_filepath | relpages
-----+-----
base/16384/16806     |         60
(1 row)
```

Each page is typically 8 kilobytes. (Remember, `relpages` is only updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`.) The file path name is of interest if you want to examine the table's disk file directly.

To show the space used by TOAST tables, use a query like the following:

```
SELECT relname, relpages
FROM pg_class,
     (SELECT reltoastrelid
      FROM pg_class
      WHERE relname = 'customer') AS ss
WHERE oid = ss.reltoastrelid OR
      oid = (SELECT indexrelid
            FROM pg_index
            WHERE indrelid = ss.reltoastrelid)
ORDER BY relname;
```

```
relname          | relpages
-----+-----
pg_toast_16806   |         0
pg_toast_16806_index |         1
```

You can easily display index sizes, too:

```
SELECT c2.relname, c2.relpages
```

```
FROM pg_class c, pg_class c2, pg_index i
WHERE c.relname = 'customer' AND
      c.oid = i.indrelid AND
      c2.oid = i.indexrelid
ORDER BY c2.relname;
```

relname	relpages
customer_id_index	26

It is easy to find your largest tables and indexes using this information:

```
SELECT relname, relpages
FROM pg_class
ORDER BY relpages DESC;
```

relname	relpages
bigtable	3290
customer	3144

28.2. Disk Full Failure

The most important disk monitoring task of a database administrator is to make sure the disk doesn't become full. A filled data disk will not result in data corruption, but it might prevent useful activity from occurring. If the disk holding the WAL files grows full, database server panic and consequent shutdown might occur.

If you cannot free up additional space on the disk by deleting other things, you can move some of the database files to other file systems by making use of tablespaces. See Section 22.6 for more information about that.

Tip

Some file systems perform badly when they are almost full, so do not wait until the disk is completely full to take action.

If your system supports per-user disk quotas, then the database will naturally be subject to whatever quota is placed on the user the server runs as. Exceeding the quota will have the same bad effects as running out of disk space entirely.

Chapter 29. Reliability and the Write-Ahead Log

This chapter explains how the Write-Ahead Log is used to obtain efficient, reliable operation.

29.1. Reliability

Reliability is an important property of any serious database system, and PostgreSQL does everything possible to guarantee reliable operation. One aspect of reliable operation is that all data recorded by a committed transaction should be stored in a nonvolatile area that is safe from power loss, operating system failure, and hardware failure (except failure of the nonvolatile area itself, of course). Successfully writing the data to the computer's permanent storage (disk drive or equivalent) ordinarily meets this requirement. In fact, even if a computer is fatally damaged, if the disk drives survive they can be moved to another computer with similar hardware and all committed transactions will remain intact.

While forcing data to the disk platters periodically might seem like a simple operation, it is not. Because disk drives are dramatically slower than main memory and CPUs, several layers of caching exist between the computer's main memory and the disk platters. First, there is the operating system's buffer cache, which caches frequently requested disk blocks and combines disk writes. Fortunately, all operating systems give applications a way to force writes from the buffer cache to disk, and PostgreSQL uses those features. (See the `wal_sync_method` parameter to adjust how this is done.)

Next, there might be a cache in the disk drive controller; this is particularly common on RAID controller cards. Some of these caches are *write-through*, meaning writes are sent to the drive as soon as they arrive. Others are *write-back*, meaning data is sent to the drive at some later time. Such caches can be a reliability hazard because the memory in the disk controller cache is volatile, and will lose its contents in a power failure. Better controller cards have *battery-backup units* (BBUs), meaning the card has a battery that maintains power to the cache in case of system power loss. After power is restored the data will be written to the disk drives.

And finally, most disk drives have caches. Some are write-through while some are write-back, and the same concerns about data loss exist for write-back drive caches as for disk controller caches. Consumer-grade IDE and SATA drives are particularly likely to have write-back caches that will not survive a power failure. Many solid-state drives (SSD) also have volatile write-back caches.

These caches can typically be disabled; however, the method for doing this varies by operating system and drive type:

- On Linux, IDE and SATA drives can be queried using `hdparm -I`; write caching is enabled if there is a `*` next to `Write cache`. `hdparm -W 0` can be used to turn off write caching. SCSI drives can be queried using `sdparm`¹. Use `sdparm --get=WCE` to check whether the write cache is enabled and `sdparm --clear=WCE` to disable it.
- On FreeBSD, IDE drives can be queried using `atacontrol` and write caching turned off using `hw.ata.wc=0` in `/boot/loader.conf`; SCSI drives can be queried using `camcontrol identify`, and the write cache both queried and changed using `sdparm` when available.
- On Solaris, the disk write cache is controlled by `format -e`. (The Solaris ZFS file system is safe with disk write-cache enabled because it issues its own disk cache flush commands.)
- On Windows, if `wal_sync_method` is `open_datasync` (the default), write caching can be disabled by unchecking `My Computer\Open\disk drive\Properties\Hardware\Properties\Policies\Enable write caching on the disk`. Alternatively, set `wal_sync_method` to `fsync` or `fsync_writethrough`, which prevent write caching.

¹ <http://sg.danny.cz/sg/sdparm.html>

- On macOS, write caching can be prevented by setting `wal_sync_method` to `fsync_writethrough`.

Recent SATA drives (those following ATAPI-6 or later) offer a drive cache flush command (`FLUSH CACHE EXT`), while SCSI drives have long supported a similar command `SYNCHRONIZE CACHE`. These commands are not directly accessible to PostgreSQL, but some file systems (e.g., ZFS, ext4) can use them to flush data to the platters on write-back-enabled drives. Unfortunately, such file systems behave suboptimally when combined with battery-backup unit (BBU) disk controllers. In such setups, the synchronize command forces all data from the controller cache to the disks, eliminating much of the benefit of the BBU. You can run the `pg_test_fsync` program to see if you are affected. If you are affected, the performance benefits of the BBU can be regained by turning off write barriers in the file system or reconfiguring the disk controller, if that is an option. If write barriers are turned off, make sure the battery remains functional; a faulty battery can potentially lead to data loss. Hopefully file system and disk controller designers will eventually address this suboptimal behavior.

When the operating system sends a write request to the storage hardware, there is little it can do to make sure the data has arrived at a truly non-volatile storage area. Rather, it is the administrator's responsibility to make certain that all storage components ensure integrity for both data and file-system metadata. Avoid disk controllers that have non-battery-backed write caches. At the drive level, disable write-back caching if the drive cannot guarantee the data will be written before shutdown. If you use SSDs, be aware that many of these do not honor cache flush commands by default. You can test for reliable I/O subsystem behavior using `diskchecker.pl`².

Another risk of data loss is posed by the disk platter write operations themselves. Disk platters are divided into sectors, commonly 512 bytes each. Every physical read or write operation processes a whole sector. When a write request arrives at the drive, it might be for some multiple of 512 bytes (PostgreSQL typically writes 8192 bytes, or 16 sectors, at a time), and the process of writing could fail due to power loss at any time, meaning some of the 512-byte sectors were written while others were not. To guard against such failures, PostgreSQL periodically writes full page images to permanent WAL storage *before* modifying the actual page on disk. By doing this, during crash recovery PostgreSQL can restore partially-written pages from WAL. If you have file-system software that prevents partial page writes (e.g., ZFS), you can turn off this page imaging by turning off the `full_page_writes` parameter. Battery-Backed Unit (BBU) disk controllers do not prevent partial page writes unless they guarantee that data is written to the BBU as full (8kB) pages.

PostgreSQL also protects against some kinds of data corruption on storage devices that may occur because of hardware errors or media failure over time, such as reading/writing garbage data.

- Each individual record in a WAL file is protected by a CRC-32 (32-bit) check that allows us to tell if record contents are correct. The CRC value is set when we write each WAL record and checked during crash recovery, archive recovery and replication.
- Data pages are not currently checksummed by default, though full page images recorded in WAL records will be protected; see `initdb` for details about enabling data page checksums.
- Internal data structures such as `pg_xact`, `pg_subtrans`, `pg_multixact`, `pg_serial`, `pg_notify`, `pg_stat`, `pg_snapshots` are not directly checksummed, nor are pages protected by full page writes. However, where such data structures are persistent, WAL records are written that allow recent changes to be accurately rebuilt at crash recovery and those WAL records are protected as discussed above.
- Individual state files in `pg_twophase` are protected by CRC-32.
- Temporary data files used in larger SQL queries for sorts, materializations and intermediate results are not currently checksummed, nor will WAL records be written for changes to those files.

PostgreSQL does not protect against correctable memory errors and it is assumed you will operate using RAM that uses industry standard Error Correcting Codes (ECC) or better protection.

² <https://brad.livejournal.com/2116715.html>

29.2. Write-Ahead Logging (WAL)

Write-Ahead Logging (WAL) is a standard method for ensuring data integrity. A detailed description can be found in most (if not all) books about transaction processing. Briefly, WAL's central concept is that changes to data files (where tables and indexes reside) must be written only after those changes have been logged, that is, after log records describing the changes have been flushed to permanent storage. If we follow this procedure, we do not need to flush data pages to disk on every transaction commit, because we know that in the event of a crash we will be able to recover the database using the log: any changes that have not been applied to the data pages can be redone from the log records. (This is roll-forward recovery, also known as REDO.)

Tip

Because WAL restores database file contents after a crash, journaled file systems are not necessary for reliable storage of the data files or WAL files. In fact, journaling overhead can reduce performance, especially if journaling causes file system *data* to be flushed to disk. Fortunately, data flushing during journaling can often be disabled with a file system mount option, e.g. `data=writeback` on a Linux ext3 file system. Journaled file systems do improve boot speed after a crash.

Using WAL results in a significantly reduced number of disk writes, because only the log file needs to be flushed to disk to guarantee that a transaction is committed, rather than every data file changed by the transaction. The log file is written sequentially, and so the cost of syncing the log is much less than the cost of flushing the data pages. This is especially true for servers handling many small transactions touching different parts of the data store. Furthermore, when the server is processing many small concurrent transactions, one `fsync` of the log file may suffice to commit many transactions.

WAL also makes it possible to support on-line backup and point-in-time recovery, as described in Section 25.3. By archiving the WAL data we can support reverting to any time instant covered by the available WAL data: we simply install a prior physical backup of the database, and replay the WAL log just as far as the desired time. What's more, the physical backup doesn't have to be an instantaneous snapshot of the database state — if it is made over some period of time, then replaying the WAL log for that period will fix any internal inconsistencies.

29.3. Asynchronous Commit

Asynchronous commit is an option that allows transactions to complete more quickly, at the cost that the most recent transactions may be lost if the database should crash. In many applications this is an acceptable trade-off.

As described in the previous section, transaction commit is normally *synchronous*: the server waits for the transaction's WAL records to be flushed to permanent storage before returning a success indication to the client. The client is therefore guaranteed that a transaction reported to be committed will be preserved, even in the event of a server crash immediately after. However, for short transactions this delay is a major component of the total transaction time. Selecting asynchronous commit mode means that the server returns success as soon as the transaction is logically completed, before the WAL records it generated have actually made their way to disk. This can provide a significant boost in throughput for small transactions.

Asynchronous commit introduces the risk of data loss. There is a short time window between the report of transaction completion to the client and the time that the transaction is truly committed (that is, it is guaranteed not to be lost if the server crashes). Thus asynchronous commit should not be used if the client will take external actions relying on the assumption that the transaction will be remembered. As an example, a bank would certainly not use asynchronous commit for a transaction recording an ATM's dispensing of cash. But in many scenarios, such as event logging, there is no need for a strong guarantee of this kind.

The risk that is taken by using asynchronous commit is of data loss, not data corruption. If the database should crash, it will recover by replaying WAL up to the last record that was flushed. The database will therefore be restored to a self-consistent state, but any transactions that were not yet flushed to disk will not be reflected in that state. The net effect is therefore loss of the last few transactions. Because the transactions are replayed in commit order, no inconsistency can be introduced — for example, if transaction B made changes relying on the effects of a previous transaction A, it is not possible for A's effects to be lost while B's effects are preserved.

The user can select the commit mode of each transaction, so that it is possible to have both synchronous and asynchronous commit transactions running concurrently. This allows flexible trade-offs between performance and certainty of transaction durability. The commit mode is controlled by the user-settable parameter `synchronous_commit`, which can be changed in any of the ways that a configuration parameter can be set. The mode used for any one transaction depends on the value of `synchronous_commit` when transaction commit begins.

Certain utility commands, for instance `DROP TABLE`, are forced to commit synchronously regardless of the setting of `synchronous_commit`. This is to ensure consistency between the server's file system and the logical state of the database. The commands supporting two-phase commit, such as `PREPARE TRANSACTION`, are also always synchronous.

If the database crashes during the risk window between an asynchronous commit and the writing of the transaction's WAL records, then changes made during that transaction *will* be lost. The duration of the risk window is limited because a background process (the “WAL writer”) flushes unwritten WAL records to disk every `wal_writer_delay` milliseconds. The actual maximum duration of the risk window is three times `wal_writer_delay` because the WAL writer is designed to favor writing whole pages at a time during busy periods.

Caution

An immediate-mode shutdown is equivalent to a server crash, and will therefore cause loss of any unflushed asynchronous commits.

Asynchronous commit provides behavior different from setting `fsync = off`. `fsync` is a server-wide setting that will alter the behavior of all transactions. It disables all logic within PostgreSQL that attempts to synchronize writes to different portions of the database, and therefore a system crash (that is, a hardware or operating system crash, not a failure of PostgreSQL itself) could result in arbitrarily bad corruption of the database state. In many scenarios, asynchronous commit provides most of the performance improvement that could be obtained by turning off `fsync`, but without the risk of data corruption.

`commit_delay` also sounds very similar to asynchronous commit, but it is actually a synchronous commit method (in fact, `commit_delay` is ignored during an asynchronous commit). `commit_delay` causes a delay just before a transaction flushes WAL to disk, in the hope that a single flush executed by one such transaction can also serve other transactions committing at about the same time. The setting can be thought of as a way of increasing the time window in which transactions can join a group about to participate in a single flush, to amortize the cost of the flush among multiple transactions.

29.4. WAL Configuration

There are several WAL-related configuration parameters that affect database performance. This section explains their use. Consult Chapter 19 for general information about setting server configuration parameters.

Checkpoints are points in the sequence of transactions at which it is guaranteed that the heap and index data files have been updated with all information written before that checkpoint. At checkpoint time, all dirty data pages are flushed to disk and a special checkpoint record is written to the log file. (The

change records were previously flushed to the WAL files.) In the event of a crash, the crash recovery procedure looks at the latest checkpoint record to determine the point in the log (known as the redo record) from which it should start the REDO operation. Any changes made to data files before that point are guaranteed to be already on disk. Hence, after a checkpoint, log segments preceding the one containing the redo record are no longer needed and can be recycled or removed. (When WAL archiving is being done, the log segments must be archived before being recycled or removed.)

The checkpoint requirement of flushing all dirty data pages to disk can cause a significant I/O load. For this reason, checkpoint activity is throttled so that I/O begins at checkpoint start and completes before the next checkpoint is due to start; this minimizes performance degradation during checkpoints.

The server's checkpoint process automatically performs a checkpoint every so often. A checkpoint is begun every `checkpoint_timeout` seconds, or if `max_wal_size` is about to be exceeded, whichever comes first. The default settings are 5 minutes and 1 GB, respectively. If no WAL has been written since the previous checkpoint, new checkpoints will be skipped even if `checkpoint_timeout` has passed. (If WAL archiving is being used and you want to put a lower limit on how often files are archived in order to bound potential data loss, you should adjust the `archive_timeout` parameter rather than the checkpoint parameters.) It is also possible to force a checkpoint by using the SQL command `CHECKPOINT`.

Reducing `checkpoint_timeout` and/or `max_wal_size` causes checkpoints to occur more often. This allows faster after-crash recovery, since less work will need to be redone. However, one must balance this against the increased cost of flushing dirty data pages more often. If `full_page_writes` is set (as is the default), there is another factor to consider. To ensure data page consistency, the first modification of a data page after each checkpoint results in logging the entire page content. In that case, a smaller checkpoint interval increases the volume of output to the WAL log, partially negating the goal of using a smaller interval, and in any case causing more disk I/O.

Checkpoints are fairly expensive, first because they require writing out all currently dirty buffers, and second because they result in extra subsequent WAL traffic as discussed above. It is therefore wise to set the checkpointing parameters high enough so that checkpoints don't happen too often. As a simple sanity check on your checkpointing parameters, you can set the `checkpoint_warning` parameter. If checkpoints happen closer together than `checkpoint_warning` seconds, a message will be output to the server log recommending increasing `max_wal_size`. Occasional appearance of such a message is not cause for alarm, but if it appears often then the checkpoint control parameters should be increased. Bulk operations such as large COPY transfers might cause a number of such warnings to appear if you have not set `max_wal_size` high enough.

To avoid flooding the I/O system with a burst of page writes, writing dirty buffers during a checkpoint is spread over a period of time. That period is controlled by `checkpoint_completion_target`, which is given as a fraction of the checkpoint interval. The I/O rate is adjusted so that the checkpoint finishes when the given fraction of `checkpoint_timeout` seconds have elapsed, or before `max_wal_size` is exceeded, whichever is sooner. With the default value of 0.5, PostgreSQL can be expected to complete each checkpoint in about half the time before the next checkpoint starts. On a system that's very close to maximum I/O throughput during normal operation, you might want to increase `checkpoint_completion_target` to reduce the I/O load from checkpoints. The disadvantage of this is that prolonging checkpoints affects recovery time, because more WAL segments will need to be kept around for possible use in recovery. Although `checkpoint_completion_target` can be set as high as 1.0, it is best to keep it less than that (perhaps 0.9 at most) since checkpoints include some other activities besides writing dirty buffers. A setting of 1.0 is quite likely to result in checkpoints not being completed on time, which would result in performance loss due to unexpected variation in the number of WAL segments needed.

On Linux and POSIX platforms `checkpoint_flush_after` allows to force the OS that pages written by the checkpoint should be flushed to disk after a configurable number of bytes. Otherwise, these pages may be kept in the OS's page cache, inducing a stall when `fsync` is issued at the end of a checkpoint. This setting will often help to reduce transaction latency, but it also can have an adverse effect on performance; particularly for workloads that are bigger than `shared_buffers`, but smaller than the OS's page cache.

The number of WAL segment files in `pg_wal` directory depends on `min_wal_size`, `max_wal_size` and the amount of WAL generated in previous checkpoint cycles. When old log segment files are no longer needed, they are removed or recycled (that is, renamed to become future segments in the numbered sequence). If, due to a short-term peak of log output rate, `max_wal_size` is exceeded, the unneeded segment files will be removed until the system gets back under this limit. Below that limit, the system recycles enough WAL files to cover the estimated need until the next checkpoint, and removes the rest. The estimate is based on a moving average of the number of WAL files used in previous checkpoint cycles. The moving average is increased immediately if the actual usage exceeds the estimate, so it accommodates peak usage rather than average usage to some extent. `min_wal_size` puts a minimum on the amount of WAL files recycled for future usage; that much WAL is always recycled for future use, even if the system is idle and the WAL usage estimate suggests that little WAL is needed.

Independently of `max_wal_size`, `wal_keep_segments + 1` most recent WAL files are kept at all times. Also, if WAL archiving is used, old segments can not be removed or recycled until they are archived. If WAL archiving cannot keep up with the pace that WAL is generated, or if `archive_command` fails repeatedly, old WAL files will accumulate in `pg_wal` until the situation is resolved. A slow or failed standby server that uses a replication slot will have the same effect (see Section 26.2.6).

In archive recovery or standby mode, the server periodically performs *restartpoints*, which are similar to checkpoints in normal operation: the server forces all its state to disk, updates the `pg_control` file to indicate that the already-processed WAL data need not be scanned again, and then recycles any old log segment files in the `pg_wal` directory. Restartpoints can't be performed more frequently than checkpoints in the master because restartpoints can only be performed at checkpoint records. A restartpoint is triggered when a checkpoint record is reached if at least `checkpoint_timeout` seconds have passed since the last restartpoint, or if WAL size is about to exceed `max_wal_size`. However, because of limitations on when a restartpoint can be performed, `max_wal_size` is often exceeded during recovery, by up to one checkpoint cycle's worth of WAL. (`max_wal_size` is never a hard limit anyway, so you should always leave plenty of headroom to avoid running out of disk space.)

There are two commonly used internal WAL functions: `XLogInsertRecord` and `XLogFlush`. `XLogInsertRecord` is used to place a new record into the WAL buffers in shared memory. If there is no space for the new record, `XLogInsertRecord` will have to write (move to kernel cache) a few filled WAL buffers. This is undesirable because `XLogInsertRecord` is used on every database low level modification (for example, row insertion) at a time when an exclusive lock is held on affected data pages, so the operation needs to be as fast as possible. What is worse, writing WAL buffers might also force the creation of a new log segment, which takes even more time. Normally, WAL buffers should be written and flushed by an `XLogFlush` request, which is made, for the most part, at transaction commit time to ensure that transaction records are flushed to permanent storage. On systems with high log output, `XLogFlush` requests might not occur often enough to prevent `XLogInsertRecord` from having to do writes. On such systems one should increase the number of WAL buffers by modifying the `wal_buffers` parameter. When `full_page_writes` is set and the system is very busy, setting `wal_buffers` higher will help smooth response times during the period immediately following each checkpoint.

The `commit_delay` parameter defines for how many microseconds a group commit leader process will sleep after acquiring a lock within `XLogFlush`, while group commit followers queue up behind the leader. This delay allows other server processes to add their commit records to the WAL buffers so that all of them will be flushed by the leader's eventual sync operation. No sleep will occur if `fsync` is not enabled, or if fewer than `commit_siblings` other sessions are currently in active transactions; this avoids sleeping when it's unlikely that any other session will commit soon. Note that on some platforms, the resolution of a sleep request is ten milliseconds, so that any nonzero `commit_delay` setting between 1 and 10000 microseconds would have the same effect. Note also that on some platforms, sleep operations may take slightly longer than requested by the parameter.

Since the purpose of `commit_delay` is to allow the cost of each flush operation to be amortized across concurrently committing transactions (potentially at the expense of transaction latency), it is

necessary to quantify that cost before the setting can be chosen intelligently. The higher that cost is, the more effective `commit_delay` is expected to be in increasing transaction throughput, up to a point. The `pg_test_fsync` program can be used to measure the average time in microseconds that a single WAL flush operation takes. A value of half of the average time the program reports it takes to flush after a single 8kB write operation is often the most effective setting for `commit_delay`, so this value is recommended as the starting point to use when optimizing for a particular workload. While tuning `commit_delay` is particularly useful when the WAL log is stored on high-latency rotating disks, benefits can be significant even on storage media with very fast sync times, such as solid-state drives or RAID arrays with a battery-backed write cache; but this should definitely be tested against a representative workload. Higher values of `commit_siblings` should be used in such cases, whereas smaller `commit_siblings` values are often helpful on higher latency media. Note that it is quite possible that a setting of `commit_delay` that is too high can increase transaction latency by so much that total transaction throughput suffers.

When `commit_delay` is set to zero (the default), it is still possible for a form of group commit to occur, but each group will consist only of sessions that reach the point where they need to flush their commit records during the window in which the previous flush operation (if any) is occurring. At higher client counts a “gangway effect” tends to occur, so that the effects of group commit become significant even when `commit_delay` is zero, and thus explicitly setting `commit_delay` tends to help less. Setting `commit_delay` can only help when (1) there are some concurrently committing transactions, and (2) throughput is limited to some degree by commit rate; but with high rotational latency this setting can be effective in increasing transaction throughput with as few as two clients (that is, a single committing client with one sibling transaction).

The `wal_sync_method` parameter determines how PostgreSQL will ask the kernel to force WAL updates out to disk. All the options should be the same in terms of reliability, with the exception of `fsync_writethrough`, which can sometimes force a flush of the disk cache even when other options do not do so. However, it's quite platform-specific which one will be the fastest. You can test the speeds of different options using the `pg_test_fsync` program. Note that this parameter is irrelevant if `fsync` has been turned off.

Enabling the `wal_debug` configuration parameter (provided that PostgreSQL has been compiled with support for it) will result in each `XLogInsertRecord` and `XLogFlush` WAL call being logged to the server log. This option might be replaced by a more general mechanism in the future.

29.5. WAL Internals

WAL is automatically enabled; no action is required from the administrator except ensuring that the disk-space requirements for the WAL logs are met, and that any necessary tuning is done (see Section 29.4).

WAL records are appended to the WAL logs as each new record is written. The insert position is described by a Log Sequence Number (LSN) that is a byte offset into the logs, increasing monotonically with each new record. LSN values are returned as the datatype `pg_lsn`. Values can be compared to calculate the volume of WAL data that separates them, so they are used to measure the progress of replication and recovery.

WAL logs are stored in the directory `pg_wal` under the data directory, as a set of segment files, normally each 16 MB in size (but the size can be changed by altering the `--wal-segsize` `initdb` option). Each segment is divided into pages, normally 8 kB each (this size can be changed via the `--with-wal-blocksize` `configure` option). The log record headers are described in `access/xlogrecord.h`; the record content is dependent on the type of event that is being logged. Segment files are given ever-increasing numbers as names, starting at `000000010000000000000000`. The numbers do not wrap, but it will take a very, very long time to exhaust the available stock of numbers.

It is advantageous if the log is located on a different disk from the main database files. This can be achieved by moving the `pg_wal` directory to another location (while the server is shut down, of course) and creating a symbolic link from the original location in the main data directory to the new location.

The aim of WAL is to ensure that the log is written before database records are altered, but this can be subverted by disk drives that falsely report a successful write to the kernel, when in fact they have only cached the data and not yet stored it on the disk. A power failure in such a situation might lead to irrecoverable data corruption. Administrators should try to ensure that disks holding PostgreSQL's WAL log files do not make such false reports. (See Section 29.1.)

After a checkpoint has been made and the log flushed, the checkpoint's position is saved in the file `pg_control`. Therefore, at the start of recovery, the server first reads `pg_control` and then the checkpoint record; then it performs the REDO operation by scanning forward from the log location indicated in the checkpoint record. Because the entire content of data pages is saved in the log on the first page modification after a checkpoint (assuming `full_page_writes` is not disabled), all pages changed since the checkpoint will be restored to a consistent state.

To deal with the case where `pg_control` is corrupt, we should support the possibility of scanning existing log segments in reverse order — newest to oldest — in order to find the latest checkpoint. This has not been implemented yet. `pg_control` is small enough (less than one disk page) that it is not subject to partial-write problems, and as of this writing there have been no reports of database failures due solely to the inability to read `pg_control` itself. So while it is theoretically a weak spot, `pg_control` does not seem to be a problem in practice.

Chapter 30. Logical Replication

Logical replication is a method of replicating data objects and their changes, based upon their replication identity (usually a primary key). We use the term logical in contrast to physical replication, which uses exact block addresses and byte-by-byte replication. PostgreSQL supports both mechanisms concurrently, see Chapter 26. Logical replication allows fine-grained control over both data replication and security.

Logical replication uses a *publish* and *subscribe* model with one or more *subscribers* subscribing to one or more *publications* on a *publisher* node. Subscribers pull data from the publications they subscribe to and may subsequently re-publish data to allow cascading replication or more complex configurations.

Logical replication of a table typically starts with taking a snapshot of the data on the publisher database and copying that to the subscriber. Once that is done, the changes on the publisher are sent to the subscriber as they occur in real-time. The subscriber applies the data in the same order as the publisher so that transactional consistency is guaranteed for publications within a single subscription. This method of data replication is sometimes referred to as transactional replication.

The typical use-cases for logical replication are:

- Sending incremental changes in a single database or a subset of a database to subscribers as they occur.
- Firing triggers for individual changes as they arrive on the subscriber.
- Consolidating multiple databases into a single one (for example for analytical purposes).
- Replicating between different major versions of PostgreSQL.
- Replicating between PostgreSQL instances on different platforms (for example Linux to Windows)
- Giving access to replicated data to different groups of users.
- Sharing a subset of the database between multiple databases.

The subscriber database behaves in the same way as any other PostgreSQL instance and can be used as a publisher for other databases by defining its own publications. When the subscriber is treated as read-only by application, there will be no conflicts from a single subscription. On the other hand, if there are other writes done either by an application or by other subscribers to the same set of tables, conflicts can arise.

30.1. Publication

A *publication* can be defined on any physical replication master. The node where a publication is defined is referred to as *publisher*. A publication is a set of changes generated from a table or a group of tables, and might also be described as a change set or replication set. Each publication exists in only one database.

Publications are different from schemas and do not affect how the table is accessed. Each table can be added to multiple publications if needed. Publications may currently only contain tables. Objects must be added explicitly, except when a publication is created for `ALL TABLES`.

Publications can choose to limit the changes they produce to any combination of `INSERT`, `UPDATE`, `DELETE`, and `TRUNCATE`, similar to how triggers are fired by particular event types. By default, all operation types are replicated.

A published table must have a “replica identity” configured in order to be able to replicate `UPDATE` and `DELETE` operations, so that appropriate rows to update or delete can be identified on the subscriber

side. By default, this is the primary key, if there is one. Another unique index (with certain additional requirements) can also be set to be the replica identity. If the table does not have any suitable key, then it can be set to replica identity “full”, which means the entire row becomes the key. This, however, is very inefficient and should only be used as a fallback if no other solution is possible. If a replica identity other than “full” is set on the publisher side, a replica identity comprising the same or fewer columns must also be set on the subscriber side. See `REPLICA IDENTITY` for details on how to set the replica identity. If a table without a replica identity is added to a publication that replicates `UPDATE` or `DELETE` operations then subsequent `UPDATE` or `DELETE` operations will cause an error on the publisher. `INSERT` operations can proceed regardless of any replica identity.

Every publication can have multiple subscribers.

A publication is created using the `CREATE PUBLICATION` command and may later be altered or dropped using corresponding commands.

The individual tables can be added and removed dynamically using `ALTER PUBLICATION`. Both the `ADD TABLE` and `DROP TABLE` operations are transactional; so the table will start or stop replicating at the correct snapshot once the transaction has committed.

30.2. Subscription

A *subscription* is the downstream side of logical replication. The node where a subscription is defined is referred to as the *subscriber*. A subscription defines the connection to another database and set of publications (one or more) to which it wants to subscribe.

The subscriber database behaves in the same way as any other PostgreSQL instance and can be used as a publisher for other databases by defining its own publications.

A subscriber node may have multiple subscriptions if desired. It is possible to define multiple subscriptions between a single publisher-subscriber pair, in which case care must be taken to ensure that the subscribed publication objects don't overlap.

Each subscription will receive changes via one replication slot (see Section 26.2.6). Additional temporary replication slots may be required for the initial data synchronization of pre-existing table data.

A logical replication subscription can be a standby for synchronous replication (see Section 26.2.8). The standby name is by default the subscription name. An alternative name can be specified as `aplication_name` in the connection information of the subscription.

Subscriptions are dumped by `pg_dump` if the current user is a superuser. Otherwise a warning is written and subscriptions are skipped, because non-superusers cannot read all subscription information from the `pg_subscription` catalog.

The subscription is added using `CREATE SUBSCRIPTION` and can be stopped/resumed at any time using the `ALTER SUBSCRIPTION` command and removed using `DROP SUBSCRIPTION`.

When a subscription is dropped and recreated, the synchronization information is lost. This means that the data has to be resynchronized afterwards.

The schema definitions are not replicated, and the published tables must exist on the subscriber. Only regular tables may be the target of replication. For example, you can't replicate to a view.

The tables are matched between the publisher and the subscriber using the fully qualified table name. Replication to differently-named tables on the subscriber is not supported.

Columns of a table are also matched by name. The order of columns in the subscriber table does not need to match that of the publisher. The data types of the columns do not need to match, as long as the text representation of the data can be converted to the target type. For example, you can replicate from a column of type `integer` to a column of type `bigint`. The target table can also have additional

columns not provided by the published table. Any such columns will be filled with the default value as specified in the definition of the target table.

30.2.1. Replication Slot Management

As mentioned earlier, each (active) subscription receives changes from a replication slot on the remote (publishing) side. Normally, the remote replication slot is created automatically when the subscription is created using `CREATE SUBSCRIPTION` and it is dropped automatically when the subscription is dropped using `DROP SUBSCRIPTION`. In some situations, however, it can be useful or necessary to manipulate the subscription and the underlying replication slot separately. Here are some scenarios:

- When creating a subscription, the replication slot already exists. In that case, the subscription can be created using the `create_slot = false` option to associate with the existing slot.
- When creating a subscription, the remote host is not reachable or in an unclear state. In that case, the subscription can be created using the `connect = false` option. The remote host will then not be contacted at all. This is what `pg_dump` uses. The remote replication slot will then have to be created manually before the subscription can be activated.
- When dropping a subscription, the replication slot should be kept. This could be useful when the subscriber database is being moved to a different host and will be activated from there. In that case, disassociate the slot from the subscription using `ALTER SUBSCRIPTION` before attempting to drop the subscription.
- When dropping a subscription, the remote host is not reachable. In that case, disassociate the slot from the subscription using `ALTER SUBSCRIPTION` before attempting to drop the subscription. If the remote database instance no longer exists, no further action is then necessary. If, however, the remote database instance is just unreachable, the replication slot should then be dropped manually; otherwise it would continue to reserve WAL and might eventually cause the disk to fill up. Such cases should be carefully investigated.

30.3. Conflicts

Logical replication behaves similarly to normal DML operations in that the data will be updated even if it was changed locally on the subscriber node. If incoming data violates any constraints the replication will stop. This is referred to as a *conflict*. When replicating `UPDATE` or `DELETE` operations, missing data will not produce a conflict and such operations will simply be skipped.

A conflict will produce an error and will stop the replication; it must be resolved manually by the user. Details about the conflict can be found in the subscriber's server log.

The resolution can be done either by changing data on the subscriber so that it does not conflict with the incoming change or by skipping the transaction that conflicts with the existing data. The transaction can be skipped by calling the `pg_replication_origin_advance()` function with a `node_name` corresponding to the subscription name, and a position. The current position of origins can be seen in the `pg_replication_origin_status` system view.

30.4. Restrictions

Logical replication currently has the following restrictions or missing functionality. These might be addressed in future releases.

- The database schema and DDL commands are not replicated. The initial schema can be copied by hand using `pg_dump --schema-only`. Subsequent schema changes would need to be kept in sync manually. (Note, however, that there is no need for the schemas to be absolutely the same on both sides.) Logical replication is robust when schema definitions change in a live database: When the schema is changed on the publisher and replicated data starts arriving at the subscriber but

does not fit into the table schema, replication will error until the schema is updated. In many cases, intermittent errors can be avoided by applying additive schema changes to the subscriber first.

- Sequence data is not replicated. The data in serial or identity columns backed by sequences will of course be replicated as part of the table, but the sequence itself would still show the start value on the subscriber. If the subscriber is used as a read-only database, then this should typically not be a problem. If, however, some kind of switchover or failover to the subscriber database is intended, then the sequences would need to be updated to the latest values, either by copying the current data from the publisher (perhaps using `pg_dump`) or by determining a sufficiently high value from the tables themselves.
- Replication of `TRUNCATE` commands is supported, but some care must be taken when truncating groups of tables connected by foreign keys. When replicating a truncate action, the subscriber will truncate the same group of tables that was truncated on the publisher, either explicitly specified or implicitly collected via `CASCADE`, minus tables that are not part of the subscription. This will work correctly if all affected tables are part of the same subscription. But if some tables to be truncated on the subscriber have foreign-key links to tables that are not part of the same (or any) subscription, then the application of the truncate action on the subscriber will fail.
- Large objects (see Chapter 34) are not replicated. There is no workaround for that, other than storing data in normal tables.
- Replication is only possible from base tables to base tables. That is, the tables on the publication and on the subscription side must be normal tables, not views, materialized views, partition root tables, or foreign tables. In the case of partitions, you can therefore replicate a partition hierarchy one-to-one, but you cannot currently replicate to a differently partitioned setup. Attempts to replicate tables other than base tables will result in an error.

30.5. Architecture

Logical replication starts by copying a snapshot of the data on the publisher database. Once that is done, changes on the publisher are sent to the subscriber as they occur in real time. The subscriber applies data in the order in which commits were made on the publisher so that transactional consistency is guaranteed for the publications within any single subscription.

Logical replication is built with an architecture similar to physical streaming replication (see Section 26.2.5). It is implemented by “walsender” and “apply” processes. The walsender process starts logical decoding (described in Chapter 48) of the WAL and loads the standard logical decoding plugin (`pgoutput`). The plugin transforms the changes read from WAL to the logical replication protocol (see Section 52.5) and filters the data according to the publication specification. The data is then continuously transferred using the streaming replication protocol to the apply worker, which maps the data to local tables and applies the individual changes as they are received, in correct transactional order.

The apply process on the subscriber database always runs with `session_replication_role` set to `replica`, which produces the usual effects on triggers and constraints.

The logical replication apply process currently only fires row triggers, not statement triggers. The initial table synchronization, however, is implemented like a `COPY` command and thus fires both row and statement triggers for `INSERT`.

30.5.1. Initial Snapshot

The initial data in existing subscribed tables are snapshotted and copied in a parallel instance of a special kind of apply process. This process will create its own temporary replication slot and copy the existing data. Once existing data is copied, the worker enters synchronization mode, which ensures that the table is brought up to a synchronized state with the main apply process by streaming any changes that happened during the initial data copy using standard logical replication. Once the synchronization is done, the control of the replication of the table is given back to the main apply process where the replication continues as normal.

30.6. Monitoring

Because logical replication is based on a similar architecture as physical streaming replication, the monitoring on a publication node is similar to monitoring of a physical replication master (see Section 26.2.5.2).

The monitoring information about subscription is visible in `pg_stat_subscription`. This view contains one row for every subscription worker. A subscription can have zero or more active subscription workers depending on its state.

Normally, there is a single apply process running for an enabled subscription. A disabled subscription or a crashed subscription will have zero rows in this view. If the initial data synchronization of any table is in progress, there will be additional workers for the tables being synchronized.

30.7. Security

The role used for the replication connection must have the `REPLICATION` attribute (or be a superuser). Access for the role must be configured in `pg_hba.conf` and it must have the `LOGIN` attribute.

In order to be able to copy the initial table data, the role used for the replication connection must have the `SELECT` privilege on a published table (or be a superuser).

To create a publication, the user must have the `CREATE` privilege in the database.

To add tables to a publication, the user must have ownership rights on the table. To create a publication that publishes all tables automatically, the user must be a superuser.

To create a subscription, the user must be a superuser.

The subscription apply process will run in the local database with the privileges of a superuser.

Privileges are only checked once at the start of a replication connection. They are not re-checked as each change record is read from the publisher, nor are they re-checked for each change when applied.

30.8. Configuration Settings

Logical replication requires several configuration options to be set.

On the publisher side, `wal_level` must be set to `logical`, and `max_replication_slots` must be set to at least the number of subscriptions expected to connect, plus some reserve for table synchronization. And `max_wal_senders` should be set to at least the same as `max_replication_slots` plus the number of physical replicas that are connected at the same time.

The subscriber also requires the `max_replication_slots` to be set. In this case it should be set to at least the number of subscriptions that will be added to the subscriber. `max_logical_replication_workers` must be set to at least the number of subscriptions, again plus some reserve for the table synchronization. Additionally the `max_worker_processes` may need to be adjusted to accommodate for replication workers, at least $(\text{max_logical_replication_workers} + 1)$. Note that some extensions and parallel queries also take worker slots from `max_worker_processes`.

30.9. Quick Setup

First set the configuration options in `postgresql.conf`:

```
wal_level = logical
```

The other required settings have default values that are sufficient for a basic setup.

`pg_hba.conf` needs to be adjusted to allow replication (the values here depend on your actual network configuration and user you want to use for connecting):

```
host      all      repuser      0.0.0.0/0      md5
```

Then on the publisher database:

```
CREATE PUBLICATION mypub FOR TABLE users, departments;
```

And on the subscriber database:

```
CREATE SUBSCRIPTION mysub CONNECTION 'dbname=foo host=bar
user=repuser' PUBLICATION mypub;
```

The above will start the replication process, which synchronizes the initial table contents of the tables `users` and `departments` and then starts replicating incremental changes to those tables.

Chapter 31. Just-in-Time Compilation (JIT)

This chapter explains what just-in-time compilation is, and how it can be configured in PostgreSQL.

31.1. What Is JIT compilation?

Just-in-Time (JIT) compilation is the process of turning some form of interpreted program evaluation into a native program, and doing so at run time. For example, instead of using general-purpose code that can evaluate arbitrary SQL expressions to evaluate a particular SQL predicate like `WHERE a.col = 3`, it is possible to generate a function that is specific to that expression and can be natively executed by the CPU, yielding a speedup.

PostgreSQL has builtin support to perform JIT compilation using LLVM¹ when PostgreSQL is built with `--with-llvm`.

See `src/backend/jit/README` for further details.

31.1.1. JIT Accelerated Operations

Currently PostgreSQL's JIT implementation has support for accelerating expression evaluation and tuple deforming. Several other operations could be accelerated in the future.

Expression evaluation is used to evaluate `WHERE` clauses, target lists, aggregates and projections. It can be accelerated by generating code specific to each case.

Tuple deforming is the process of transforming an on-disk tuple (see Section 68.6.1) into its in-memory representation. It can be accelerated by creating a function specific to the table layout and the number of columns to be extracted.

31.1.2. Inlining

PostgreSQL is very extensible and allows new data types, functions, operators and other database objects to be defined; see Chapter 37. In fact the built-in objects are implemented using nearly the same mechanisms. This extensibility implies some overhead, for example due to function calls (see Section 37.3). To reduce that overhead, JIT compilation can inline the bodies of small functions into the expressions using them. That allows a significant percentage of the overhead to be optimized away.

31.1.3. Optimization

LLVM has support for optimizing generated code. Some of the optimizations are cheap enough to be performed whenever JIT is used, while others are only beneficial for longer-running queries. See <https://llvm.org/docs/Passes.html#transform-passes> for more details about optimizations.

31.2. When to JIT?

JIT compilation is beneficial primarily for long-running CPU-bound queries. Frequently these will be analytical queries. For short queries the added overhead of performing JIT compilation will often be higher than the time it can save.

To determine whether JIT compilation should be used, the total estimated cost of a query (see Chapter 70 and Section 19.7.2) is used. The estimated cost of the query will be compared with the setting of

¹ <https://llvm.org/>

`jit_above_cost`. If the cost is higher, JIT compilation will be performed. Two further decisions are then needed. Firstly, if the estimated cost is more than the setting of `jit_inline_above_cost`, short functions and operators used in the query will be inlined. Secondly, if the estimated cost is more than the setting of `jit_optimize_above_cost`, expensive optimizations are applied to improve the generated code. Each of these options increases the JIT compilation overhead, but can reduce query execution time considerably.

These cost-based decisions will be made at plan time, not execution time. This means that when prepared statements are in use, and a generic plan is used (see `PREPARE`), the values of the configuration parameters in effect at prepare time control the decisions, not the settings at execution time.

Note

If `jit` is set to `off`, or if no JIT implementation is available (for example because the server was compiled without `--with-llvm`), JIT will not be performed, even if it would be beneficial based on the above criteria. Setting `jit` to `off` has effects at both plan and execution time.

`EXPLAIN` can be used to see whether JIT is used or not. As an example, here is a query that is not using JIT:

```
=# EXPLAIN ANALYZE SELECT SUM(relpages) FROM pg_class;
                                         QUERY PLAN
-----
Aggregate  (cost=16.27..16.29 rows=1 width=8) (actual
time=0.303..0.303 rows=1 loops=1)
  -> Seq Scan on pg_class  (cost=0.00..15.42 rows=342 width=4)
      (actual time=0.017..0.111 rows=356 loops=1)
Planning Time: 0.116 ms
Execution Time: 0.365 ms
(4 rows)
```

Given the cost of the plan, it is entirely reasonable that no JIT was used; the cost of JIT would have been bigger than the potential savings. Adjusting the cost limits will lead to JIT use:

```
=# SET jit_above_cost = 10;
SET
=# EXPLAIN ANALYZE SELECT SUM(relpages) FROM pg_class;
                                         QUERY PLAN
-----
Aggregate  (cost=16.27..16.29 rows=1 width=8) (actual
time=6.049..6.049 rows=1 loops=1)
  -> Seq Scan on pg_class  (cost=0.00..15.42 rows=342 width=4)
      (actual time=0.019..0.052 rows=356 loops=1)
Planning Time: 0.133 ms
JIT:
  Functions: 3
  Options: Inlining false, Optimization false, Expressions true,
Deforming true
  Timing: Generation 1.259 ms, Inlining 0.000 ms, Optimization
0.797 ms, Emission 5.048 ms, Total 7.104 ms
Execution Time: 7.416 ms
```

As visible here, JIT was used, but inlining and expensive optimization were not. If `jit_inline_above_cost` or `jit_optimize_above_cost` were also lowered, that would change.

31.3. Configuration

The configuration variable `jit` determines whether JIT compilation is enabled or disabled. If it is enabled, the configuration variables `jit_above_cost`, `jit_inline_above_cost`, and `jit_optimize_above_cost` determine whether JIT compilation is performed for a query, and how much effort is spent doing so.

`jit_provider` determines which JIT implementation is used. It is rarely required to be changed. See Section 31.4.2.

For development and debugging purposes a few additional configuration parameters exist, as described in Section 19.17.

31.4. Extensibility

31.4.1. Inlining Support for Extensions

PostgreSQL's JIT implementation can inline the bodies of functions of types `C` and `internal`, as well as operators based on such functions. To do so for functions in extensions, the definitions of those functions need to be made available. When using PGXS to build an extension against a server that has been compiled with LLVM JIT support, the relevant files will be built and installed automatically.

The relevant files have to be installed into `$pkglibdir/bitcode/$extension/` and a summary of them into `$pkglibdir/bitcode/$extension.index.bc`, where `$pkglibdir` is the directory returned by `pg_config --pkglibdir` and `$extension` is the base name of the extension's shared library.

Note

For functions built into PostgreSQL itself, the bitcode is installed into `$pkglibdir/bitcode/postgres`.

31.4.2. Pluggable JIT Providers

PostgreSQL provides a JIT implementation based on LLVM. The interface to the JIT provider is pluggable and the provider can be changed without recompiling (although currently, the build process only provides inlining support data for LLVM). The active provider is chosen via the setting `jit_provider`.

31.4.2.1. JIT Provider Interface

A JIT provider is loaded by dynamically loading the named shared library. The normal library search path is used to locate the library. To provide the required JIT provider callbacks and to indicate that the library is actually a JIT provider, it needs to provide a C function named `_PG_jit_provider_init`. This function is passed a struct that needs to be filled with the callback function pointers for individual actions:

```
struct JitProviderCallbacks
{
    JitProviderResetAfterErrorCB reset_after_error;
    JitProviderReleaseContextCB release_context;
    JitProviderCompileExprCB compile_expr;
};

extern void _PG_jit_provider_init(JitProviderCallbacks *cb);
```

Chapter 32. Regression Tests

The regression tests are a comprehensive set of tests for the SQL implementation in PostgreSQL. They test standard SQL operations as well as the extended capabilities of PostgreSQL.

32.1. Running the Tests

The regression tests can be run against an already installed and running server, or using a temporary installation within the build tree. Furthermore, there is a “parallel” and a “sequential” mode for running the tests. The sequential method runs each test script alone, while the parallel method starts up multiple server processes to run groups of tests in parallel. Parallel testing adds confidence that interprocess communication and locking are working correctly.

32.1.1. Running the Tests Against a Temporary Installation

To run the parallel regression tests after building but before installation, type:

```
make check
```

in the top-level directory. (Or you can change to `src/test/regress` and run the command there.) At the end you should see something like:

```
=====  
All 193 tests passed.  
=====
```

or otherwise a note about which tests failed. See Section 32.2 below before assuming that a “failure” represents a serious problem.

Because this test method runs a temporary server, it will not work if you did the build as the root user, since the server will not start as root. Recommended procedure is not to do the build as root, or else to perform testing after completing the installation.

If you have configured PostgreSQL to install into a location where an older PostgreSQL installation already exists, and you perform `make check` before installing the new version, you might find that the tests fail because the new programs try to use the already-installed shared libraries. (Typical symptoms are complaints about undefined symbols.) If you wish to run the tests before overwriting the old installation, you'll need to build with `configure --disable-rpath`. It is not recommended that you use this option for the final installation, however.

The parallel regression test starts quite a few processes under your user ID. Presently, the maximum concurrency is twenty parallel test scripts, which means forty processes: there's a server process and a `psql` process for each test script. So if your system enforces a per-user limit on the number of processes, make sure this limit is at least fifty or so, else you might get random-seeming failures in the parallel test. If you are not in a position to raise the limit, you can cut down the degree of parallelism by setting the `MAX_CONNECTIONS` parameter. For example:

```
make MAX_CONNECTIONS=10 check
```

runs no more than ten tests concurrently.

32.1.2. Running the Tests Against an Existing Installation

To run the tests after installation (see Chapter 16), initialize a data directory and start the server as explained in Chapter 18, then type:

```
make installcheck
```

or for a parallel test:

```
make installcheck-parallel
```

The tests will expect to contact the server at the local host and the default port number, unless directed otherwise by `PGHOST` and `PGPORT` environment variables. The tests will be run in a database named `regression`; any existing database by this name will be dropped.

The tests will also transiently create some cluster-wide objects, such as roles, tablespaces, and subscriptions. These objects will have names beginning with `regress_`. Beware of using `installcheck` mode with an installation that has any actual global objects named that way.

32.1.3. Additional Test Suites

The `make check` and `make installcheck` commands run only the “core” regression tests, which test built-in functionality of the PostgreSQL server. The source distribution contains many additional test suites, most of them having to do with add-on functionality such as optional procedural languages.

To run all test suites applicable to the modules that have been selected to be built, including the core tests, type one of these commands at the top of the build tree:

```
make check-world  
make installcheck-world
```

These commands run the tests using temporary servers or an already-installed server, respectively, just as previously explained for `make check` and `make installcheck`. Other considerations are the same as previously explained for each method. Note that `make check-world` builds a separate instance (temporary data directory) for each tested module, so it requires more time and disk space than `make installcheck-world`.

On a modern machine with multiple CPU cores and no tight operating-system limits, you can make things go substantially faster with parallelism. The recipe that most PostgreSQL developers actually use for running all tests is something like

```
make check-world -j8 >/dev/null
```

with a `-j` limit near to or a bit more than the number of available cores. Discarding stdout eliminates chatter that's not interesting when you just want to verify success. (In case of failure, the stderr messages are usually enough to determine where to look closer.)

Alternatively, you can run individual test suites by typing `make check` or `make installcheck` in the appropriate subdirectory of the build tree. Keep in mind that `make installcheck` assumes you've installed the relevant module(s), not only the core server.

The additional tests that can be invoked this way include:

- Regression tests for optional procedural languages. These are located under `src/pl`.

- Regression tests for contrib modules, located under contrib. Not all contrib modules have tests.
- Regression tests for the ECPG interface library, located in `src/interfaces/ecpg/test`.
- Tests for core-supported authentication methods, located in `src/test/authentication`. (See below for additional authentication-related tests.)
- Tests stressing behavior of concurrent sessions, located in `src/test/isolation`.
- Tests for crash recovery and physical replication, located in `src/test/recovery`.
- Tests for logical replication, located in `src/test/subscription`.
- Tests of client programs, located under `src/bin`.

When using `installcheck` mode, these tests will create and destroy test databases whose names include `regression`, for example `pl_regression` or `contrib_regression`. Beware of using `installcheck` mode with an installation that has any non-test databases named that way.

Some of these auxiliary test suites use the TAP infrastructure explained in Section 32.4. The TAP-based tests are run only when PostgreSQL was configured with the option `--enable-tap-tests`. This is recommended for development, but can be omitted if there is no suitable Perl installation.

Some test suites are not run by default, either because they are not secure to run on a multiuser system or because they require special software. You can decide which test suites to run additionally by setting the make or environment variable `PG_TEST_EXTRA` to a whitespace-separated list, for example:

```
make check-world PG_TEST_EXTRA='kerberos ldap ssl'
```

The following values are currently supported:

kerberos

Runs the test suite under `src/test/kerberos`. This requires an MIT Kerberos installation and opens TCP/IP listen sockets.

ldap

Runs the test suite under `src/test/ldap`. This requires an OpenLDAP installation and opens TCP/IP listen sockets.

ssl

Runs the test suite under `src/test/ssl`. This opens TCP/IP listen sockets.

Tests for features that are not supported by the current build configuration are not run even if they are mentioned in `PG_TEST_EXTRA`.

In addition, there are tests in `src/test/modules` which will be run by `make check-world` but not by `make installcheck-world`. This is because they install non-production extensions or have other side-effects that are considered undesirable for a production installation. You can use `make install` and `make installcheck` in one of those subdirectories if you wish, but it's not recommended to do so with a non-test server.

32.1.4. Locale and Encoding

By default, tests using a temporary installation use the locale defined in the current environment and the corresponding database encoding as determined by `initdb`. It can be useful to test different locales by setting the appropriate environment variables, for example:

```
make check LANG=C
make check LC_COLLATE=en_US.utf8 LC_CTYPE=fr_CA.utf8
```

For implementation reasons, setting `LC_ALL` does not work for this purpose; all the other locale-related environment variables do work.

When testing against an existing installation, the locale is determined by the existing database cluster and cannot be set separately for the test run.

You can also choose the database encoding explicitly by setting the variable `ENCODING`, for example:

```
make check LANG=C ENCODING=EUC_JP
```

Setting the database encoding this way typically only makes sense if the locale is `C`; otherwise the encoding is chosen automatically from the locale, and specifying an encoding that does not match the locale will result in an error.

The database encoding can be set for tests against either a temporary or an existing installation, though in the latter case it must be compatible with the installation's locale.

32.1.5. Extra Tests

The core regression test suite contains a few test files that are not run by default, because they might be platform-dependent or take a very long time to run. You can run these or other extra test files by setting the variable `EXTRA_TESTS`. For example, to run the `numeric_big` test:

```
make check EXTRA_TESTS=numeric_big
```

To run the collation tests:

```
make check EXTRA_TESTS='collate.linux.utf8 collate.icu.utf8'
LANG=en_US.utf8
```

The `collate.linux.utf8` test works only on Linux/glibc platforms. The `collate.icu.utf8` test only works when support for ICU was built. Both tests will only succeed when run in a database that uses UTF-8 encoding.

32.1.6. Testing Hot Standby

The source distribution also contains regression tests for the static behavior of Hot Standby. These tests require a running primary server and a running standby server that is accepting new WAL changes from the primary (using either file-based log shipping or streaming replication). Those servers are not automatically created for you, nor is replication setup documented here. Please check the various sections of the documentation devoted to the required commands and related issues.

To run the Hot Standby tests, first create a database called `regression` on the primary:

```
psql -h primary -c "CREATE DATABASE regression"
```

Next, run the preparatory script `src/test/regress/sql/hs_primary_setup.sql` on the primary in the `regression` database, for example:

```
psql -h primary -f src/test/regress/sql/hs_primary_setup.sql
regression
```

Allow these changes to propagate to the standby.

Now arrange for the default database connection to be to the standby server under test (for example, by setting the `PGHOST` and `PGPORT` environment variables). Finally, run `make standbycheck` in the regression directory:

```
cd src/test/regress
make standbycheck
```

Some extreme behaviors can also be generated on the primary using the script `src/test/regress/sql/hs_primary_extremes.sql` to allow the behavior of the standby to be tested.

32.2. Test Evaluation

Some properly installed and fully functional PostgreSQL installations can “fail” some of these regression tests due to platform-specific artifacts such as varying floating-point representation and message wording. The tests are currently evaluated using a simple `diff` comparison against the outputs generated on a reference system, so the results are sensitive to small system differences. When a test is reported as “failed”, always examine the differences between expected and actual results; you might find that the differences are not significant. Nonetheless, we still strive to maintain accurate reference files across all supported platforms, so it can be expected that all tests pass.

The actual outputs of the regression tests are in files in the `src/test/regress/results` directory. The test script uses `diff` to compare each output file against the reference outputs stored in the `src/test/regress/expected` directory. Any differences are saved for your inspection in `src/test/regress/regression.diffs`. (When running a test suite other than the core tests, these files of course appear in the relevant subdirectory, not `src/test/regress`.)

If you don't like the `diff` options that are used by default, set the environment variable `PG_REGRESS_DIFF_OPTS`, for instance `PG_REGRESS_DIFF_OPTS='-c'`. (Or you can run `diff` yourself, if you prefer.)

If for some reason a particular platform generates a “failure” for a given test, but inspection of the output convinces you that the result is valid, you can add a new comparison file to silence the failure report in future test runs. See Section 32.3 for details.

32.2.1. Error Message Differences

Some of the regression tests involve intentional invalid input values. Error messages can come from either the PostgreSQL code or from the host platform system routines. In the latter case, the messages can vary between platforms, but should reflect similar information. These differences in messages will result in a “failed” regression test that can be validated by inspection.

32.2.2. Locale Differences

If you run the tests against a server that was initialized with a collation-order locale other than `C`, then there might be differences due to sort order and subsequent failures. The regression test suite is set up to handle this problem by providing alternate result files that together are known to handle a large number of locales.

To run the tests in a different locale when using the temporary-installation method, pass the appropriate locale-related environment variables on the `make` command line, for example:

```
make check LANG=de_DE.utf8
```

(The regression test driver unsets `LC_ALL`, so it does not work to choose the locale using that variable.) To use no locale, either unset all locale-related environment variables (or set them to `C`) or use the following special invocation:

```
make check NO_LOCALE=1
```

When running the tests against an existing installation, the locale setup is determined by the existing installation. To change it, initialize the database cluster with a different locale by passing the appropriate options to `initdb`.

In general, it is advisable to try to run the regression tests in the locale setup that is wanted for production use, as this will exercise the locale- and encoding-related code portions that will actually be used in production. Depending on the operating system environment, you might get failures, but then you will at least know what locale-specific behaviors to expect when running real applications.

32.2.3. Date and Time Differences

Most of the date and time results are dependent on the time zone environment. The reference files are generated for time zone `PST8PDT` (Berkeley, California), and there will be apparent failures if the tests are not run with that time zone setting. The regression test driver sets environment variable `PGTZ` to `PST8PDT`, which normally ensures proper results.

32.2.4. Floating-Point Differences

Some of the tests involve computing 64-bit floating-point numbers (`double precision`) from table columns. Differences in results involving mathematical functions of `double precision` columns have been observed. The `float8` and `geometry` tests are particularly prone to small differences across platforms, or even with different compiler optimization settings. Human eyeball comparison is needed to determine the real significance of these differences which are usually 10 places to the right of the decimal point.

Some systems display minus zero as `-0`, while others just show `0`.

Some systems signal errors from `pow()` and `exp()` differently from the mechanism expected by the current PostgreSQL code.

32.2.5. Row Ordering Differences

You might see differences in which the same rows are output in a different order than what appears in the expected file. In most cases this is not, strictly speaking, a bug. Most of the regression test scripts are not so pedantic as to use an `ORDER BY` for every single `SELECT`, and so their result row orderings are not well-defined according to the SQL specification. In practice, since we are looking at the same queries being executed on the same data by the same software, we usually get the same result ordering on all platforms, so the lack of `ORDER BY` is not a problem. Some queries do exhibit cross-platform ordering differences, however. When testing against an already-installed server, ordering differences can also be caused by non-C locale settings or non-default parameter settings, such as custom values of `work_mem` or the planner cost parameters.

Therefore, if you see an ordering difference, it's not something to worry about, unless the query does have an `ORDER BY` that your result is violating. However, please report it anyway, so that we can add an `ORDER BY` to that particular query to eliminate the bogus "failure" in future releases.

You might wonder why we don't order all the regression test queries explicitly to get rid of this issue once and for all. The reason is that that would make the regression tests less useful, not more, since they'd tend to exercise query plan types that produce ordered results to the exclusion of those that don't.

32.2.6. Insufficient Stack Depth

If the `errors` test results in a server crash at the `select infinite_recurse()` command, it means that the platform's limit on process stack size is smaller than the `max_stack_depth` parameter indicates. This can be fixed by running the server under a higher stack size limit (4MB is recommended

with the default value of `max_stack_depth`). If you are unable to do that, an alternative is to reduce the value of `max_stack_depth`.

On platforms supporting `getrlimit()`, the server should automatically choose a safe value of `max_stack_depth`; so unless you've manually overridden this setting, a failure of this kind is a reportable bug.

32.2.7. The “random” Test

The `random` test script is intended to produce random results. In very rare cases, this causes that regression test to fail. Typing:

```
diff results/random.out expected/random.out
```

should produce only one or a few lines of differences. You need not worry unless the `random` test fails repeatedly.

32.2.8. Configuration Parameters

When running the tests against an existing installation, some non-default parameter settings could cause the tests to fail. For example, changing parameters such as `enable_seqscan` or `enable_indexscan` could cause plan changes that would affect the results of tests that use `EXPLAIN`.

32.3. Variant Comparison Files

Since some of the tests inherently produce environment-dependent results, we have provided ways to specify alternate “expected” result files. Each regression test can have several comparison files showing possible results on different platforms. There are two independent mechanisms for determining which comparison file is used for each test.

The first mechanism allows comparison files to be selected for specific platforms. There is a mapping file, `src/test/regress/resultmap`, that defines which comparison file to use for each platform. To eliminate bogus test “failures” for a particular platform, you first choose or make a variant result file, and then add a line to the `resultmap` file.

Each line in the mapping file is of the form

```
testname:output:platformpattern=comparisonfilename
```

The test name is just the name of the particular regression test module. The output value indicates which output file to check. For the standard regression tests, this is always `out`. The value corresponds to the file extension of the output file. The platform pattern is a pattern in the style of the Unix tool `expr` (that is, a regular expression with an implicit `^` anchor at the start). It is matched against the platform name as printed by `config.guess`. The comparison file name is the base name of the substitute result comparison file.

For example: some systems lack a working `strtof` function, for which our workaround causes rounding errors in the `float4` regression test. Therefore, we provide a variant comparison file, `float4-misrounded-input.out`, which includes the results to be expected on these systems. To silence the bogus “failure” message on HP-UX 10 platforms, `resultmap` includes:

```
float4:out:hppa.*-hp-hpux10.*=float4-misrounded-input.out
```

which will trigger on any machine where the output of `config.guess` matches `hppa.*-hp-hpux10.*`. Other lines in `resultmap` select the variant comparison file for other platforms where it's appropriate.

The second selection mechanism for variant comparison files is much more automatic: it simply uses the “best match” among several supplied comparison files. The regression test driver script considers both the standard comparison file for a test, `testname.out`, and variant files named `testname_digit.out` (where the *digit* is any single digit 0-9). If any such file is an exact match, the test is considered to pass; otherwise, the one that generates the shortest diff is used to create the failure report. (If `resultmap` includes an entry for the particular test, then the base `testname` is the substitute name given in `resultmap`.)

For example, for the `char` test, the comparison file `char.out` contains results that are expected in the C and POSIX locales, while the file `char_1.out` contains results sorted as they appear in many other locales.

The best-match mechanism was devised to cope with locale-dependent results, but it can be used in any situation where the test results cannot be predicted easily from the platform name alone. A limitation of this mechanism is that the test driver cannot tell which variant is actually “correct” for the current environment; it will just pick the variant that seems to work best. Therefore it is safest to use this mechanism only for variant results that you are willing to consider equally valid in all contexts.

32.4. TAP Tests

Various tests, particularly the client program tests under `src/bin`, use the Perl TAP tools and are run using the Perl testing program `prove`. You can pass command-line options to `prove` by setting the make variable `PROVE_FLAGS`, for example:

```
make -C src/bin check PROVE_FLAGS='--timer'
```

See the manual page of `prove` for more information.

The make variable `PROVE_TESTS` can be used to define a whitespace-separated list of paths relative to the `Makefile` invoking `prove` to run the specified subset of tests instead of the default `t/* .pl`. For example:

```
make check PROVE_TESTS='t/001_test1.pl t/003_test3.pl'
```

The TAP tests require the Perl module `IPC::Run`. This module is available from CPAN or an operating system package.

Generically speaking, the TAP tests will test the executables in a previously-installed installation tree if you say `make installcheck`, or will build a new local installation tree from current sources if you say `make check`. In either case they will initialize a local instance (data directory) and transiently run a server in it. Some of these tests run more than one server. Thus, these tests can be fairly resource-intensive.

It's important to realize that the TAP tests will start test server(s) even when you say `make installcheck`; this is unlike the traditional non-TAP testing infrastructure, which expects to use an already-running test server in that case. Some PostgreSQL subdirectories contain both traditional-style and TAP-style tests, meaning that `make installcheck` will produce a mix of results from temporary servers and the already-running test server.

32.5. Test Coverage Examination

The PostgreSQL source code can be compiled with coverage testing instrumentation, so that it becomes possible to examine which parts of the code are covered by the regression tests or any other test suite that is run with the code. This is currently supported when compiling with GCC and requires the `gcov` and `lcov` programs.

A typical workflow would look like this:

```
./configure --enable-coverage ... OTHER OPTIONS ...  
make  
make check # or other test suite  
make coverage-html
```

Then point your HTML browser to `coverage/index.html`. The make commands also work in subdirectories.

If you don't have `lcov` or prefer text output over an HTML report, you can also run

```
make coverage
```

instead of `make coverage-html`, which will produce `.gcov` output files for each source file relevant to the test. (`make coverage` and `make coverage-html` will overwrite each other's files, so mixing them might be confusing.)

To reset the execution counts between test runs, run:

```
make coverage-clean
```

Part IV. Client Interfaces

This part describes the client programming interfaces distributed with PostgreSQL. Each of these chapters can be read independently. Note that there are many other programming interfaces for client programs that are distributed separately and contain their own documentation (Appendix H lists some of the more popular ones). Readers of this part should be familiar with using SQL commands to manipulate and query the database (see Part II) and of course with the programming language that the interface uses.

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Chapter 33. libpq - C Library

libpq is the C application programmer's interface to PostgreSQL. libpq is a set of library functions that allow client programs to pass queries to the PostgreSQL backend server and to receive the results of these queries.

libpq is also the underlying engine for several other PostgreSQL application interfaces, including those written for C++, Perl, Python, Tcl and ECPG. So some aspects of libpq's behavior will be important to you if you use one of those packages. In particular, Section 33.14, Section 33.15 and Section 33.18 describe behavior that is visible to the user of any application that uses libpq.

Some short programs are included at the end of this chapter (Section 33.21) to show how to write programs that use libpq. There are also several complete examples of libpq applications in the directory `src/test/examples` in the source code distribution.

Client programs that use libpq must include the header file `libpq-fe.h` and must link with the libpq library.

33.1. Database Connection Control Functions

The following functions deal with making a connection to a PostgreSQL backend server. An application program can have several backend connections open at one time. (One reason to do that is to access more than one database.) Each connection is represented by a `PGconn` object, which is obtained from the function `PQconnectdb`, `PQconnectdbParams`, or `PQsetdbLogin`. Note that these functions will always return a non-null object pointer, unless perhaps there is too little memory even to allocate the `PGconn` object. The `PQstatus` function should be called to check the return value for a successful connection before queries are sent via the connection object.

Warning

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin each session by removing publicly-writable schemas from `search_path`. One can set parameter key word `options` to value `-csearch_path=`. Alternately, one can issue `PQexec(conn, "SELECT pg_catalog.set_config('search_path', '', false)")` after connecting. This consideration is not specific to libpq; it applies to every interface for executing arbitrary SQL commands.

Warning

On Unix, forking a process with open libpq connections can lead to unpredictable results because the parent and child processes share the same sockets and operating system resources. For this reason, such usage is not recommended, though doing an `exec` from the child process to load a new executable is safe.

Note

On Windows, there is a way to improve performance if a single database connection is repeatedly started and shutdown. Internally, libpq calls `WSAStartup()` and `WSACleanup()` for connection startup and shutdown, respectively. `WSAStartup()` increments an internal Windows library reference count which is decremented by `WSA-`

`Cleanup()`. When the reference count is just one, calling `WSACleanup()` frees all resources and all DLLs are unloaded. This is an expensive operation. To avoid this, an application can manually call `WSAStartup()` so resources will not be freed when the last database connection is closed.

`PQconnectdbParams`

Makes a new connection to the database server.

```
PGconn *PQconnectdbParams(const char * const *keywords,
                          const char * const *values,
                          int expand_dbname);
```

This function opens a new database connection using the parameters taken from two NULL-terminated arrays. The first, `keywords`, is defined as an array of strings, each one being a key word. The second, `values`, gives the value for each key word. Unlike `PQsetdbLogin` below, the parameter set can be extended without changing the function signature, so use of this function (or its nonblocking analogs `PQconnectStartParams` and `PQconnectPoll`) is preferred for new application programming.

The currently recognized parameter key words are listed in Section 33.1.2.

When `expand_dbname` is non-zero, the `dbname` key word value is allowed to be recognized as a connection string. Only the first occurrence of `dbname` is expanded this way, any subsequent `dbname` value is processed as plain database name. More details on the possible connection string formats appear in Section 33.1.1.

The passed arrays can be empty to use all default parameters, or can contain one or more parameter settings. They should be matched in length. Processing will stop at the first NULL element in the `keywords` array.

If any parameter is NULL or an empty string, the corresponding environment variable (see Section 33.14) is checked. If the environment variable is not set either, then the indicated built-in defaults are used.

In general key words are processed from the beginning of these arrays in index order. The effect of this is that when key words are repeated, the last processed value is retained. Therefore, through careful placement of the `dbname` key word, it is possible to determine what may be overridden by a `conninfo` string, and what may not.

`PQconnectdb`

Makes a new connection to the database server.

```
PGconn *PQconnectdb(const char *conninfo);
```

This function opens a new database connection using the parameters taken from the string `conninfo`.

The passed string can be empty to use all default parameters, or it can contain one or more parameter settings separated by whitespace, or it can contain a URI. See Section 33.1.1 for details.

`PQsetdbLogin`

Makes a new connection to the database server.

```
PGconn *PQsetdbLogin(const char *pghost,
                    const char *pgport,
                    const char *pgoptions,
                    const char *pgtty,
                    const char *dbName,
                    const char *login,
                    const char *pwd);
```

This is the predecessor of `PQconnectdb` with a fixed set of parameters. It has the same functionality except that the missing parameters will always take on default values. Write `NULL` or an empty string for any one of the fixed parameters that is to be defaulted.

If the `dbName` contains an `=` sign or has a valid connection URI prefix, it is taken as a `conninfo` string in exactly the same way as if it had been passed to `PQconnectdb`, and the remaining parameters are then applied as specified for `PQconnectdbParams`.

PQsetdb

Makes a new connection to the database server.

```
PGconn *PQsetdb(char *pghost,
               char *pgport,
               char *pgoptions,
               char *pgtty,
               char *dbName);
```

This is a macro that calls `PQsetdbLogin` with null pointers for the `login` and `pwd` parameters. It is provided for backward compatibility with very old programs.

PQconnectStartParams

PQconnectStart

PQconnectPoll

Make a connection to the database server in a nonblocking manner.

```
PGconn *PQconnectStartParams(const char * const *keywords,
                             const char * const *values,
                             int expand_dbname);
```

```
PGconn *PQconnectStart(const char *conninfo);
```

```
PostgresPollingStatusType PQconnectPoll(PGconn *conn);
```

These three functions are used to open a connection to a database server such that your application's thread of execution is not blocked on remote I/O whilst doing so. The point of this approach is that the waits for I/O to complete can occur in the application's main loop, rather than down inside `PQconnectdbParams` or `PQconnectdb`, and so the application can manage this operation in parallel with other activities.

With `PQconnectStartParams`, the database connection is made using the parameters taken from the `keywords` and `values` arrays, and controlled by `expand_dbname`, as described above for `PQconnectdbParams`.

With `PQconnectStart`, the database connection is made using the parameters taken from the string `conninfo` as described above for `PQconnectdb`.

Neither `PQconnectStartParams` nor `PQconnectStart` nor `PQconnectPoll` will block, so long as a number of restrictions are met:

- The `hostaddr` parameter must be used appropriately to prevent DNS queries from being made. See the documentation of this parameter in Section 33.1.2 for details.
- If you call `PQtrace`, ensure that the stream object into which you trace will not block.
- You must ensure that the socket is in the appropriate state before calling `PQconnectPoll`, as described below.

To begin a nonblocking connection request, call `PQconnectStart` or `PQconnectStartParams`. If the result is null, then libpq has been unable to allocate a new `PGconn` structure. Otherwise, a valid `PGconn` pointer is returned (though not yet representing a valid connection to the database). Next call `PQstatus(conn)`. If the result is `CONNECTION_BAD`, the connection attempt has already failed, typically because of invalid connection parameters.

If `PQconnectStart` or `PQconnectStartParams` succeeds, the next stage is to poll libpq so that it can proceed with the connection sequence. Use `PQsocket(conn)` to obtain the descriptor of the socket underlying the database connection. (Caution: do not assume that the socket remains the same across `PQconnectPoll` calls.) Loop thus: If `PQconnectPoll(conn)` last returned `PGRES_POLLING_READING`, wait until the socket is ready to read (as indicated by `select()`, `poll()`, or similar system function). Then call `PQconnectPoll(conn)` again. Conversely, if `PQconnectPoll(conn)` last returned `PGRES_POLLING_WRITING`, wait until the socket is ready to write, then call `PQconnectPoll(conn)` again. On the first iteration, i.e. if you have yet to call `PQconnectPoll`, behave as if it last returned `PGRES_POLLING_WRITING`. Continue this loop until `PQconnectPoll(conn)` returns `PGRES_POLLING_FAILED`, indicating the connection procedure has failed, or `PGRES_POLLING_OK`, indicating the connection has been successfully made.

At any time during connection, the status of the connection can be checked by calling `PQstatus`. If this call returns `CONNECTION_BAD`, then the connection procedure has failed; if the call returns `CONNECTION_OK`, then the connection is ready. Both of these states are equally detectable from the return value of `PQconnectPoll`, described above. Other states might also occur during (and only during) an asynchronous connection procedure. These indicate the current stage of the connection procedure and might be useful to provide feedback to the user for example. These statuses are:

`CONNECTION_STARTED`

Waiting for connection to be made.

`CONNECTION_MADE`

Connection OK; waiting to send.

`CONNECTION_AWAITING_RESPONSE`

Waiting for a response from the server.

`CONNECTION_AUTH_OK`

Received authentication; waiting for backend start-up to finish.

`CONNECTION_SSL_STARTUP`

Negotiating SSL encryption.

`CONNECTION_SETENV`

Negotiating environment-driven parameter settings.

`CONNECTION_CHECK_WRITABLE`

Checking if connection is able to handle write transactions.

CONNECTION_CONSUME

Consuming any remaining response messages on connection.

Note that, although these constants will remain (in order to maintain compatibility), an application should never rely upon these occurring in a particular order, or at all, or on the status always being one of these documented values. An application might do something like this:

```
switch(PQstatus(conn))
{
    case CONNECTION_STARTED:
        feedback = "Connecting...";
        break;

    case CONNECTION_MADE:
        feedback = "Connected to server...";
        break;

    .
    .
    .

    default:
        feedback = "Connecting...";
}

```

The `connect_timeout` connection parameter is ignored when using `PQconnectPoll`; it is the application's responsibility to decide whether an excessive amount of time has elapsed. Otherwise, `PQconnectStart` followed by a `PQconnectPoll` loop is equivalent to `PQconnectdb`.

Note that when `PQconnectStart` or `PQconnectStartParams` returns a non-null pointer, you must call `PQfinish` when you are finished with it, in order to dispose of the structure and any associated memory blocks. This must be done even if the connection attempt fails or is abandoned.

PQconndefaults

Returns the default connection options.

```
PQconninfoOption *PQconndefaults(void);
```

```
typedef struct
{
    char    *keyword;    /* The keyword of the option */
    char    *envvar;     /* Fallback environment variable name */
    char    *compiled;   /* Fallback compiled in default value */
    char    *val;        /* Option's current value, or NULL */
    char    *label;     /* Label for field in connect dialog */
    char    *dispchar;  /* Indicates how to display this field
                        in a connect dialog. Values are:
                        ""      Display entered value as is
                        "*"     Password field - hide value
                        "D"     Debug option - don't show by
                                default */
    int     dispsize;   /* Field size in characters for dialog */
} PQconninfoOption;
```

Returns a connection options array. This can be used to determine all possible `PQconnectdb` options and their current default values. The return value points to an array of `PQconninfoOp-`

tion structures, which ends with an entry having a null keyword pointer. The null pointer is returned if memory could not be allocated. Note that the current default values (val fields) will depend on environment variables and other context. A missing or invalid service file will be silently ignored. Callers must treat the connection options data as read-only.

After processing the options array, free it by passing it to `PQconninfoFree`. If this is not done, a small amount of memory is leaked for each call to `PQconnndefaults`.

`PQconninfo`

Returns the connection options used by a live connection.

```
PQconninfoOption *PQconninfo(PGconn *conn);
```

Returns a connection options array. This can be used to determine all possible `PQconnectdb` options and the values that were used to connect to the server. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null keyword pointer. All notes above for `PQconnndefaults` also apply to the result of `PQconninfo`.

`PQconninfoParse`

Returns parsed connection options from the provided connection string.

```
PQconninfoOption *PQconninfoParse(const char *conninfo, char **errmsg);
```

Parses a connection string and returns the resulting options as an array; or returns `NULL` if there is a problem with the connection string. This function can be used to extract the `PQconnectdb` options in the provided connection string. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null keyword pointer.

All legal options will be present in the result array, but the `PQconninfoOption` for any option not present in the connection string will have `val` set to `NULL`; default values are not inserted.

If `errmsg` is not `NULL`, then `*errmsg` is set to `NULL` on success, else to a malloc'd error string explaining the problem. (It is also possible for `*errmsg` to be set to `NULL` and the function to return `NULL`; this indicates an out-of-memory condition.)

After processing the options array, free it by passing it to `PQconninfoFree`. If this is not done, some memory is leaked for each call to `PQconninfoParse`. Conversely, if an error occurs and `errmsg` is not `NULL`, be sure to free the error string using `PQfreemem`.

`PQfinish`

Closes the connection to the server. Also frees memory used by the `PGconn` object.

```
void PQfinish(PGconn *conn);
```

Note that even if the server connection attempt fails (as indicated by `PQstatus`), the application should call `PQfinish` to free the memory used by the `PGconn` object. The `PGconn` pointer must not be used again after `PQfinish` has been called.

`PQreset`

Resets the communication channel to the server.

```
void PQreset(PGconn *conn);
```

This function will close the connection to the server and attempt to reestablish a new connection to the same server, using all the same parameters previously used. This might be useful for error recovery if a working connection is lost.

```
PQresetStart  
PQresetPoll
```

Reset the communication channel to the server, in a nonblocking manner.

```
int PQresetStart(PGconn *conn);
```

```
PostgresPollingStatusType PQresetPoll(PGconn *conn);
```

These functions will close the connection to the server and attempt to reestablish a new connection to the same server, using all the same parameters previously used. This can be useful for error recovery if a working connection is lost. They differ from `PQreset` (above) in that they act in a nonblocking manner. These functions suffer from the same restrictions as `PQconnectStartParams`, `PQconnectStart` and `PQconnectPoll`.

To initiate a connection reset, call `PQresetStart`. If it returns 0, the reset has failed. If it returns 1, poll the reset using `PQresetPoll` in exactly the same way as you would create the connection using `PQconnectPoll`.

```
PQpingParams
```

`PQpingParams` reports the status of the server. It accepts connection parameters identical to those of `PQconnectdbParams`, described above. It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

```
PGPing PQpingParams(const char * const *keywords,  
                   const char * const *values,  
                   int expand_dbname);
```

The function returns one of the following values:

```
PQPING_OK
```

The server is running and appears to be accepting connections.

```
PQPING_REJECT
```

The server is running but is in a state that disallows connections (startup, shutdown, or crash recovery).

```
PQPING_NO_RESPONSE
```

The server could not be contacted. This might indicate that the server is not running, or that there is something wrong with the given connection parameters (for example, wrong port number), or that there is a network connectivity problem (for example, a firewall blocking the connection request).

```
PQPING_NO_ATTEMPT
```

No attempt was made to contact the server, because the supplied parameters were obviously incorrect or there was some client-side problem (for example, out of memory).

PQping

PQping reports the status of the server. It accepts connection parameters identical to those of PQconnectdb, described above. It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

```
PGPing PQping(const char *conninfo);
```

The return values are the same as for PQpingParams.

33.1.1. Connection Strings

Several libpq functions parse a user-specified string to obtain connection parameters. There are two accepted formats for these strings: plain `keyword = value` strings and URIs. URIs generally follow RFC 3986¹, except that multi-host connection strings are allowed as further described below.

33.1.1.1. Keyword/Value Connection Strings

In the first format, each parameter setting is in the form `keyword = value`. Spaces around the equal sign are optional. To write an empty value, or a value containing spaces, surround it with single quotes, e.g., `keyword = 'a value'`. Single quotes and backslashes within the value must be escaped with a backslash, i.e., `\'` and `\\`.

Example:

```
host=localhost port=5432 dbname=mydb connect_timeout=10
```

The recognized parameter key words are listed in Section 33.1.2.

33.1.1.2. Connection URIs

The general form for a connection URI is:

```
postgresql://[user[:password]@[netloc][:port][,...] [/dbname]][?
param1=value1&...]
```

The URI scheme designator can be either `postgresql://` or `postgres://`. Each of the URI parts is optional. The following examples illustrate valid URI syntax uses:

```
postgresql://
postgresql://localhost
postgresql://localhost:5433
postgresql://localhost/mydb
postgresql://user@localhost
postgresql://user:secret@localhost
postgresql://other@localhost/otherdb?
connect_timeout=10&application_name=myapp
postgresql://host1:123,host2:456/somedb?
target_session_attrs=any&application_name=myapp
```

Components of the hierarchical part of the URI can also be given as parameters. For example:

¹ <https://tools.ietf.org/html/rfc3986>

```
postgresql:///mydb?host=localhost&port=5433
```

Percent-encoding may be used to include symbols with special meaning in any of the URI parts, e.g. replace = with %3D.

Any connection parameters not corresponding to key words listed in Section 33.1.2 are ignored and a warning message about them is sent to `stderr`.

For improved compatibility with JDBC connection URIs, instances of parameter `ssl=true` are translated into `sslmode=require`.

The host part may be either host name or an IP address. To specify an IPv6 host address, enclose it in square brackets:

```
postgresql://[2001:db8::1234]/database
```

The host component is interpreted as described for the parameter `host`. In particular, a Unix-domain socket connection is chosen if the host part is either empty or starts with a slash, otherwise a TCP/IP connection is initiated. Note, however, that the slash is a reserved character in the hierarchical part of the URI. So, to specify a non-standard Unix-domain socket directory, either omit the host specification in the URI and specify the host as a parameter, or percent-encode the path in the host component of the URI:

```
postgresql:///dbname?host=/var/lib/postgresql
postgresql://%2Fvar%2Flib%2Fpostgresql/dbname
```

It is possible to specify multiple host components, each with an optional port component, in a single URI. A URI of the form `postgresql://host1:port1,host2:port2,host3:port3/` is equivalent to a connection string of the form `host=host1,host2,host3 port=port1,port2,port3`. Each host will be tried in turn until a connection is successfully established.

33.1.1.3. Specifying Multiple Hosts

It is possible to specify multiple hosts to connect to, so that they are tried in the given order. In the Keyword/Value format, the `host`, `hostaddr`, and `port` options accept a comma-separated list of values. The same number of elements must be given in each option that is specified, such that e.g. the first `hostaddr` corresponds to the first host name, the second `hostaddr` corresponds to the second host name, and so forth. As an exception, if only one `port` is specified, it applies to all the hosts.

In the connection URI format, you can list multiple `host:port` pairs separated by commas, in the `host` component of the URI.

In either format, a single host name can translate to multiple network addresses. A common example of this is a host that has both an IPv4 and an IPv6 address.

When multiple hosts are specified, or when a single host name is translated to multiple addresses, all the hosts and addresses will be tried in order, until one succeeds. If none of the hosts can be reached, the connection fails. If a connection is established successfully, but authentication fails, the remaining hosts in the list are not tried.

If a password file is used, you can have different passwords for different hosts. All the other connection options are the same for every host in the list; it is not possible to e.g. specify different usernames for different hosts.

33.1.2. Parameter Key Words

The currently recognized parameter key words are:

host

Name of host to connect to. If a host name begins with a slash, it specifies Unix-domain communication rather than TCP/IP communication; the value is the name of the directory in which the socket file is stored. The default behavior when `host` is not specified, or is empty, is to connect to a Unix-domain socket in `/tmp` (or whatever socket directory was specified when PostgreSQL was built). On machines without Unix-domain sockets, the default is to connect to `localhost`.

A comma-separated list of host names is also accepted, in which case each host name in the list is tried in order; an empty item in the list selects the default behavior as explained above. See Section 33.1.1.3 for details.

hostaddr

Numeric IP address of host to connect to. This should be in the standard IPv4 address format, e.g., `172.28.40.9`. If your machine supports IPv6, you can also use those addresses. TCP/IP communication is always used when a nonempty string is specified for this parameter.

Using `hostaddr` instead of `host` allows the application to avoid a host name look-up, which might be important in applications with time constraints. However, a host name is required for GSSAPI or SSPI authentication methods, as well as for `verify-full` SSL certificate verification. The following rules are used:

- If `host` is specified without `hostaddr`, a host name lookup occurs. (When using `PQconnectPoll`, the lookup occurs when `PQconnectPoll` first considers this host name, and it may cause `PQconnectPoll` to block for a significant amount of time.)
- If `hostaddr` is specified without `host`, the value for `hostaddr` gives the server network address. The connection attempt will fail if the authentication method requires a host name.
- If both `host` and `hostaddr` are specified, the value for `hostaddr` gives the server network address. The value for `host` is ignored unless the authentication method requires it, in which case it will be used as the host name.

Note that authentication is likely to fail if `host` is not the name of the server at network address `hostaddr`. Also, when both `host` and `hostaddr` are specified, `host` is used to identify the connection in a password file (see Section 33.15).

A comma-separated list of `hostaddr` values is also accepted, in which case each host in the list is tried in order. An empty item in the list causes the corresponding host name to be used, or the default host name if that is empty as well. See Section 33.1.1.3 for details.

Without either a host name or host address, `libpq` will connect using a local Unix-domain socket; or on machines without Unix-domain sockets, it will attempt to connect to `localhost`.

port

Port number to connect to at the server host, or socket file name extension for Unix-domain connections. If multiple hosts were given in the `host` or `hostaddr` parameters, this parameter may specify a comma-separated list of ports of the same length as the host list, or it may specify a single port number to be used for all hosts. An empty string, or an empty item in a comma-separated list, specifies the default port number established when PostgreSQL was built.

dbname

The database name. Defaults to be the same as the user name. In certain contexts, the value is checked for extended formats; see Section 33.1.1 for more details on those.

user

PostgreSQL user name to connect as. Defaults to be the same as the operating system name of the user running the application.

password

Password to be used if the server demands password authentication.

passfile

Specifies the name of the file used to store passwords (see Section 33.15). Defaults to `~/ .pgpass`, or `%APPDATA%\postgresql\pgpass.conf` on Microsoft Windows. (No error is reported if this file does not exist.)

connect_timeout

Maximum wait for connection, in seconds (write as a decimal integer, e.g. 10). Zero, negative, or not specified means wait indefinitely. The minimum allowed timeout is 2 seconds, therefore a value of 1 is interpreted as 2. This timeout applies separately to each host name or IP address. For example, if you specify two hosts and `connect_timeout` is 5, each host will time out if no connection is made within 5 seconds, so the total time spent waiting for a connection might be up to 10 seconds.

client_encoding

This sets the `client_encoding` configuration parameter for this connection. In addition to the values accepted by the corresponding server option, you can use `auto` to determine the right encoding from the current locale in the client (`LC_CTYPE` environment variable on Unix systems).

options

Specifies command-line options to send to the server at connection start. For example, setting this to `-c geqo=off` sets the session's value of the `geqo` parameter to `off`. Spaces within this string are considered to separate command-line arguments, unless escaped with a backslash (`\`); write `\\` to represent a literal backslash. For a detailed discussion of the available options, consult Chapter 19.

application_name

Specifies a value for the `application_name` configuration parameter.

fallback_application_name

Specifies a fallback value for the `application_name` configuration parameter. This value will be used if no value has been given for `application_name` via a connection parameter or the `PGAPPNAME` environment variable. Specifying a fallback name is useful in generic utility programs that wish to set a default application name but allow it to be overridden by the user.

keepalives

Controls whether client-side TCP keepalives are used. The default value is 1, meaning on, but you can change this to 0, meaning off, if keepalives are not wanted. This parameter is ignored for connections made via a Unix-domain socket.

keepalives_idle

Controls the number of seconds of inactivity after which TCP should send a keepalive message to the server. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where `TCP_KEEPIIDLE` or an equivalent socket option is available, and on Windows; on other systems, it has no effect.

keepalives_interval

Controls the number of seconds after which a TCP keepalive message that is not acknowledged by the server should be retransmitted. A value of zero uses the system default. This parameter is

ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where `TCP_KEEPINTVL` or an equivalent socket option is available, and on Windows; on other systems, it has no effect.

`keepalives_count`

Controls the number of TCP keepalives that can be lost before the client's connection to the server is considered dead. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where `TCP_KEEPCNT` or an equivalent socket option is available; on other systems, it has no effect.

`tcp_user_timeout`

Controls the number of milliseconds that transmitted data may remain unacknowledged before a connection is forcibly closed. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket. It is only supported on systems where `TCP_USER_TIMEOUT` is available; on other systems, it has no effect.

`tty`

Ignored (formerly, this specified where to send server debug output).

`replication`

This option determines whether the connection should use the replication protocol instead of the normal protocol. This is what PostgreSQL replication connections as well as tools such as `pg_basebackup` use internally, but it can also be used by third-party applications. For a description of the replication protocol, consult Section 52.4.

The following values, which are case-insensitive, are supported:

`true, on, yes, 1`

The connection goes into physical replication mode.

`database`

The connection goes into logical replication mode, connecting to the database specified in the `dbname` parameter.

`false, off, no, 0`

The connection is a regular one, which is the default behavior.

In physical or logical replication mode, only the simple query protocol can be used.

`gssencmode`

This option determines whether or with what priority a secure GSS TCP/IP connection will be negotiated with the server. There are three modes:

`disable`

only try a non-GSSAPI-encrypted connection

`prefer` (default)

if there are GSSAPI credentials present (i.e., in a credentials cache), first try a GSSAPI-encrypted connection; if that fails or there are no credentials, try a non-GSSAPI-encrypted connection. This is the default when PostgreSQL has been compiled with GSSAPI support.

`require`

only try a GSSAPI-encrypted connection

`gssencmode` is ignored for Unix domain socket communication. If PostgreSQL is compiled without GSSAPI support, using the `require` option will cause an error, while `prefer` will be accepted but libpq will not actually attempt a GSSAPI-encrypted connection.

`sslmode`

This option determines whether or with what priority a secure SSL TCP/IP connection will be negotiated with the server. There are six modes:

`disable`

only try a non-SSL connection

`allow`

first try a non-SSL connection; if that fails, try an SSL connection

`prefer` (default)

first try an SSL connection; if that fails, try a non-SSL connection

`require`

only try an SSL connection. If a root CA file is present, verify the certificate in the same way as if `verify-ca` was specified

`verify-ca`

only try an SSL connection, and verify that the server certificate is issued by a trusted certificate authority (CA)

`verify-full`

only try an SSL connection, verify that the server certificate is issued by a trusted CA and that the requested server host name matches that in the certificate

See Section 33.18 for a detailed description of how these options work.

`sslmode` is ignored for Unix domain socket communication. If PostgreSQL is compiled without SSL support, using options `require`, `verify-ca`, or `verify-full` will cause an error, while options `allow` and `prefer` will be accepted but libpq will not actually attempt an SSL connection.

`requiressl`

This option is deprecated in favor of the `sslmode` setting.

If set to 1, an SSL connection to the server is required (this is equivalent to `sslmode require`). libpq will then refuse to connect if the server does not accept an SSL connection. If set to 0 (default), libpq will negotiate the connection type with the server (equivalent to `sslmode prefer`). This option is only available if PostgreSQL is compiled with SSL support.

`sslcompression`

If set to 1, data sent over SSL connections will be compressed. If set to 0, compression will be disabled. The default is 0. This parameter is ignored if a connection without SSL is made.

SSL compression is nowadays considered insecure and its use is no longer recommended. OpenSSL 1.1.0 disables compression by default, and many operating system distributions disable it in prior versions as well, so setting this parameter to on will not have any effect if the server does not accept compression. On the other hand, OpenSSL before 1.0.0 does not support disabling compression, so this parameter is ignored with those versions, and whether compression is used depends on the server.

If security is not a primary concern, compression can improve throughput if the network is the bottleneck. Disabling compression can improve response time and throughput if CPU performance is the limiting factor.

sslcert

This parameter specifies the file name of the client SSL certificate, replacing the default `~/.postgresql/postgresql.crt`. This parameter is ignored if an SSL connection is not made.

sslkey

This parameter specifies the location for the secret key used for the client certificate. It can either specify a file name that will be used instead of the default `~/.postgresql/postgresql.key`, or it can specify a key obtained from an external “engine” (engines are OpenSSL loadable modules). An external engine specification should consist of a colon-separated engine name and an engine-specific key identifier. This parameter is ignored if an SSL connection is not made.

sslrootcert

This parameter specifies the name of a file containing SSL certificate authority (CA) certificate(s). If the file exists, the server's certificate will be verified to be signed by one of these authorities. The default is `~/.postgresql/root.crt`.

sslcr1

This parameter specifies the file name of the SSL certificate revocation list (CRL). Certificates listed in this file, if it exists, will be rejected while attempting to authenticate the server's certificate. The default is `~/.postgresql/root.crl`.

requirepeer

This parameter specifies the operating-system user name of the server, for example `requirepeer=postgres`. When making a Unix-domain socket connection, if this parameter is set, the client checks at the beginning of the connection that the server process is running under the specified user name; if it is not, the connection is aborted with an error. This parameter can be used to provide server authentication similar to that available with SSL certificates on TCP/IP connections. (Note that if the Unix-domain socket is in `/tmp` or another publicly writable location, any user could start a server listening there. Use this parameter to ensure that you are connected to a server run by a trusted user.) This option is only supported on platforms for which the peer authentication method is implemented; see Section 20.9.

krbsrvname

Kerberos service name to use when authenticating with GSSAPI. This must match the service name specified in the server configuration for Kerberos authentication to succeed. (See also Section 20.6.)

gsslib

GSS library to use for GSSAPI authentication. Only used on Windows. Set to `gssapi` to force libpq to use the GSSAPI library for authentication instead of the default SSPI.

`service`

Service name to use for additional parameters. It specifies a service name in `pg_service.conf` that holds additional connection parameters. This allows applications to specify only a service name so connection parameters can be centrally maintained. See Section 33.16.

`target_session_attrs`

If this parameter is set to `read-write`, only a connection in which read-write transactions are accepted by default is considered acceptable. The query `SHOW transaction_read_only` will be sent upon any successful connection; if it returns `on`, the connection will be closed. If multiple hosts were specified in the connection string, any remaining servers will be tried just as if the connection attempt had failed. The default value of this parameter, `any`, regards all connections as acceptable.

33.2. Connection Status Functions

These functions can be used to interrogate the status of an existing database connection object.

Tip

libpq application programmers should be careful to maintain the `PGconn` abstraction. Use the accessor functions described below to get at the contents of `PGconn`. Reference to internal `PGconn` fields using `libpq-int.h` is not recommended because they are subject to change in the future.

The following functions return parameter values established at connection. These values are fixed for the life of the connection. If a multi-host connection string is used, the values of `PQhost`, `PQport`, and `PQpass` can change if a new connection is established using the same `PGconn` object. Other values are fixed for the lifetime of the `PGconn` object.

`PQdb`

Returns the database name of the connection.

```
char *PQdb(const PGconn *conn);
```

`PQuser`

Returns the user name of the connection.

```
char *PQuser(const PGconn *conn);
```

`PQpass`

Returns the password of the connection.

```
char *PQpass(const PGconn *conn);
```

`PQpass` will return either the password specified in the connection parameters, or if there was none and the password was obtained from the password file, it will return that. In the latter case, if multiple hosts were specified in the connection parameters, it is not possible to rely on the result of `PQpass` until the connection is established. The status of the connection can be checked using the function `PQstatus`.

PQhost

Returns the server host name of the active connection. This can be a host name, an IP address, or a directory path if the connection is via Unix socket. (The path case can be distinguished because it will always be an absolute path, beginning with /.)

```
char *PQhost(const PGconn *conn);
```

If the connection parameters specified both `host` and `hostaddr`, then `PQhost` will return the `host` information. If only `hostaddr` was specified, then that is returned. If multiple hosts were specified in the connection parameters, `PQhost` returns the host actually connected to.

`PQhost` returns `NULL` if the `conn` argument is `NULL`. Otherwise, if there is an error producing the host information (perhaps if the connection has not been fully established or there was an error), it returns an empty string.

If multiple hosts were specified in the connection parameters, it is not possible to rely on the result of `PQhost` until the connection is established. The status of the connection can be checked using the function `PQstatus`.

PQhostaddr

Returns the server IP address of the active connection. This can be the address that a host name resolved to, or an IP address provided through the `hostaddr` parameter.

```
char *PQhostaddr(const PGconn *conn);
```

`PQhostaddr` returns `NULL` if the `conn` argument is `NULL`. Otherwise, if there is an error producing the host information (perhaps if the connection has not been fully established or there was an error), it returns an empty string.

PQport

Returns the port of the active connection.

```
char *PQport(const PGconn *conn);
```

If multiple ports were specified in the connection parameters, `PQport` returns the port actually connected to.

`PQport` returns `NULL` if the `conn` argument is `NULL`. Otherwise, if there is an error producing the port information (perhaps if the connection has not been fully established or there was an error), it returns an empty string.

If multiple ports were specified in the connection parameters, it is not possible to rely on the result of `PQport` until the connection is established. The status of the connection can be checked using the function `PQstatus`.

PQtty

Returns the debug TTY of the connection. (This is obsolete, since the server no longer pays attention to the TTY setting, but the function remains for backward compatibility.)

```
char *PQtty(const PGconn *conn);
```

PQoptions

Returns the command-line options passed in the connection request.

```
char *PQoptions(const PGconn *conn);
```

The following functions return status data that can change as operations are executed on the `PGconn` object.

PQstatus

Returns the status of the connection.

```
ConnStatusType PQstatus(const PGconn *conn);
```

The status can be one of a number of values. However, only two of these are seen outside of an asynchronous connection procedure: `CONNECTION_OK` and `CONNECTION_BAD`. A good connection to the database has the status `CONNECTION_OK`. A failed connection attempt is signaled by status `CONNECTION_BAD`. Ordinarily, an OK status will remain so until `PQfinish`, but a communications failure might result in the status changing to `CONNECTION_BAD` prematurely. In that case the application could try to recover by calling `PQreset`.

See the entry for `PQconnectStartParams`, `PQconnectStart` and `PQconnectPoll` with regards to other status codes that might be returned.

PQtransactionStatus

Returns the current in-transaction status of the server.

```
PGTransactionStatusType PQtransactionStatus(const PGconn *conn);
```

The status can be `PQTRANS_IDLE` (currently idle), `PQTRANS_ACTIVE` (a command is in progress), `PQTRANS_INTRANS` (idle, in a valid transaction block), or `PQTRANS_INERROR` (idle, in a failed transaction block). `PQTRANS_UNKNOWN` is reported if the connection is bad. `PQTRANS_ACTIVE` is reported only when a query has been sent to the server and not yet completed.

PQparameterStatus

Looks up a current parameter setting of the server.

```
const char *PQparameterStatus(const PGconn *conn, const char
    *paramName);
```

Certain parameter values are reported by the server automatically at connection startup or whenever their values change. `PQparameterStatus` can be used to interrogate these settings. It returns the current value of a parameter if known, or `NULL` if the parameter is not known.

Parameters reported as of the current release include `server_version`, `server_encoding`, `client_encoding`, `application_name`, `is_superuser`, `session_authorization`, `DateStyle`, `IntervalStyle`, `TimeZone`, `integer_datetimes`, and `standard_conforming_strings`. (`server_encoding`, `TimeZone`, and `integer_datetimes` were not reported by releases before 8.0; `standard_conforming_strings` was not reported by releases before 8.1; `IntervalStyle` was not reported by releases before 8.4; `application_name` was not reported by releases before 9.0.) Note that `server_version`, `server_encoding` and `integer_datetimes` cannot change after startup.

Pre-3.0-protocol servers do not report parameter settings, but libpq includes logic to obtain values for `server_version` and `client_encoding` anyway. Applications are encouraged

to use `PQparameterStatus` rather than *ad hoc* code to determine these values. (Beware however that on a pre-3.0 connection, changing `client_encoding` via `SET` after connection startup will not be reflected by `PQparameterStatus`.) For `server_version`, see also `PQserverVersion`, which returns the information in a numeric form that is much easier to compare against.

If no value for `standard_conforming_strings` is reported, applications can assume it is off, that is, backslashes are treated as escapes in string literals. Also, the presence of this parameter can be taken as an indication that the escape string syntax (`E' . . . '`) is accepted.

Although the returned pointer is declared `const`, it in fact points to mutable storage associated with the `PGconn` structure. It is unwise to assume the pointer will remain valid across queries.

`PQprotocolVersion`

Interrogates the frontend/backend protocol being used.

```
int PQprotocolVersion(const PGconn *conn);
```

Applications might wish to use this function to determine whether certain features are supported. Currently, the possible values are 2 (2.0 protocol), 3 (3.0 protocol), or zero (connection bad). The protocol version will not change after connection startup is complete, but it could theoretically change during a connection reset. The 3.0 protocol will normally be used when communicating with PostgreSQL 7.4 or later servers; pre-7.4 servers support only protocol 2.0. (Protocol 1.0 is obsolete and not supported by libpq.)

`PQserverVersion`

Returns an integer representing the server version.

```
int PQserverVersion(const PGconn *conn);
```

Applications might use this function to determine the version of the database server they are connected to. The result is formed by multiplying the server's major version number by 10000 and adding the minor version number. For example, version 10.1 will be returned as 100001, and version 11.0 will be returned as 110000. Zero is returned if the connection is bad.

Prior to major version 10, PostgreSQL used three-part version numbers in which the first two parts together represented the major version. For those versions, `PQserverVersion` uses two digits for each part; for example version 9.1.5 will be returned as 90105, and version 9.2.0 will be returned as 90200.

Therefore, for purposes of determining feature compatibility, applications should divide the result of `PQserverVersion` by 100 not 10000 to determine a logical major version number. In all release series, only the last two digits differ between minor releases (bug-fix releases).

`PQerrorMessage`

Returns the error message most recently generated by an operation on the connection.

```
char *PQerrorMessage(const PGconn *conn);
```

Nearly all libpq functions will set a message for `PQerrorMessage` if they fail. Note that by libpq convention, a nonempty `PQerrorMessage` result can consist of multiple lines, and will include a trailing newline. The caller should not free the result directly. It will be freed when the associated `PGconn` handle is passed to `PQfinish`. The result string should not be expected to remain the same across operations on the `PGconn` structure.

PQsocket

Obtains the file descriptor number of the connection socket to the server. A valid descriptor will be greater than or equal to 0; a result of -1 indicates that no server connection is currently open. (This will not change during normal operation, but could change during connection setup or reset.)

```
int PQsocket(const PGconn *conn);
```

PQbackendPID

Returns the process ID (PID) of the backend process handling this connection.

```
int PQbackendPID(const PGconn *conn);
```

The backend PID is useful for debugging purposes and for comparison to NOTIFY messages (which include the PID of the notifying backend process). Note that the PID belongs to a process executing on the database server host, not the local host!

PQconnectionNeedsPassword

Returns true (1) if the connection authentication method required a password, but none was available. Returns false (0) if not.

```
int PQconnectionNeedsPassword(const PGconn *conn);
```

This function can be applied after a failed connection attempt to decide whether to prompt the user for a password.

PQconnectionUsedPassword

Returns true (1) if the connection authentication method used a password. Returns false (0) if not.

```
int PQconnectionUsedPassword(const PGconn *conn);
```

This function can be applied after either a failed or successful connection attempt to detect whether the server demanded a password.

The following functions return information related to SSL. This information usually doesn't change after a connection is established.

PQsslInUse

Returns true (1) if the connection uses SSL, false (0) if not.

```
int PQsslInUse(const PGconn *conn);
```

PQsslAttribute

Returns SSL-related information about the connection.

```
const char *PQsslAttribute(const PGconn *conn, const char  
    *attribute_name);
```

The list of available attributes varies depending on the SSL library being used, and the type of connection. If an attribute is not available, returns NULL.

The following attributes are commonly available:

library

Name of the SSL implementation in use. (Currently, only "OpenSSL" is implemented)

protocol

SSL/TLS version in use. Common values are "TLSv1", "TLSv1.1" and "TLSv1.2", but an implementation may return other strings if some other protocol is used.

key_bits

Number of key bits used by the encryption algorithm.

cipher

A short name of the ciphersuite used, e.g. "DHE-RSA-DES-CBC3-SHA". The names are specific to each SSL implementation.

compression

If SSL compression is in use, returns the name of the compression algorithm, or "on" if compression is used but the algorithm is not known. If compression is not in use, returns "off".

PQsslAttributeNames

Return an array of SSL attribute names available. The array is terminated by a NULL pointer.

```
const char * const * PQsslAttributeNames(const PGconn *conn);
```

PQsslStruct

Return a pointer to an SSL-implementation-specific object describing the connection.

```
void *PQsslStruct(const PGconn *conn, const char *struct_name);
```

The struct(s) available depend on the SSL implementation in use. For OpenSSL, there is one struct, available under the name "OpenSSL", and it returns a pointer to the OpenSSL SSL struct. To use this function, code along the following lines could be used:

```
#include <libpq-fe.h>
#include <openssl/ssl.h>
...

SSL *ssl;

dbconn = PQconnectdb(...);
...

ssl = PQsslStruct(dbconn, "OpenSSL");
if (ssl)
{
    /* use OpenSSL functions to access ssl */
}
```

This structure can be used to verify encryption levels, check server certificates, and more. Refer to the OpenSSL documentation for information about this structure.

PQgetssl

Returns the SSL structure used in the connection, or null if SSL is not in use.

```
void *PQgetssl(const PGconn *conn);
```

This function is equivalent to `PQsslStruct(conn, "OpenSSL")`. It should not be used in new applications, because the returned struct is specific to OpenSSL and will not be available if another SSL implementation is used. To check if a connection uses SSL, call `PQsslInUse` instead, and for more details about the connection, use `PQsslAttribute`.

33.3. Command Execution Functions

Once a connection to a database server has been successfully established, the functions described here are used to perform SQL queries and commands.

33.3.1. Main Functions

PQexec

Submits a command to the server and waits for the result.

```
PGresult *PQexec(PGconn *conn, const char *command);
```

Returns a `PGresult` pointer or possibly a null pointer. A non-null pointer will generally be returned except in out-of-memory conditions or serious errors such as inability to send the command to the server. The `PQresultStatus` function should be called to check the return value for any errors (including the value of a null pointer, in which case it will return `PGRES_FATAL_ERROR`). Use `PQerrorMessage` to get more information about such errors.

The command string can include multiple SQL commands (separated by semicolons). Multiple queries sent in a single `PQexec` call are processed in a single transaction, unless there are explicit `BEGIN/COMMIT` commands included in the query string to divide it into multiple transactions. (See Section 52.2.2.1 for more details about how the server handles multi-query strings.) Note however that the returned `PGresult` structure describes only the result of the last command executed from the string. Should one of the commands fail, processing of the string stops with it and the returned `PGresult` describes the error condition.

PQexecParams

Submits a command to the server and waits for the result, with the ability to pass parameters separately from the SQL command text.

```
PGresult *PQexecParams(PGconn *conn,
                       const char *command,
                       int nParams,
                       const Oid *paramTypes,
                       const char * const *paramValues,
                       const int *paramLengths,
                       const int *paramFormats,
                       int resultFormat);
```

`PQexecParams` is like `PQexec`, but offers additional functionality: parameter values can be specified separately from the command string proper, and query results can be requested in either text or binary format. `PQexecParams` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The function arguments are:

conn

The connection object to send the command through.

command

The SQL command string to be executed. If parameters are used, they are referred to in the command string as \$1, \$2, etc.

nParams

The number of parameters supplied; it is the length of the arrays *paramTypes[]*, *paramValues[]*, *paramLengths[]*, and *paramFormats[]*. (The array pointers can be NULL when *nParams* is zero.)

paramTypes[]

Specifies, by OID, the data types to be assigned to the parameter symbols. If *paramTypes* is NULL, or any particular element in the array is zero, the server infers a data type for the parameter symbol in the same way it would do for an untyped literal string.

paramValues[]

Specifies the actual values of the parameters. A null pointer in this array means the corresponding parameter is null; otherwise the pointer points to a zero-terminated text string (for text format) or binary data in the format expected by the server (for binary format).

paramLengths[]

Specifies the actual data lengths of binary-format parameters. It is ignored for null parameters and text-format parameters. The array pointer can be null when there are no binary parameters.

paramFormats[]

Specifies whether parameters are text (put a zero in the array entry for the corresponding parameter) or binary (put a one in the array entry for the corresponding parameter). If the array pointer is null then all parameters are presumed to be text strings.

Values passed in binary format require knowledge of the internal representation expected by the backend. For example, integers must be passed in network byte order. Passing numeric values requires knowledge of the server storage format, as implemented in `src/backend/utils/adt/numeric.c::numeric_send()` and `src/backend/utils/adt/numeric.c::numeric_recv()`.

resultFormat

Specify zero to obtain results in text format, or one to obtain results in binary format. (There is not currently a provision to obtain different result columns in different formats, although that is possible in the underlying protocol.)

The primary advantage of `PQexecParams` over `PQexec` is that parameter values can be separated from the command string, thus avoiding the need for tedious and error-prone quoting and escaping.

Unlike `PQexec`, `PQexecParams` allows at most one SQL command in the given string. (There can be semicolons in it, but not more than one nonempty command.) This is a limitation of the underlying protocol, but has some usefulness as an extra defense against SQL-injection attacks.

Tip

Specifying parameter types via OIDs is tedious, particularly if you prefer not to hard-wire particular OID values into your program. However, you can avoid doing so even in cases where the server by itself cannot determine the type of the parameter, or chooses a different type than you want. In the SQL command text, attach an explicit cast to the parameter symbol to show what data type you will send. For example:

```
SELECT * FROM mytable WHERE x = $1::bigint;
```

This forces parameter `$1` to be treated as `bigint`, whereas by default it would be assigned the same type as `x`. Forcing the parameter type decision, either this way or by specifying a numeric type OID, is strongly recommended when sending parameter values in binary format, because binary format has less redundancy than text format and so there is less chance that the server will detect a type mismatch mistake for you.

PQprepare

Submits a request to create a prepared statement with the given parameters, and waits for completion.

```
PGresult *PQprepare(PGconn *conn,
                   const char *stmtName,
                   const char *query,
                   int nParams,
                   const Oid *paramTypes);
```

`PQprepare` creates a prepared statement for later execution with `PQexecPrepared`. This feature allows commands to be executed repeatedly without being parsed and planned each time; see `PREPARE` for details. `PQprepare` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The function creates a prepared statement named `stmtName` from the `query` string, which must contain a single SQL command. `stmtName` can be "" to create an unnamed statement, in which case any pre-existing unnamed statement is automatically replaced; otherwise it is an error if the statement name is already defined in the current session. If any parameters are used, they are referred to in the query as `$1`, `$2`, etc. `nParams` is the number of parameters for which types are pre-specified in the array `paramTypes[]`. (The array pointer can be `NULL` when `nParams` is zero.) `paramTypes[]` specifies, by OID, the data types to be assigned to the parameter symbols. If `paramTypes` is `NULL`, or any particular element in the array is zero, the server assigns a data type to the parameter symbol in the same way it would do for an untyped literal string. Also, the query can use parameter symbols with numbers higher than `nParams`; data types will be inferred for these symbols as well. (See `PQdescribePrepared` for a means to find out what data types were inferred.)

As with `PQexec`, the result is normally a `PGresult` object whose contents indicate server-side success or failure. A null result indicates out-of-memory or inability to send the command at all. Use `PQerrorMessage` to get more information about such errors.

Prepared statements for use with `PQexecPrepared` can also be created by executing SQL `PREPARE` statements. Also, although there is no libpq function for deleting a prepared statement, the SQL `DEALLOCATE` statement can be used for that purpose.

PQexecPrepared

Sends a request to execute a prepared statement with given parameters, and waits for the result.

```
PGresult *PQexecPrepared(PGconn *conn,
                          const char *stmtName,
                          int nParams,
                          const char * const *paramValues,
                          const int *paramLengths,
                          const int *paramFormats,
                          int resultFormat);
```

`PQexecPrepared` is like `PQexecParams`, but the command to be executed is specified by naming a previously-prepared statement, instead of giving a query string. This feature allows commands that will be used repeatedly to be parsed and planned just once, rather than each time they are executed. The statement must have been prepared previously in the current session. `PQexecPrepared` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The parameters are identical to `PQexecParams`, except that the name of a prepared statement is given instead of a query string, and the `paramTypes[]` parameter is not present (it is not needed since the prepared statement's parameter types were determined when it was created).

PQdescribePrepared

Submits a request to obtain information about the specified prepared statement, and waits for completion.

```
PGresult *PQdescribePrepared(PGconn *conn, const char
                              *stmtName);
```

`PQdescribePrepared` allows an application to obtain information about a previously prepared statement. `PQdescribePrepared` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

`stmtName` can be "" or NULL to reference the unnamed statement, otherwise it must be the name of an existing prepared statement. On success, a `PGresult` with status `PGRES_COMMAND_OK` is returned. The functions `PQnparams` and `PQparamtype` can be applied to this `PGresult` to obtain information about the parameters of the prepared statement, and the functions `PQnfields`, `PQfname`, `PQftype`, etc provide information about the result columns (if any) of the statement.

PQdescribePortal

Submits a request to obtain information about the specified portal, and waits for completion.

```
PGresult *PQdescribePortal(PGconn *conn, const char
                            *portalName);
```

`PQdescribePortal` allows an application to obtain information about a previously created portal. (libpq does not provide any direct access to portals, but you can use this function to inspect the properties of a cursor created with a `DECLARE CURSOR SQL` command.) `PQdescribePortal` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

`portalName` can be "" or NULL to reference the unnamed portal, otherwise it must be the name of an existing portal. On success, a `PGresult` with status `PGRES_COMMAND_OK` is returned.

The functions `PQnfields`, `PQfname`, `PQftype`, etc can be applied to the `PGresult` to obtain information about the result columns (if any) of the portal.

The `PGresult` structure encapsulates the result returned by the server. libpq application programmers should be careful to maintain the `PGresult` abstraction. Use the accessor functions below to get at the contents of `PGresult`. Avoid directly referencing the fields of the `PGresult` structure because they are subject to change in the future.

`PQresultStatus`

Returns the result status of the command.

```
ExecStatusType PQresultStatus(const PGresult *res);
```

`PQresultStatus` can return one of the following values:

`PGRES_EMPTY_QUERY`

The string sent to the server was empty.

`PGRES_COMMAND_OK`

Successful completion of a command returning no data.

`PGRES_TUPLES_OK`

Successful completion of a command returning data (such as a `SELECT` or `SHOW`).

`PGRES_COPY_OUT`

Copy Out (from server) data transfer started.

`PGRES_COPY_IN`

Copy In (to server) data transfer started.

`PGRES_BAD_RESPONSE`

The server's response was not understood.

`PGRES_NONFATAL_ERROR`

A nonfatal error (a notice or warning) occurred.

`PGRES_FATAL_ERROR`

A fatal error occurred.

`PGRES_COPY_BOTH`

Copy In/Out (to and from server) data transfer started. This feature is currently used only for streaming replication, so this status should not occur in ordinary applications.

`PGRES_SINGLE_TUPLE`

The `PGresult` contains a single result tuple from the current command. This status occurs only when single-row mode has been selected for the query (see Section 33.5).

If the result status is `PGRES_TUPLES_OK` or `PGRES_SINGLE_TUPLE`, then the functions described below can be used to retrieve the rows returned by the query. Note that a `SELECT` command that happens to retrieve zero rows still shows `PGRES_TUPLES_OK`. `PGRES_COM-`

MAND_OK is for commands that can never return rows (INSERT or UPDATE without a RETURNING clause, etc.). A response of PGRES_EMPTY_QUERY might indicate a bug in the client software.

A result of status PGRES_NONFATAL_ERROR will never be returned directly by PQexec or other query execution functions; results of this kind are instead passed to the notice processor (see Section 33.12).

PQresStatus

Converts the enumerated type returned by PQresultStatus into a string constant describing the status code. The caller should not free the result.

```
char *PQresStatus(ExecStatusType status);
```

PQresultErrorMessage

Returns the error message associated with the command, or an empty string if there was no error.

```
char *PQresultErrorMessage(const PGresult *res);
```

If there was an error, the returned string will include a trailing newline. The caller should not free the result directly. It will be freed when the associated PGresult handle is passed to PQclear.

Immediately following a PQexec or PQgetResult call, PQerrorMessage (on the connection) will return the same string as PQresultErrorMessage (on the result). However, a PGresult will retain its error message until destroyed, whereas the connection's error message will change when subsequent operations are done. Use PQresultErrorMessage when you want to know the status associated with a particular PGresult; use PQerrorMessage when you want to know the status from the latest operation on the connection.

PQresultVerboseErrorMessage

Returns a reformatted version of the error message associated with a PGresult object.

```
char *PQresultVerboseErrorMessage(const PGresult *res,
                                  PGVerbosity verbosity,
                                  PGContextVisibility
                                  show_context);
```

In some situations a client might wish to obtain a more detailed version of a previously-reported error. PQresultVerboseErrorMessage addresses this need by computing the message that would have been produced by PQresultErrorMessage if the specified verbosity settings had been in effect for the connection when the given PGresult was generated. If the PGresult is not an error result, "PGresult is not an error result" is reported instead. The returned string includes a trailing newline.

Unlike most other functions for extracting data from a PGresult, the result of this function is a freshly allocated string. The caller must free it using PQfreemem() when the string is no longer needed.

A NULL return is possible if there is insufficient memory.

PQresultErrorField

Returns an individual field of an error report.

```
char *PQresultErrorField(const PGresult *res, int fieldcode);
```

fieldcode is an error field identifier; see the symbols listed below. NULL is returned if the PGresult is not an error or warning result, or does not include the specified field. Field values will normally not include a trailing newline. The caller should not free the result directly. It will be freed when the associated PGresult handle is passed to PQclear.

The following field codes are available:

PG_DIAG_SEVERITY

The severity; the field contents are ERROR, FATAL, or PANIC (in an error message), or WARNING, NOTICE, DEBUG, INFO, or LOG (in a notice message), or a localized translation of one of these. Always present.

PG_DIAG_SEVERITY_NONLOCALIZED

The severity; the field contents are ERROR, FATAL, or PANIC (in an error message), or WARNING, NOTICE, DEBUG, INFO, or LOG (in a notice message). This is identical to the PG_DIAG_SEVERITY field except that the contents are never localized. This is present only in reports generated by PostgreSQL versions 9.6 and later.

PG_DIAG_SQLSTATE

The SQLSTATE code for the error. The SQLSTATE code identifies the type of error that has occurred; it can be used by front-end applications to perform specific operations (such as error handling) in response to a particular database error. For a list of the possible SQLSTATE codes, see Appendix A. This field is not localizable, and is always present.

PG_DIAG_MESSAGE_PRIMARY

The primary human-readable error message (typically one line). Always present.

PG_DIAG_MESSAGE_DETAIL

Detail: an optional secondary error message carrying more detail about the problem. Might run to multiple lines.

PG_DIAG_MESSAGE_HINT

Hint: an optional suggestion what to do about the problem. This is intended to differ from detail in that it offers advice (potentially inappropriate) rather than hard facts. Might run to multiple lines.

PG_DIAG_STATEMENT_POSITION

A string containing a decimal integer indicating an error cursor position as an index into the original statement string. The first character has index 1, and positions are measured in characters not bytes.

PG_DIAG_INTERNAL_POSITION

This is defined the same as the PG_DIAG_STATEMENT_POSITION field, but it is used when the cursor position refers to an internally generated command rather than the one submitted by the client. The PG_DIAG_INTERNAL_QUERY field will always appear when this field appears.

PG_DIAG_INTERNAL_QUERY

The text of a failed internally-generated command. This could be, for example, a SQL query issued by a PL/pgSQL function.

PG_DIAG_CONTEXT

An indication of the context in which the error occurred. Presently this includes a call stack traceback of active procedural language functions and internally-generated queries. The trace is one entry per line, most recent first.

PG_DIAG_SCHEMA_NAME

If the error was associated with a specific database object, the name of the schema containing that object, if any.

PG_DIAG_TABLE_NAME

If the error was associated with a specific table, the name of the table. (Refer to the schema name field for the name of the table's schema.)

PG_DIAG_COLUMN_NAME

If the error was associated with a specific table column, the name of the column. (Refer to the schema and table name fields to identify the table.)

PG_DIAG_DATATYPE_NAME

If the error was associated with a specific data type, the name of the data type. (Refer to the schema name field for the name of the data type's schema.)

PG_DIAG_CONSTRAINT_NAME

If the error was associated with a specific constraint, the name of the constraint. Refer to fields listed above for the associated table or domain. (For this purpose, indexes are treated as constraints, even if they weren't created with constraint syntax.)

PG_DIAG_SOURCE_FILE

The file name of the source-code location where the error was reported.

PG_DIAG_SOURCE_LINE

The line number of the source-code location where the error was reported.

PG_DIAG_SOURCE_FUNCTION

The name of the source-code function reporting the error.

Note

The fields for schema name, table name, column name, data type name, and constraint name are supplied only for a limited number of error types; see Appendix A. Do not assume that the presence of any of these fields guarantees the presence of another field. Core error sources observe the interrelationships noted above, but user-defined functions may use these fields in other ways. In the same vein, do not assume that these fields denote contemporary objects in the current database.

The client is responsible for formatting displayed information to meet its needs; in particular it should break long lines as needed. Newline characters appearing in the error message fields should be treated as paragraph breaks, not line breaks.

Errors generated internally by libpq will have severity and primary message, but typically no other fields. Errors returned by a pre-3.0-protocol server will include severity and primary message, and sometimes a detail message, but no other fields.

Note that error fields are only available from `PGresult` objects, not `PGconn` objects; there is no `PQerrorMessage` function.

`PQclear`

Frees the storage associated with a `PGresult`. Every command result should be freed via `PQclear` when it is no longer needed.

```
void PQclear(PGresult *res);
```

You can keep a `PGresult` object around for as long as you need it; it does not go away when you issue a new command, nor even if you close the connection. To get rid of it, you must call `PQclear`. Failure to do this will result in memory leaks in your application.

33.3.2. Retrieving Query Result Information

These functions are used to extract information from a `PGresult` object that represents a successful query result (that is, one that has status `PGRES_TUPLES_OK` or `PGRES_SINGLE_TUPLE`). They can also be used to extract information from a successful Describe operation: a Describe's result has all the same column information that actual execution of the query would provide, but it has zero rows. For objects with other status values, these functions will act as though the result has zero rows and zero columns.

`PQntuples`

Returns the number of rows (tuples) in the query result. (Note that `PGresult` objects are limited to no more than `INT_MAX` rows, so an `int` result is sufficient.)

```
int PQntuples(const PGresult *res);
```

`PQnfields`

Returns the number of columns (fields) in each row of the query result.

```
int PQnfields(const PGresult *res);
```

`PQfname`

Returns the column name associated with the given column number. Column numbers start at 0. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

```
char *PQfname(const PGresult *res,  
              int column_number);
```

NULL is returned if the column number is out of range.

`PQfnumber`

Returns the column number associated with the given column name.

```
int PQfnumber(const PGresult *res,  
              const char *column_name);
```

-1 is returned if the given name does not match any column.

The given name is treated like an identifier in an SQL command, that is, it is downcased unless double-quoted. For example, given a query result generated from the SQL command:

```
SELECT 1 AS FOO, 2 AS "BAR";
```

we would have the results:

```
PQfname(res, 0)          foo
PQfname(res, 1)          BAR
PQfnumber(res, "FOO")    0
PQfnumber(res, "foo")    0
PQfnumber(res, "BAR")    -1
PQfnumber(res, "\"BAR\"") 1
```

PQftable

Returns the OID of the table from which the given column was fetched. Column numbers start at 0.

```
Oid PQftable(const PGresult *res,
             int column_number);
```

InvalidOid is returned if the column number is out of range, or if the specified column is not a simple reference to a table column, or when using pre-3.0 protocol. You can query the system table `pg_class` to determine exactly which table is referenced.

The type `Oid` and the constant `InvalidOid` will be defined when you include the libpq header file. They will both be some integer type.

PQftablecol

Returns the column number (within its table) of the column making up the specified query result column. Query-result column numbers start at 0, but table columns have nonzero numbers.

```
int PQftablecol(const PGresult *res,
                int column_number);
```

Zero is returned if the column number is out of range, or if the specified column is not a simple reference to a table column, or when using pre-3.0 protocol.

PQfformat

Returns the format code indicating the format of the given column. Column numbers start at 0.

```
int PQfformat(const PGresult *res,
              int column_number);
```

Format code zero indicates textual data representation, while format code one indicates binary representation. (Other codes are reserved for future definition.)

PQftype

Returns the data type associated with the given column number. The integer returned is the internal OID number of the type. Column numbers start at 0.

```
Oid PQftype(const PGresult *res,
            int column_number);
```

You can query the system table `pg_type` to obtain the names and properties of the various data types. The OIDs of the built-in data types are defined in the file `src/include/catalog/pg_type_d.h` in the source tree.

PQfmod

Returns the type modifier of the column associated with the given column number. Column numbers start at 0.

```
int PQfmod(const PGresult *res,
           int column_number);
```

The interpretation of modifier values is type-specific; they typically indicate precision or size limits. The value -1 is used to indicate “no information available”. Most data types do not use modifiers, in which case the value is always -1.

PQfsize

Returns the size in bytes of the column associated with the given column number. Column numbers start at 0.

```
int PQfsize(const PGresult *res,
            int column_number);
```

`PQfsize` returns the space allocated for this column in a database row, in other words the size of the server's internal representation of the data type. (Accordingly, it is not really very useful to clients.) A negative value indicates the data type is variable-length.

PQbinaryTuples

Returns 1 if the `PGresult` contains binary data and 0 if it contains text data.

```
int PQbinaryTuples(const PGresult *res);
```

This function is deprecated (except for its use in connection with `COPY`), because it is possible for a single `PGresult` to contain text data in some columns and binary data in others. `PQfformat` is preferred. `PQbinaryTuples` returns 1 only if all columns of the result are binary (format 1).

PQgetvalue

Returns a single field value of one row of a `PGresult`. Row and column numbers start at 0. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

```
char *PQgetvalue(const PGresult *res,
                 int row_number,
                 int column_number);
```

For data in text format, the value returned by `PQgetvalue` is a null-terminated character string representation of the field value. For data in binary format, the value is in the binary representation determined by the data type's `typsend` and `typreceive` functions. (The value is actually followed by a zero byte in this case too, but that is not ordinarily useful, since the value is likely to contain embedded nulls.)

An empty string is returned if the field value is null. See `PQgetisnull` to distinguish null values from empty-string values.

The pointer returned by `PQgetvalue` points to storage that is part of the `PGresult` structure. One should not modify the data it points to, and one must explicitly copy the data into other storage if it is to be used past the lifetime of the `PGresult` structure itself.

`PQgetisnull`

Tests a field for a null value. Row and column numbers start at 0.

```
int PQgetisnull(const PGresult *res,
               int row_number,
               int column_number);
```

This function returns 1 if the field is null and 0 if it contains a non-null value. (Note that `PQgetvalue` will return an empty string, not a null pointer, for a null field.)

`PQgetlength`

Returns the actual length of a field value in bytes. Row and column numbers start at 0.

```
int PQgetlength(const PGresult *res,
               int row_number,
               int column_number);
```

This is the actual data length for the particular data value, that is, the size of the object pointed to by `PQgetvalue`. For text data format this is the same as `strlen()`. For binary format this is essential information. Note that one should *not* rely on `PQfsize` to obtain the actual data length.

`PQnparams`

Returns the number of parameters of a prepared statement.

```
int PQnparams(const PGresult *res);
```

This function is only useful when inspecting the result of `PQdescribePrepared`. For other types of queries it will return zero.

`PQparamtype`

Returns the data type of the indicated statement parameter. Parameter numbers start at 0.

```
Oid PQparamtype(const PGresult *res, int param_number);
```

This function is only useful when inspecting the result of `PQdescribePrepared`. For other types of queries it will return zero.

`PQprint`

Prints out all the rows and, optionally, the column names to the specified output stream.

```
void PQprint(FILE *fout,          /* output stream */
             const PGresult *res,
```

```

        const PQprintOpt *po);
typedef struct
{
    pqbool  header;      /* print output field headings and row
count */
    pqbool  align;      /* fill align the fields */
    pqbool  standard;   /* old brain dead format */
    pqbool  html3;     /* output HTML tables */
    pqbool  expanded;   /* expand tables */
    pqbool  pager;     /* use pager for output if needed */
    char    *fieldSep;  /* field separator */
    char    *tableOpt;  /* attributes for HTML table element */
    char    *caption;   /* HTML table caption */
    char    **fieldName; /* null-terminated array of replacement
field names */
} PQprintOpt;

```

This function was formerly used by `psql` to print query results, but this is no longer the case. Note that it assumes all the data is in text format.

33.3.3. Retrieving Other Result Information

These functions are used to extract other information from `PGresult` objects.

`PQcmdStatus`

Returns the command status tag from the SQL command that generated the `PGresult`.

```
char *PQcmdStatus(PGresult *res);
```

Commonly this is just the name of the command, but it might include additional data such as the number of rows processed. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

`PQcmdTuples`

Returns the number of rows affected by the SQL command.

```
char *PQcmdTuples(PGresult *res);
```

This function returns a string containing the number of rows affected by the SQL statement that generated the `PGresult`. This function can only be used following the execution of a `SELECT`, `CREATE TABLE AS`, `INSERT`, `UPDATE`, `DELETE`, `MOVE`, `FETCH`, or `COPY` statement, or an `EXECUTE` of a prepared query that contains an `INSERT`, `UPDATE`, or `DELETE` statement. If the command that generated the `PGresult` was anything else, `PQcmdTuples` returns an empty string. The caller should not free the return value directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

`PQoidValue`

Returns the OID of the inserted row, if the SQL command was an `INSERT` that inserted exactly one row into a table that has OIDs, or a `EXECUTE` of a prepared query containing a suitable `INSERT` statement. Otherwise, this function returns `InvalidOid`. This function will also return `InvalidOid` if the table affected by the `INSERT` statement does not contain OIDs.

```
Oid PQoidValue(const PGresult *res);
```

`PQoidStatus`

This function is deprecated in favor of `PQoidValue` and is not thread-safe. It returns a string with the OID of the inserted row, while `PQoidValue` returns the OID value.

```
char *PQoidStatus(const PGresult *res);
```

33.3.4. Escaping Strings for Inclusion in SQL Commands

`PQescapeLiteral`

```
char *PQescapeLiteral(PGconn *conn, const char *str, size_t
    length);
```

`PQescapeLiteral` escapes a string for use within an SQL command. This is useful when inserting data values as literal constants in SQL commands. Certain characters (such as quotes and backslashes) must be escaped to prevent them from being interpreted specially by the SQL parser. `PQescapeLiteral` performs this operation.

`PQescapeLiteral` returns an escaped version of the `str` parameter in memory allocated with `malloc()`. This memory should be freed using `PQfreemem()` when the result is no longer needed. A terminating zero byte is not required, and should not be counted in `length`. (If a terminating zero byte is found before `length` bytes are processed, `PQescapeLiteral` stops at the zero; the behavior is thus rather like `strncpy`.) The return string has all special characters replaced so that they can be properly processed by the PostgreSQL string literal parser. A terminating zero byte is also added. The single quotes that must surround PostgreSQL string literals are included in the result string.

On error, `PQescapeLiteral` returns NULL and a suitable message is stored in the `conn` object.

Tip

It is especially important to do proper escaping when handling strings that were received from an untrustworthy source. Otherwise there is a security risk: you are vulnerable to “SQL injection” attacks wherein unwanted SQL commands are fed to your database.

Note that it is neither necessary nor correct to do escaping when a data value is passed as a separate parameter in `PQexecParams` or its sibling routines.

`PQescapeIdentifier`

```
char *PQescapeIdentifier(PGconn *conn, const char *str, size_t
    length);
```

`PQescapeIdentifier` escapes a string for use as an SQL identifier, such as a table, column, or function name. This is useful when a user-supplied identifier might contain special characters that would otherwise not be interpreted as part of the identifier by the SQL parser, or when the identifier might contain upper case characters whose case should be preserved.

`PQescapeIdentifier` returns a version of the `str` parameter escaped as an SQL identifier in memory allocated with `malloc()`. This memory must be freed using `PQfreemem()` when the result is no longer needed. A terminating zero byte is not required, and should not be counted in

length. (If a terminating zero byte is found before *length* bytes are processed, `PQescapeIdentifier` stops at the zero; the behavior is thus rather like `strncpy`.) The return string has all special characters replaced so that it will be properly processed as an SQL identifier. A terminating zero byte is also added. The return string will also be surrounded by double quotes.

On error, `PQescapeIdentifier` returns NULL and a suitable message is stored in the *conn* object.

Tip

As with string literals, to prevent SQL injection attacks, SQL identifiers must be escaped when they are received from an untrustworthy source.

`PQescapeStringConn`

```
size_t PQescapeStringConn(PGconn *conn,
                          char *to, const char *from, size_t
                          length,
                          int *error);
```

`PQescapeStringConn` escapes string literals, much like `PQescapeLiteral`. Unlike `PQescapeLiteral`, the caller is responsible for providing an appropriately sized buffer. Furthermore, `PQescapeStringConn` does not generate the single quotes that must surround PostgreSQL string literals; they should be provided in the SQL command that the result is inserted into. The parameter *from* points to the first character of the string that is to be escaped, and the *length* parameter gives the number of bytes in this string. A terminating zero byte is not required, and should not be counted in *length*. (If a terminating zero byte is found before *length* bytes are processed, `PQescapeStringConn` stops at the zero; the behavior is thus rather like `strncpy`.) *to* shall point to a buffer that is able to hold at least one more byte than twice the value of *length*, otherwise the behavior is undefined. Behavior is likewise undefined if the *to* and *from* strings overlap.

If the *error* parameter is not NULL, then **error* is set to zero on success, nonzero on error. Presently the only possible error conditions involve invalid multibyte encoding in the source string. The output string is still generated on error, but it can be expected that the server will reject it as malformed. On error, a suitable message is stored in the *conn* object, whether or not *error* is NULL.

`PQescapeStringConn` returns the number of bytes written to *to*, not including the terminating zero byte.

`PQescapeString`

`PQescapeString` is an older, deprecated version of `PQescapeStringConn`.

```
size_t PQescapeString(char *to, const char *from, size_t
                     length);
```

The only difference from `PQescapeStringConn` is that `PQescapeString` does not take *PGconn* or *error* parameters. Because of this, it cannot adjust its behavior depending on the connection properties (such as character encoding) and therefore *it might give the wrong results*. Also, it has no way to report error conditions.

`PQescapeString` can be used safely in client programs that work with only one PostgreSQL connection at a time (in this case it can find out what it needs to know “behind the scenes”). In other contexts it is a security hazard and should be avoided in favor of `PQescapeStringConn`.

PQescapeByteaConn

Escapes binary data for use within an SQL command with the type `bytea`. As with `PQescapeStringConn`, this is only used when inserting data directly into an SQL command string.

```
unsigned char *PQescapeByteaConn(PGconn *conn,
                                  const unsigned char *from,
                                  size_t from_length,
                                  size_t *to_length);
```

Certain byte values must be escaped when used as part of a `bytea` literal in an SQL statement. `PQescapeByteaConn` escapes bytes using either hex encoding or backslash escaping. See Section 8.4 for more information.

The `from` parameter points to the first byte of the string that is to be escaped, and the `from_length` parameter gives the number of bytes in this binary string. (A terminating zero byte is neither necessary nor counted.) The `to_length` parameter points to a variable that will hold the resultant escaped string length. This result string length includes the terminating zero byte of the result.

`PQescapeByteaConn` returns an escaped version of the `from` parameter binary string in memory allocated with `malloc()`. This memory should be freed using `PQfreemem()` when the result is no longer needed. The return string has all special characters replaced so that they can be properly processed by the PostgreSQL string literal parser, and the `bytea` input function. A terminating zero byte is also added. The single quotes that must surround PostgreSQL string literals are not part of the result string.

On error, a null pointer is returned, and a suitable error message is stored in the `conn` object. Currently, the only possible error is insufficient memory for the result string.

PQescapeBytea

`PQescapeBytea` is an older, deprecated version of `PQescapeByteaConn`.

```
unsigned char *PQescapeBytea(const unsigned char *from,
                              size_t from_length,
                              size_t *to_length);
```

The only difference from `PQescapeByteaConn` is that `PQescapeBytea` does not take a `PGconn` parameter. Because of this, `PQescapeBytea` can only be used safely in client programs that use a single PostgreSQL connection at a time (in this case it can find out what it needs to know “behind the scenes”). It *might give the wrong results* if used in programs that use multiple database connections (use `PQescapeByteaConn` in such cases).

PQunescapeBytea

Converts a string representation of binary data into binary data — the reverse of `PQescapeBytea`. This is needed when retrieving `bytea` data in text format, but not when retrieving it in binary format.

```
unsigned char *PQunescapeBytea(const unsigned char *from, size_t
                                *to_length);
```

The `from` parameter points to a string such as might be returned by `PQgetvalue` when applied to a `bytea` column. `PQunescapeBytea` converts this string representation into its binary representation. It returns a pointer to a buffer allocated with `malloc()`, or `NULL` on error, and puts

the size of the buffer in *to_length*. The result must be freed using `PQfreemem` when it is no longer needed.

This conversion is not exactly the inverse of `PQescapeBytea`, because the string is not expected to be “escaped” when received from `PQgetvalue`. In particular this means there is no need for string quoting considerations, and so no need for a `PGconn` parameter.

33.4. Asynchronous Command Processing

The `PQexec` function is adequate for submitting commands in normal, synchronous applications. It has a few deficiencies, however, that can be of importance to some users:

- `PQexec` waits for the command to be completed. The application might have other work to do (such as maintaining a user interface), in which case it won't want to block waiting for the response.
- Since the execution of the client application is suspended while it waits for the result, it is hard for the application to decide that it would like to try to cancel the ongoing command. (It can be done from a signal handler, but not otherwise.)
- `PQexec` can return only one `PGresult` structure. If the submitted command string contains multiple SQL commands, all but the last `PGresult` are discarded by `PQexec`.
- `PQexec` always collects the command's entire result, buffering it in a single `PGresult`. While this simplifies error-handling logic for the application, it can be impractical for results containing many rows.

Applications that do not like these limitations can instead use the underlying functions that `PQexec` is built from: `PQsendQuery` and `PQgetResult`. There are also `PQsendQueryParams`, `PQsendPrepare`, `PQsendQueryPrepared`, `PQsendDescribePrepared`, and `PQsendDescribePortal`, which can be used with `PQgetResult` to duplicate the functionality of `PQexecParams`, `PQprepare`, `PQexecPrepared`, `PQdescribePrepared`, and `PQdescribePortal` respectively.

`PQsendQuery`

Submits a command to the server without waiting for the result(s). 1 is returned if the command was successfully dispatched and 0 if not (in which case, use `PQerrorMessage` to get more information about the failure).

```
int PQsendQuery(PGconn *conn, const char *command);
```

After successfully calling `PQsendQuery`, call `PQgetResult` one or more times to obtain the results. `PQsendQuery` cannot be called again (on the same connection) until `PQgetResult` has returned a null pointer, indicating that the command is done.

`PQsendQueryParams`

Submits a command and separate parameters to the server without waiting for the result(s).

```
int PQsendQueryParams(PGconn *conn,
                     const char *command,
                     int nParams,
                     const Oid *paramTypes,
                     const char * const *paramValues,
                     const int *paramLengths,
                     const int *paramFormats,
```

```
int resultFormat);
```

This is equivalent to `PQsendQuery` except that query parameters can be specified separately from the query string. The function's parameters are handled identically to `PQexecParams`. Like `PQexecParams`, it will not work on 2.0-protocol connections, and it allows only one command in the query string.

`PQsendPrepare`

Sends a request to create a prepared statement with the given parameters, without waiting for completion.

```
int PQsendPrepare(PGconn *conn,
                 const char *stmtName,
                 const char *query,
                 int nParams,
                 const Oid *paramTypes);
```

This is an asynchronous version of `PQprepare`: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call `PQgetResult` to determine whether the server successfully created the prepared statement. The function's parameters are handled identically to `PQprepare`. Like `PQprepare`, it will not work on 2.0-protocol connections.

`PQsendQueryPrepared`

Sends a request to execute a prepared statement with given parameters, without waiting for the result(s).

```
int PQsendQueryPrepared(PGconn *conn,
                       const char *stmtName,
                       int nParams,
                       const char * const *paramValues,
                       const int *paramLengths,
                       const int *paramFormats,
                       int resultFormat);
```

This is similar to `PQsendQueryParams`, but the command to be executed is specified by naming a previously-prepared statement, instead of giving a query string. The function's parameters are handled identically to `PQexecPrepared`. Like `PQexecPrepared`, it will not work on 2.0-protocol connections.

`PQsendDescribePrepared`

Submits a request to obtain information about the specified prepared statement, without waiting for completion.

```
int PQsendDescribePrepared(PGconn *conn, const char *stmtName);
```

This is an asynchronous version of `PQdescribePrepared`: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call `PQgetResult` to obtain the results. The function's parameters are handled identically to `PQdescribePrepared`. Like `PQdescribePrepared`, it will not work on 2.0-protocol connections.

`PQsendDescribePortal`

Submits a request to obtain information about the specified portal, without waiting for completion.

```
int PQsendDescribePortal(PGconn *conn, const char *portalName);
```

This is an asynchronous version of `PQdescribePortal`: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call `PQgetResult` to obtain the results. The function's parameters are handled identically to `PQdescribePortal`. Like `PQdescribePortal`, it will not work on 2.0-protocol connections.

`PQgetResult`

Waits for the next result from a prior `PQsendQuery`, `PQsendQueryParams`, `PQsendPrepare`, `PQsendQueryPrepared`, `PQsendDescribePrepared`, or `PQsendDescribePortal` call, and returns it. A null pointer is returned when the command is complete and there will be no more results.

```
PGresult *PQgetResult(PGconn *conn);
```

`PQgetResult` must be called repeatedly until it returns a null pointer, indicating that the command is done. (If called when no command is active, `PQgetResult` will just return a null pointer at once.) Each non-null result from `PQgetResult` should be processed using the same `PGresult` accessor functions previously described. Don't forget to free each result object with `PQclear` when done with it. Note that `PQgetResult` will block only if a command is active and the necessary response data has not yet been read by `PQconsumeInput`.

Note

Even when `PQresultStatus` indicates a fatal error, `PQgetResult` should be called until it returns a null pointer, to allow libpq to process the error information completely.

Using `PQsendQuery` and `PQgetResult` solves one of `PQexec`'s problems: If a command string contains multiple SQL commands, the results of those commands can be obtained individually. (This allows a simple form of overlapped processing, by the way: the client can be handling the results of one command while the server is still working on later queries in the same command string.)

Another frequently-desired feature that can be obtained with `PQsendQuery` and `PQgetResult` is retrieving large query results a row at a time. This is discussed in Section 33.5.

By itself, calling `PQgetResult` will still cause the client to block until the server completes the next SQL command. This can be avoided by proper use of two more functions:

`PQconsumeInput`

If input is available from the server, consume it.

```
int PQconsumeInput(PGconn *conn);
```

`PQconsumeInput` normally returns 1 indicating “no error”, but returns 0 if there was some kind of trouble (in which case `PQerrorMessage` can be consulted). Note that the result does not say whether any input data was actually collected. After calling `PQconsumeInput`, the application can check `PQisBusy` and/or `PQnotifies` to see if their state has changed.

`PQconsumeInput` can be called even if the application is not prepared to deal with a result or notification just yet. The function will read available data and save it in a buffer, thereby causing a `select()` read-ready indication to go away. The application can thus use `PQconsumeInput` to clear the `select()` condition immediately, and then examine the results at leisure.

PQisBusy

Returns 1 if a command is busy, that is, `PQgetResult` would block waiting for input. A 0 return indicates that `PQgetResult` can be called with assurance of not blocking.

```
int PQisBusy(PGconn *conn);
```

`PQisBusy` will not itself attempt to read data from the server; therefore `PQconsumeInput` must be invoked first, or the busy state will never end.

A typical application using these functions will have a main loop that uses `select()` or `poll()` to wait for all the conditions that it must respond to. One of the conditions will be input available from the server, which in terms of `select()` means readable data on the file descriptor identified by `PQsocket`. When the main loop detects input ready, it should call `PQconsumeInput` to read the input. It can then call `PQisBusy`, followed by `PQgetResult` if `PQisBusy` returns false (0). It can also call `PQnotifies` to detect NOTIFY messages (see Section 33.8).

A client that uses `PQsendQuery/PQgetResult` can also attempt to cancel a command that is still being processed by the server; see Section 33.6. But regardless of the return value of `PQcancel`, the application must continue with the normal result-reading sequence using `PQgetResult`. A successful cancellation will simply cause the command to terminate sooner than it would have otherwise.

By using the functions described above, it is possible to avoid blocking while waiting for input from the database server. However, it is still possible that the application will block waiting to send output to the server. This is relatively uncommon but can happen if very long SQL commands or data values are sent. (It is much more probable if the application sends data via `COPY IN`, however.) To prevent this possibility and achieve completely nonblocking database operation, the following additional functions can be used.

PQsetnonblocking

Sets the nonblocking status of the connection.

```
int PQsetnonblocking(PGconn *conn, int arg);
```

Sets the state of the connection to nonblocking if `arg` is 1, or blocking if `arg` is 0. Returns 0 if OK, -1 if error.

In the nonblocking state, calls to `PQsendQuery`, `PQputline`, `PQputnbytes`, `PQputCopyData`, and `PQendcopy` will not block but instead return an error if they need to be called again.

Note that `PQexec` does not honor nonblocking mode; if it is called, it will act in blocking fashion anyway.

PQisnonblocking

Returns the blocking status of the database connection.

```
int PQisnonblocking(const PGconn *conn);
```

Returns 1 if the connection is set to nonblocking mode and 0 if blocking.

PQflush

Attempts to flush any queued output data to the server. Returns 0 if successful (or if the send queue is empty), -1 if it failed for some reason, or 1 if it was unable to send all the data in the send queue yet (this case can only occur if the connection is nonblocking).

```
int PQflush(PGconn *conn);
```

After sending any command or data on a nonblocking connection, call `PQflush`. If it returns 1, wait for the socket to become read- or write-ready. If it becomes write-ready, call `PQflush` again. If it becomes read-ready, call `PQconsumeInput`, then call `PQflush` again. Repeat until `PQflush` returns 0. (It is necessary to check for read-ready and drain the input with `PQconsumeInput`, because the server can block trying to send us data, e.g. NOTICE messages, and won't read our data until we read its.) Once `PQflush` returns 0, wait for the socket to be read-ready and then read the response as described above.

33.5. Retrieving Query Results Row-by-Row

Ordinarily, libpq collects a SQL command's entire result and returns it to the application as a single `PGresult`. This can be unworkable for commands that return a large number of rows. For such cases, applications can use `PQsendQuery` and `PQgetResult` in *single-row mode*. In this mode, the result row(s) are returned to the application one at a time, as they are received from the server.

To enter single-row mode, call `PQsetSingleRowMode` immediately after a successful call of `PQsendQuery` (or a sibling function). This mode selection is effective only for the currently executing query. Then call `PQgetResult` repeatedly, until it returns null, as documented in Section 33.4. If the query returns any rows, they are returned as individual `PGresult` objects, which look like normal query results except for having status code `PGRES_SINGLE_TUPLE` instead of `PGRES_TUPLES_OK`. After the last row, or immediately if the query returns zero rows, a zero-row object with status `PGRES_TUPLES_OK` is returned; this is the signal that no more rows will arrive. (But note that it is still necessary to continue calling `PQgetResult` until it returns null.) All of these `PGresult` objects will contain the same row description data (column names, types, etc) that an ordinary `PGresult` object for the query would have. Each object should be freed with `PQclear` as usual.

```
PQsetSingleRowMode
```

Select single-row mode for the currently-executing query.

```
int PQsetSingleRowMode(PGconn *conn);
```

This function can only be called immediately after `PQsendQuery` or one of its sibling functions, before any other operation on the connection such as `PQconsumeInput` or `PQgetResult`. If called at the correct time, the function activates single-row mode for the current query and returns 1. Otherwise the mode stays unchanged and the function returns 0. In any case, the mode reverts to normal after completion of the current query.

Caution

While processing a query, the server may return some rows and then encounter an error, causing the query to be aborted. Ordinarily, libpq discards any such rows and reports only the error. But in single-row mode, those rows will have already been returned to the application. Hence, the application will see some `PGRES_SINGLE_TUPLE` `PGresult` objects followed by a `PGRES_FATAL_ERROR` object. For proper transactional behavior, the application must be designed to discard or undo whatever has been done with the previously-processed rows, if the query ultimately fails.

33.6. Canceling Queries in Progress

A client application can request cancellation of a command that is still being processed by the server, using the functions described in this section.

PQgetCancel

Creates a data structure containing the information needed to cancel a command issued through a particular database connection.

```
PGcancel *PQgetCancel(PGconn *conn);
```

`PQgetCancel` creates a `PGcancel` object given a `PGconn` connection object. It will return `NULL` if the given `conn` is `NULL` or an invalid connection. The `PGcancel` object is an opaque structure that is not meant to be accessed directly by the application; it can only be passed to `PQcancel` or `PQfreeCancel`.

PQfreeCancel

Frees a data structure created by `PQgetCancel`.

```
void PQfreeCancel(PGcancel *cancel);
```

`PQfreeCancel` frees a data object previously created by `PQgetCancel`.

PQcancel

Requests that the server abandon processing of the current command.

```
int PQcancel(PGcancel *cancel, char *errbuf, int errbufsize);
```

The return value is 1 if the cancel request was successfully dispatched and 0 if not. If not, `errbuf` is filled with an explanatory error message. `errbuf` must be a char array of size `errbufsize` (the recommended size is 256 bytes).

Successful dispatch is no guarantee that the request will have any effect, however. If the cancellation is effective, the current command will terminate early and return an error result. If the cancellation fails (say, because the server was already done processing the command), then there will be no visible result at all.

`PQcancel` can safely be invoked from a signal handler, if the `errbuf` is a local variable in the signal handler. The `PGcancel` object is read-only as far as `PQcancel` is concerned, so it can also be invoked from a thread that is separate from the one manipulating the `PGconn` object.

PQrequestCancel

`PQrequestCancel` is a deprecated variant of `PQcancel`.

```
int PQrequestCancel(PGconn *conn);
```

Requests that the server abandon processing of the current command. It operates directly on the `PGconn` object, and in case of failure stores the error message in the `PGconn` object (whence it can be retrieved by `PQerrorMessage`). Although the functionality is the same, this approach creates hazards for multiple-thread programs and signal handlers, since it is possible that overwriting the `PGconn`'s error message will mess up the operation currently in progress on the connection.

33.7. The Fast-Path Interface

PostgreSQL provides a fast-path interface to send simple function calls to the server.

Tip

This interface is somewhat obsolete, as one can achieve similar performance and greater functionality by setting up a prepared statement to define the function call. Then, executing the statement with binary transmission of parameters and results substitutes for a fast-path function call.

The function `PQfn` requests execution of a server function via the fast-path interface:

```
PGresult *PQfn(PGconn *conn,
              int fnid,
              int *result_buf,
              int *result_len,
              int result_is_int,
              const PQArgBlock *args,
              int nargs);
```

```
typedef struct
{
    int len;
    int isint;
    union
    {
        int *ptr;
        int integer;
    } u;
} PQArgBlock;
```

The `fnid` argument is the OID of the function to be executed. `args` and `nargs` define the parameters to be passed to the function; they must match the declared function argument list. When the `isint` field of a parameter structure is true, the `u.integer` value is sent to the server as an integer of the indicated length (this must be 2 or 4 bytes); proper byte-swapping occurs. When `isint` is false, the indicated number of bytes at `*u.ptr` are sent with no processing; the data must be in the format expected by the server for binary transmission of the function's argument data type. (The declaration of `u.ptr` as being of type `int *` is historical; it would be better to consider it `void *`.) `result_buf` points to the buffer in which to place the function's return value. The caller must have allocated sufficient space to store the return value. (There is no check!) The actual result length in bytes will be returned in the integer pointed to by `result_len`. If a 2- or 4-byte integer result is expected, set `result_is_int` to 1, otherwise set it to 0. Setting `result_is_int` to 1 causes libpq to byte-swap the value if necessary, so that it is delivered as a proper `int` value for the client machine; note that a 4-byte integer is delivered into `*result_buf` for either allowed result size. When `result_is_int` is 0, the binary-format byte string sent by the server is returned unmodified. (In this case it's better to consider `result_buf` as being of type `void *`.)

`PQfn` always returns a valid `PGresult` pointer. The result status should be checked before the result is used. The caller is responsible for freeing the `PGresult` with `PQclear` when it is no longer needed.

Note that it is not possible to handle null arguments, null results, nor set-valued results when using this interface.

33.8. Asynchronous Notification

PostgreSQL offers asynchronous notification via the `LISTEN` and `NOTIFY` commands. A client session registers its interest in a particular notification channel with the `LISTEN` command (and can stop

listening with the `UNLISTEN` command). All sessions listening on a particular channel will be notified asynchronously when a `NOTIFY` command with that channel name is executed by any session. A “payload” string can be passed to communicate additional data to the listeners.

libpq applications submit `LISTEN`, `UNLISTEN`, and `NOTIFY` commands as ordinary SQL commands. The arrival of `NOTIFY` messages can subsequently be detected by calling `PQnotifies`.

The function `PQnotifies` returns the next notification from a list of unhandled notification messages received from the server. It returns a null pointer if there are no pending notifications. Once a notification is returned from `PQnotifies`, it is considered handled and will be removed from the list of notifications.

```
PGnotify *PQnotifies(PGconn *conn);

typedef struct pgNotify
{
    char *relname;           /* notification channel name */
    int be_pid;             /* process ID of notifying server
    process */
    char *extra;            /* notification payload string */
} PGnotify;
```

After processing a `PGnotify` object returned by `PQnotifies`, be sure to free it with `PQfreemem`. It is sufficient to free the `PGnotify` pointer; the `relname` and `extra` fields do not represent separate allocations. (The names of these fields are historical; in particular, channel names need not have anything to do with relation names.)

Example 33.2 gives a sample program that illustrates the use of asynchronous notification.

`PQnotifies` does not actually read data from the server; it just returns messages previously absorbed by another libpq function. In ancient releases of libpq, the only way to ensure timely receipt of `NOTIFY` messages was to constantly submit commands, even empty ones, and then check `PQnotifies` after each `PQexec`. While this still works, it is deprecated as a waste of processing power.

A better way to check for `NOTIFY` messages when you have no useful commands to execute is to call `PQconsumeInput`, then check `PQnotifies`. You can use `select()` to wait for data to arrive from the server, thereby using no CPU power unless there is something to do. (See `PQsocket` to obtain the file descriptor number to use with `select()`.) Note that this will work OK whether you submit commands with `PQsendQuery/PQgetResult` or simply use `PQexec`. You should, however, remember to check `PQnotifies` after each `PQgetResult` or `PQexec`, to see if any notifications came in during the processing of the command.

33.9. Functions Associated with the COPY Command

The `COPY` command in PostgreSQL has options to read from or write to the network connection used by libpq. The functions described in this section allow applications to take advantage of this capability by supplying or consuming copied data.

The overall process is that the application first issues the SQL `COPY` command via `PQexec` or one of the equivalent functions. The response to this (if there is no error in the command) will be a `PGresult` object bearing a status code of `PGRES_COPY_OUT` or `PGRES_COPY_IN` (depending on the specified copy direction). The application should then use the functions of this section to receive or transmit data rows. When the data transfer is complete, another `PGresult` object is returned to indicate success or failure of the transfer. Its status will be `PGRES_COMMAND_OK` for success or `PGRES_FATAL_ERROR` if some problem was encountered. At this point further SQL commands can

be issued via `PQexec`. (It is not possible to execute other SQL commands using the same connection while the COPY operation is in progress.)

If a COPY command is issued via `PQexec` in a string that could contain additional commands, the application must continue fetching results via `PQgetResult` after completing the COPY sequence. Only when `PQgetResult` returns NULL is it certain that the `PQexec` command string is done and it is safe to issue more commands.

The functions of this section should be executed only after obtaining a result status of `PGRES_COPY_OUT` or `PGRES_COPY_IN` from `PQexec` or `PQgetResult`.

A `PGresult` object bearing one of these status values carries some additional data about the COPY operation that is starting. This additional data is available using functions that are also used in connection with query results:

`PQnfields`

Returns the number of columns (fields) to be copied.

`PQbinaryTuples`

0 indicates the overall copy format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary. See COPY for more information.

`PQfformat`

Returns the format code (0 for text, 1 for binary) associated with each column of the copy operation. The per-column format codes will always be zero when the overall copy format is textual, but the binary format can support both text and binary columns. (However, as of the current implementation of COPY, only binary columns appear in a binary copy; so the per-column formats always match the overall format at present.)

Note

These additional data values are only available when using protocol 3.0. When using protocol 2.0, all these functions will return 0.

33.9.1. Functions for Sending COPY Data

These functions are used to send data during COPY FROM STDIN. They will fail if called when the connection is not in COPY_IN state.

`PQputCopyData`

Sends data to the server during COPY_IN state.

```
int PQputCopyData(PGconn *conn,
                  const char *buffer,
                  int nbytes);
```

Transmits the COPY data in the specified *buffer*, of length *nbytes*, to the server. The result is 1 if the data was queued, zero if it was not queued because of full buffers (this will only happen in nonblocking mode), or -1 if an error occurred. (Use `PQerrorMessage` to retrieve details if the return value is -1. If the value is zero, wait for write-ready and try again.)

The application can divide the COPY data stream into buffer loads of any convenient size. Buffer-load boundaries have no semantic significance when sending. The contents of the data stream must match the data format expected by the COPY command; see COPY for details.

PQputCopyEnd

Sends end-of-data indication to the server during COPY_IN state.

```
int PQputCopyEnd(PGconn *conn,
                 const char *errmsg);
```

Ends the COPY_IN operation successfully if *errmsg* is NULL. If *errmsg* is not NULL then the COPY is forced to fail, with the string pointed to by *errmsg* used as the error message. (One should not assume that this exact error message will come back from the server, however, as the server might have already failed the COPY for its own reasons. Also note that the option to force failure does not work when using pre-3.0-protocol connections.)

The result is 1 if the termination message was sent; or in nonblocking mode, this may only indicate that the termination message was successfully queued. (In nonblocking mode, to be certain that the data has been sent, you should next wait for write-ready and call PQflush, repeating until it returns zero.) Zero indicates that the function could not queue the termination message because of full buffers; this will only happen in nonblocking mode. (In this case, wait for write-ready and try the PQputCopyEnd call again.) If a hard error occurs, -1 is returned; you can use PQerrorMessage to retrieve details.

After successfully calling PQputCopyEnd, call PQgetResult to obtain the final result status of the COPY command. One can wait for this result to be available in the usual way. Then return to normal operation.

33.9.2. Functions for Receiving COPY Data

These functions are used to receive data during COPY TO STDOUT. They will fail if called when the connection is not in COPY_OUT state.

PQgetCopyData

Receives data from the server during COPY_OUT state.

```
int PQgetCopyData(PGconn *conn,
                  char **buffer,
                  int async);
```

Attempts to obtain another row of data from the server during a COPY. Data is always returned one data row at a time; if only a partial row is available, it is not returned. Successful return of a data row involves allocating a chunk of memory to hold the data. The *buffer* parameter must be non-NULL. **buffer* is set to point to the allocated memory, or to NULL in cases where no buffer is returned. A non-NULL result buffer should be freed using PQfreemem when no longer needed.

When a row is successfully returned, the return value is the number of data bytes in the row (this will always be greater than zero). The returned string is always null-terminated, though this is probably only useful for textual COPY. A result of zero indicates that the COPY is still in progress, but no row is yet available (this is only possible when *async* is true). A result of -1 indicates that the COPY is done. A result of -2 indicates that an error occurred (consult PQerrorMessage for the reason).

When *async* is true (not zero), PQgetCopyData will not block waiting for input; it will return zero if the COPY is still in progress but no complete row is available. (In this case wait for read-

ready and then call `PQconsumeInput` before calling `PQgetCopyData` again.) When `async` is false (zero), `PQgetCopyData` will block until data is available or the operation completes.

After `PQgetCopyData` returns -1, call `PQgetResult` to obtain the final result status of the COPY command. One can wait for this result to be available in the usual way. Then return to normal operation.

33.9.3. Obsolete Functions for COPY

These functions represent older methods of handling COPY. Although they still work, they are deprecated due to poor error handling, inconvenient methods of detecting end-of-data, and lack of support for binary or nonblocking transfers.

`PQgetline`

Reads a newline-terminated line of characters (transmitted by the server) into a buffer string of size *length*.

```
int PQgetline(PGconn *conn,
             char *buffer,
             int length);
```

This function copies up to *length*-1 characters into the buffer and converts the terminating newline into a zero byte. `PQgetline` returns EOF at the end of input, 0 if the entire line has been read, and 1 if the buffer is full but the terminating newline has not yet been read.

Note that the application must check to see if a new line consists of the two characters `\.`, which indicates that the server has finished sending the results of the COPY command. If the application might receive lines that are more than *length*-1 characters long, care is needed to be sure it recognizes the `\.` line correctly (and does not, for example, mistake the end of a long data line for a terminator line).

`PQgetlineAsync`

Reads a row of COPY data (transmitted by the server) into a buffer without blocking.

```
int PQgetlineAsync(PGconn *conn,
                 char *buffer,
                 int bufsize);
```

This function is similar to `PQgetline`, but it can be used by applications that must read COPY data asynchronously, that is, without blocking. Having issued the COPY command and gotten a `PGRES_COPY_OUT` response, the application should call `PQconsumeInput` and `PQgetlineAsync` until the end-of-data signal is detected.

Unlike `PQgetline`, this function takes responsibility for detecting end-of-data.

On each call, `PQgetlineAsync` will return data if a complete data row is available in libpq's input buffer. Otherwise, no data is returned until the rest of the row arrives. The function returns -1 if the end-of-copy-data marker has been recognized, or 0 if no data is available, or a positive number giving the number of bytes of data returned. If -1 is returned, the caller must next call `PQendcopy`, and then return to normal processing.

The data returned will not extend beyond a data-row boundary. If possible a whole row will be returned at one time. But if the buffer offered by the caller is too small to hold a row sent by the server, then a partial data row will be returned. With textual data this can be detected by testing whether the last returned byte is `\n` or not. (In a binary COPY, actual parsing of the COPY data

format will be needed to make the equivalent determination.) The returned string is not null-terminated. (If you want to add a terminating null, be sure to pass a *bufsize* one smaller than the room actually available.)

PQputline

Sends a null-terminated string to the server. Returns 0 if OK and EOF if unable to send the string.

```
int PQputline(PGconn *conn,
              const char *string);
```

The COPY data stream sent by a series of calls to `PQputline` has the same format as that returned by `PQgetlineAsync`, except that applications are not obliged to send exactly one data row per `PQputline` call; it is okay to send a partial line or multiple lines per call.

Note

Before PostgreSQL protocol 3.0, it was necessary for the application to explicitly send the two characters `\.` as a final line to indicate to the server that it had finished sending COPY data. While this still works, it is deprecated and the special meaning of `\.` can be expected to be removed in a future release. It is sufficient to call `PQendcopy` after having sent the actual data.

PQputnbytes

Sends a non-null-terminated string to the server. Returns 0 if OK and EOF if unable to send the string.

```
int PQputnbytes(PGconn *conn,
                const char *buffer,
                int nbytes);
```

This is exactly like `PQputline`, except that the data buffer need not be null-terminated since the number of bytes to send is specified directly. Use this procedure when sending binary data.

PQendcopy

Synchronizes with the server.

```
int PQendcopy(PGconn *conn);
```

This function waits until the server has finished the copying. It should either be issued when the last string has been sent to the server using `PQputline` or when the last string has been received from the server using `PQgetline`. It must be issued or the server will get “out of sync” with the client. Upon return from this function, the server is ready to receive the next SQL command. The return value is 0 on successful completion, nonzero otherwise. (Use `PQerrorMessage` to retrieve details if the return value is nonzero.)

When using `PQgetResult`, the application should respond to a `PGRES_COPY_OUT` result by executing `PQgetline` repeatedly, followed by `PQendcopy` after the terminator line is seen. It should then return to the `PQgetResult` loop until `PQgetResult` returns a null pointer. Similarly a `PGRES_COPY_IN` result is processed by a series of `PQputline` calls followed by `PQendcopy`, then return to the `PQgetResult` loop. This arrangement will ensure that a COPY command embedded in a series of SQL commands will be executed correctly.

Older applications are likely to submit a `COPY` via `PQexec` and assume that the transaction is done after `PQendcopy`. This will work correctly only if the `COPY` is the only SQL command in the command string.

33.10. Control Functions

These functions control miscellaneous details of libpq's behavior.

`PQclientEncoding`

Returns the client encoding.

```
int PQclientEncoding(const PGconn *conn);
```

Note that it returns the encoding ID, not a symbolic string such as `EUC_JP`. If unsuccessful, it returns -1. To convert an encoding ID to an encoding name, you can use:

```
char *pg_encoding_to_char(int encoding_id);
```

`PQsetClientEncoding`

Sets the client encoding.

```
int PQsetClientEncoding(PGconn *conn, const char *encoding);
```

`conn` is a connection to the server, and `encoding` is the encoding you want to use. If the function successfully sets the encoding, it returns 0, otherwise -1. The current encoding for this connection can be determined by using `PQclientEncoding`.

`PQsetErrorVerbosity`

Determines the verbosity of messages returned by `PQerrorMessage` and `PQresultErrorMessage`.

```
typedef enum
{
    PQERRORS_TERSE,
    PQERRORS_DEFAULT,
    PQERRORS_VERBOSE,
    PQERRORS_SQLSTATE
} PGVerbosity;
```

```
PGVerbosity PQsetErrorVerbosity(PGconn *conn, PGVerbosity
    verbosity);
```

`PQsetErrorVerbosity` sets the verbosity mode, returning the connection's previous setting. In *TERSE* mode, returned messages include severity, primary text, and position only; this will normally fit on a single line. The *DEFAULT* mode produces messages that include the above plus any detail, hint, or context fields (these might span multiple lines). The *VERBOSE* mode includes all available fields. The *SQLSTATE* mode includes only the error severity and the `SQLSTATE` error code, if one is available (if not, the output is like *TERSE* mode).

Changing the verbosity setting does not affect the messages available from already-existing `PGresult` objects, only subsequently-created ones. (But see `PQresultVerboseErrorMessage` if you want to print a previous error with a different verbosity.)

PQsetErrorContextVisibility

Determines the handling of `CONTEXT` fields in messages returned by `PQerrorMessage` and `PQresultErrorMessage`.

```
typedef enum
{
    PQSHOW_CONTEXT_NEVER,
    PQSHOW_CONTEXT_ERRORS,
    PQSHOW_CONTEXT_ALWAYS
} PGContextVisibility;

PGContextVisibility PQsetErrorContextVisibility(PGconn *conn,
        PGContextVisibility show_context);
```

`PQsetErrorContextVisibility` sets the context display mode, returning the connection's previous setting. This mode controls whether the `CONTEXT` field is included in messages. The *NEVER* mode never includes `CONTEXT`, while *ALWAYS* always includes it if available. In *ERRORS* mode (the default), `CONTEXT` fields are included only in error messages, not in notices and warnings. (However, if the verbosity setting is *TERSE* or *SQLSTATE*, `CONTEXT` fields are omitted regardless of the context display mode.)

Changing this mode does not affect the messages available from already-existing `PGresult` objects, only subsequently-created ones. (But see `PQresultVerboseErrorMessage` if you want to print a previous error with a different display mode.)

PQtrace

Enables tracing of the client/server communication to a debugging file stream.

```
void PQtrace(PGconn *conn, FILE *stream);
```

Note

On Windows, if the libpq library and an application are compiled with different flags, this function call will crash the application because the internal representation of the `FILE` pointers differ. Specifically, multithreaded/single-threaded, release/debug, and static/dynamic flags should be the same for the library and all applications using that library.

PQuntrace

Disables tracing started by `PQtrace`.

```
void PQuntrace(PGconn *conn);
```

33.11. Miscellaneous Functions

As always, there are some functions that just don't fit anywhere.

PQfreemem

Frees memory allocated by libpq.

```
void PQfreemem(void *ptr);
```

Frees memory allocated by libpq, particularly PQescapeByteaConn, PQescapeBytea, PQunescapeBytea, and PQnotifies. It is particularly important that this function, rather than `free()`, be used on Microsoft Windows. This is because allocating memory in a DLL and releasing it in the application works only if multithreaded/single-threaded, release/debug, and static/dynamic flags are the same for the DLL and the application. On non-Microsoft Windows platforms, this function is the same as the standard library function `free()`.

PQconninfoFree

Frees the data structures allocated by PQconndefaults or PQconninfoParse.

```
void PQconninfoFree(PQconninfoOption *connOptions);
```

A simple PQfreemem will not do for this, since the array contains references to subsidiary strings.

PQencryptPasswordConn

Prepares the encrypted form of a PostgreSQL password.

```
char *PQencryptPasswordConn(PGconn *conn, const char *passwd,
                             const char *user, const char *algorithm);
```

This function is intended to be used by client applications that wish to send commands like `ALTER USER joe PASSWORD 'pwd'`. It is good practice not to send the original cleartext password in such a command, because it might be exposed in command logs, activity displays, and so on. Instead, use this function to convert the password to encrypted form before it is sent.

The *passwd* and *user* arguments are the cleartext password, and the SQL name of the user it is for. *algorithm* specifies the encryption algorithm to use to encrypt the password. Currently supported algorithms are `md5` and `scram-sha-256` (`on` and `off` are also accepted as aliases for `md5`, for compatibility with older server versions). Note that support for `scram-sha-256` was introduced in PostgreSQL version 10, and will not work correctly with older server versions. If *algorithm* is `NULL`, this function will query the server for the current value of the `password_encryption` setting. That can block, and will fail if the current transaction is aborted, or if the connection is busy executing another query. If you wish to use the default algorithm for the server but want to avoid blocking, query `password_encryption` yourself before calling `PQencryptPasswordConn`, and pass that value as the *algorithm*.

The return value is a string allocated by `malloc`. The caller can assume the string doesn't contain any special characters that would require escaping. Use `PQfreemem` to free the result when done with it. On error, returns `NULL`, and a suitable message is stored in the connection object.

PQencryptPassword

Prepares the md5-encrypted form of a PostgreSQL password.

```
char *PQencryptPassword(const char *passwd, const char *user);
```

`PQencryptPassword` is an older, deprecated version of `PQencryptPasswordConn`. The difference is that `PQencryptPassword` does not require a connection object, and `md5` is always used as the encryption algorithm.

PQmakeEmptyPGresult

Constructs an empty `PGresult` object with the given status.

```
PGresult *PQmakeEmptyPGresult(PGconn *conn, ExecStatusType
    status);
```

This is libpq's internal function to allocate and initialize an empty `PGresult` object. This function returns `NULL` if memory could not be allocated. It is exported because some applications find it useful to generate result objects (particularly objects with error status) themselves. If `conn` is not null and `status` indicates an error, the current error message of the specified connection is copied into the `PGresult`. Also, if `conn` is not null, any event procedures registered in the connection are copied into the `PGresult`. (They do not get `PGEVT_RESULTCREATE` calls, but see `PQfireResultCreateEvents`.) Note that `PQclear` should eventually be called on the object, just as with a `PGresult` returned by libpq itself.

`PQfireResultCreateEvents`

Fires a `PGEVT_RESULTCREATE` event (see Section 33.13) for each event procedure registered in the `PGresult` object. Returns non-zero for success, zero if any event procedure fails.

```
int PQfireResultCreateEvents(PGconn *conn, PGresult *res);
```

The `conn` argument is passed through to event procedures but not used directly. It can be `NULL` if the event procedures won't use it.

Event procedures that have already received a `PGEVT_RESULTCREATE` or `PGEVT_RESULTCOPY` event for this object are not fired again.

The main reason that this function is separate from `PQmakeEmptyPGresult` is that it is often appropriate to create a `PGresult` and fill it with data before invoking the event procedures.

`PQcopyResult`

Makes a copy of a `PGresult` object. The copy is not linked to the source result in any way and `PQclear` must be called when the copy is no longer needed. If the function fails, `NULL` is returned.

```
PGresult *PQcopyResult(const PGresult *src, int flags);
```

This is not intended to make an exact copy. The returned result is always put into `PGRES_TUPLES_OK` status, and does not copy any error message in the source. (It does copy the command status string, however.) The `flags` argument determines what else is copied. It is a bitwise OR of several flags. `PG_COPYRES_ATTRS` specifies copying the source result's attributes (column definitions). `PG_COPYRES_TUPLES` specifies copying the source result's tuples. (This implies copying the attributes, too.) `PG_COPYRES_NOTICEHOOKS` specifies copying the source result's notify hooks. `PG_COPYRES_EVENTS` specifies copying the source result's events. (But any instance data associated with the source is not copied.)

`PQsetResultAttrs`

Sets the attributes of a `PGresult` object.

```
int PQsetResultAttrs(PGresult *res, int numAttributes,
    PGresAttDesc *attDescs);
```

The provided `attDescs` are copied into the result. If the `attDescs` pointer is `NULL` or `numAttributes` is less than one, the request is ignored and the function succeeds. If `res` already contains attributes, the function will fail. If the function fails, the return value is zero. If the function succeeds, the return value is non-zero.

PQsetvalue

Sets a tuple field value of a `PGresult` object.

```
int PQsetvalue(PGresult *res, int tup_num, int field_num, char
               *value, int len);
```

The function will automatically grow the result's internal tuples array as needed. However, the `tup_num` argument must be less than or equal to `PQntuples`, meaning this function can only grow the tuples array one tuple at a time. But any field of any existing tuple can be modified in any order. If a value at `field_num` already exists, it will be overwritten. If `len` is -1 or `value` is NULL, the field value will be set to an SQL null value. The `value` is copied into the result's private storage, thus is no longer needed after the function returns. If the function fails, the return value is zero. If the function succeeds, the return value is non-zero.

PQresultAlloc

Allocate subsidiary storage for a `PGresult` object.

```
void *PQresultAlloc(PGresult *res, size_t nBytes);
```

Any memory allocated with this function will be freed when `res` is cleared. If the function fails, the return value is NULL. The result is guaranteed to be adequately aligned for any type of data, just as for `malloc`.

PQresultMemorySize

Retrieves the number of bytes allocated for a `PGresult` object.

```
size_t PQresultMemorySize(const PGresult *res);
```

This value is the sum of all `malloc` requests associated with the `PGresult` object, that is, all the space that will be freed by `PQclear`. This information can be useful for managing memory consumption.

PQlibVersion

Return the version of libpq that is being used.

```
int PQlibVersion(void);
```

The result of this function can be used to determine, at run time, whether specific functionality is available in the currently loaded version of libpq. The function can be used, for example, to determine which connection options are available in `PQconnectdb`.

The result is formed by multiplying the library's major version number by 10000 and adding the minor version number. For example, version 10.1 will be returned as 100001, and version 11.0 will be returned as 110000.

Prior to major version 10, PostgreSQL used three-part version numbers in which the first two parts together represented the major version. For those versions, `PQlibVersion` uses two digits for each part; for example version 9.1.5 will be returned as 90105, and version 9.2.0 will be returned as 90200.

Therefore, for purposes of determining feature compatibility, applications should divide the result of `PQlibVersion` by 100 not 10000 to determine a logical major version number. In all release series, only the last two digits differ between minor releases (bug-fix releases).

Note

This function appeared in PostgreSQL version 9.1, so it cannot be used to detect required functionality in earlier versions, since calling it will create a link dependency on version 9.1 or later.

33.12. Notice Processing

Notice and warning messages generated by the server are not returned by the query execution functions, since they do not imply failure of the query. Instead they are passed to a notice handling function, and execution continues normally after the handler returns. The default notice handling function prints the message on `stderr`, but the application can override this behavior by supplying its own handling function.

For historical reasons, there are two levels of notice handling, called the notice receiver and notice processor. The default behavior is for the notice receiver to format the notice and pass a string to the notice processor for printing. However, an application that chooses to provide its own notice receiver will typically ignore the notice processor layer and just do all the work in the notice receiver.

The function `PQsetNoticeReceiver` sets or examines the current notice receiver for a connection object. Similarly, `PQsetNoticeProcessor` sets or examines the current notice processor.

```
typedef void (*PQnoticeReceiver) (void *arg, const PGresult *res);

PQnoticeReceiver
PQsetNoticeReceiver(PGconn *conn,
                   PQnoticeReceiver proc,
                   void *arg);

typedef void (*PQnoticeProcessor) (void *arg, const char *message);

PQnoticeProcessor
PQsetNoticeProcessor(PGconn *conn,
                    PQnoticeProcessor proc,
                    void *arg);
```

Each of these functions returns the previous notice receiver or processor function pointer, and sets the new value. If you supply a null function pointer, no action is taken, but the current pointer is returned.

When a notice or warning message is received from the server, or generated internally by libpq, the notice receiver function is called. It is passed the message in the form of a `PGRES_NONFATAL_ERROR` `PGresult`. (This allows the receiver to extract individual fields using `PQresultErrorField`, or obtain a complete preformatted message using `PQresultErrorMessage` or `PQresultVerboseErrorMessage`.) The same void pointer passed to `PQsetNoticeReceiver` is also passed. (This pointer can be used to access application-specific state if needed.)

The default notice receiver simply extracts the message (using `PQresultErrorMessage`) and passes it to the notice processor.

The notice processor is responsible for handling a notice or warning message given in text form. It is passed the string text of the message (including a trailing newline), plus a void pointer that is the same one passed to `PQsetNoticeProcessor`. (This pointer can be used to access application-specific state if needed.)

The default notice processor is simply:

```
static void
defaultNoticeProcessor(void *arg, const char *message)
{
    fprintf(stderr, "%s", message);
}
```

Once you have set a notice receiver or processor, you should expect that that function could be called as long as either the `PGconn` object or `PGresult` objects made from it exist. At creation of a `PGresult`, the `PGconn`'s current notice handling pointers are copied into the `PGresult` for possible use by functions like `PQgetvalue`.

33.13. Event System

libpq's event system is designed to notify registered event handlers about interesting libpq events, such as the creation or destruction of `PGconn` and `PGresult` objects. A principal use case is that this allows applications to associate their own data with a `PGconn` or `PGresult` and ensure that that data is freed at an appropriate time.

Each registered event handler is associated with two pieces of data, known to libpq only as opaque `void *` pointers. There is a *passthrough* pointer that is provided by the application when the event handler is registered with a `PGconn`. The passthrough pointer never changes for the life of the `PGconn` and all `PGresults` generated from it; so if used, it must point to long-lived data. In addition there is an *instance data* pointer, which starts out `NULL` in every `PGconn` and `PGresult`. This pointer can be manipulated using the `PQinstanceData`, `PQsetInstanceData`, `PQresultInstanceData` and `PQsetResultInstanceData` functions. Note that unlike the passthrough pointer, instance data of a `PGconn` is not automatically inherited by `PGresults` created from it. libpq does not know what passthrough and instance data pointers point to (if anything) and will never attempt to free them — that is the responsibility of the event handler.

33.13.1. Event Types

The enum `PGEventId` names the types of events handled by the event system. All its values have names beginning with `PGEVT`. For each event type, there is a corresponding event info structure that carries the parameters passed to the event handlers. The event types are:

`PGEVT_REGISTER`

The register event occurs when `PQregisterEventProc` is called. It is the ideal time to initialize any `instanceData` an event procedure may need. Only one register event will be fired per event handler per connection. If the event procedure fails, the registration is aborted.

```
typedef struct
{
    PGconn *conn;
} PGEventRegister;
```

When a `PGEVT_REGISTER` event is received, the `evtInfo` pointer should be cast to a `PGEventRegister *`. This structure contains a `PGconn` that should be in the `CONNECTION_OK` status; guaranteed if one calls `PQregisterEventProc` right after obtaining a good `PGconn`. When returning a failure code, all cleanup must be performed as no `PGEVT_CONNDESTROY` event will be sent.

`PGEVT_CONNRESET`

The connection reset event is fired on completion of `PQreset` or `PQresetPoll`. In both cases, the event is only fired if the reset was successful. If the event procedure fails, the entire connection

reset will fail; the PGconn is put into CONNECTION_BAD status and PQresetPoll will return PGRES_POLLING_FAILED.

```
typedef struct
{
    PGconn *conn;
} PGEvtConnReset;
```

When a PGEVT_CONNRESET event is received, the *evtInfo* pointer should be cast to a PGEvtConnReset *. Although the contained PGconn was just reset, all event data remains unchanged. This event should be used to reset/reload/requery any associated instanceData. Note that even if the event procedure fails to process PGEVT_CONNRESET, it will still receive a PGEVT_CONNDESTROY event when the connection is closed.

PGEVT_CONNDESTROY

The connection destroy event is fired in response to PQfinish. It is the event procedure's responsibility to properly clean up its event data as libpq has no ability to manage this memory. Failure to clean up will lead to memory leaks.

```
typedef struct
{
    PGconn *conn;
} PGEvtConnDestroy;
```

When a PGEVT_CONNDESTROY event is received, the *evtInfo* pointer should be cast to a PGEvtConnDestroy *. This event is fired prior to PQfinish performing any other cleanup. The return value of the event procedure is ignored since there is no way of indicating a failure from PQfinish. Also, an event procedure failure should not abort the process of cleaning up unwanted memory.

PGEVT_RESULTCREATE

The result creation event is fired in response to any query execution function that generates a result, including PQgetResult. This event will only be fired after the result has been created successfully.

```
typedef struct
{
    PGconn *conn;
    PGresult *result;
} PGEvtResultCreate;
```

When a PGEVT_RESULTCREATE event is received, the *evtInfo* pointer should be cast to a PGEvtResultCreate *. The *conn* is the connection used to generate the result. This is the ideal place to initialize any instanceData that needs to be associated with the result. If the event procedure fails, the result will be cleared and the failure will be propagated. The event procedure must not try to PQclear the result object for itself. When returning a failure code, all cleanup must be performed as no PGEVT_RESULTDESTROY event will be sent.

PGEVT_RESULTCOPY

The result copy event is fired in response to PQcopyResult. This event will only be fired after the copy is complete. Only event procedures that have successfully handled the PGEVT_RESULTCREATE or PGEVT_RESULTCOPY event for the source result will receive PGEVT_RESULTCOPY events.

```
typedef struct
{
    const PGresult *src;
    PGresult *dest;
} PGEventResultCopy;
```

When a `PGEVT_RESULTCOPY` event is received, the `evtInfo` pointer should be cast to a `PGEventResultCopy *`. The `src` result is what was copied while the `dest` result is the copy destination. This event can be used to provide a deep copy of `instanceData`, since `PQcopyResult` cannot do that. If the event procedure fails, the entire copy operation will fail and the `dest` result will be cleared. When returning a failure code, all cleanup must be performed as no `PGEVT_RESULTDESTROY` event will be sent for the destination result.

`PGEVT_RESULTDESTROY`

The result destroy event is fired in response to a `PQclear`. It is the event procedure's responsibility to properly clean up its event data as libpq has no ability to manage this memory. Failure to clean up will lead to memory leaks.

```
typedef struct
{
    PGresult *result;
} PGEventResultDestroy;
```

When a `PGEVT_RESULTDESTROY` event is received, the `evtInfo` pointer should be cast to a `PGEventResultDestroy *`. This event is fired prior to `PQclear` performing any other cleanup. The return value of the event procedure is ignored since there is no way of indicating a failure from `PQclear`. Also, an event procedure failure should not abort the process of cleaning up unwanted memory.

33.13.2. Event Callback Procedure

`PGEventProc`

`PGEventProc` is a typedef for a pointer to an event procedure, that is, the user callback function that receives events from libpq. The signature of an event procedure must be

```
int eventproc(PGEventId evtId, void *evtInfo, void *passThrough)
```

The `evtId` parameter indicates which `PGEVT` event occurred. The `evtInfo` pointer must be cast to the appropriate structure type to obtain further information about the event. The `passThrough` parameter is the pointer provided to `PQregisterEventProc` when the event procedure was registered. The function should return a non-zero value if it succeeds and zero if it fails.

A particular event procedure can be registered only once in any `PGconn`. This is because the address of the procedure is used as a lookup key to identify the associated instance data.

Caution

On Windows, functions can have two different addresses: one visible from outside a DLL and another visible from inside the DLL. One should be careful that only one of these addresses is used with libpq's event-procedure functions, else confusion will result. The simplest rule for writing code that will work is to ensure that

event procedures are declared `static`. If the procedure's address must be available outside its own source file, expose a separate function to return the address.

33.13.3. Event Support Functions

PQregisterEventProc

Registers an event callback procedure with libpq.

```
int PQregisterEventProc(PGconn *conn, PGEventProc proc,
                       const char *name, void *passThrough);
```

An event procedure must be registered once on each `PGconn` you want to receive events about. There is no limit, other than memory, on the number of event procedures that can be registered with a connection. The function returns a non-zero value if it succeeds and zero if it fails.

The `proc` argument will be called when a libpq event is fired. Its memory address is also used to lookup `instanceData`. The `name` argument is used to refer to the event procedure in error messages. This value cannot be `NULL` or a zero-length string. The name string is copied into the `PGconn`, so what is passed need not be long-lived. The `passThrough` pointer is passed to the `proc` whenever an event occurs. This argument can be `NULL`.

PQsetInstanceData

Sets the connection `conn`'s `instanceData` for procedure `proc` to `data`. This returns non-zero for success and zero for failure. (Failure is only possible if `proc` has not been properly registered in `conn`.)

```
int PQsetInstanceData(PGconn *conn, PGEventProc proc, void
                      *data);
```

PQinstanceData

Returns the connection `conn`'s `instanceData` associated with procedure `proc`, or `NULL` if there is none.

```
void *PQinstanceData(const PGconn *conn, PGEventProc proc);
```

PQresultSetInstanceData

Sets the result's `instanceData` for `proc` to `data`. This returns non-zero for success and zero for failure. (Failure is only possible if `proc` has not been properly registered in the result.)

```
int PQresultSetInstanceData(PGresult *res, PGEventProc proc,
                            void *data);
```

Beware that any storage represented by `data` will not be accounted for by `PQresultMemorySize`, unless it is allocated using `PQresultAlloc`. (Doing so is recommendable because it eliminates the need to free such storage explicitly when the result is destroyed.)

PQresultInstanceData

Returns the result's `instanceData` associated with `proc`, or `NULL` if there is none.

```
void *PQresultInstanceData(const PGresult *res, PGEventProc
                           proc);
```

33.13.4. Event Example

Here is a skeleton example of managing private data associated with libpq connections and results.

```

/* required header for libpq events (note: includes libpq-fe.h) */
#include <libpq-events.h>

/* The instanceData */
typedef struct
{
    int n;
    char *str;
} mydata;

/* PGEventProc */
static int myEventProc(PGEventId evtId, void *evtInfo, void
    *passThrough);

int
main(void)
{
    mydata *data;
    PGresult *res;
    PGconn *conn =
        PQconnectdb("dbname=postgres options=-csearch_path=");

    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
        PQfinish(conn);
        return 1;
    }

    /* called once on any connection that should receive events.
     * Sends a PGEVT_REGISTER to myEventProc.
     */
    if (!PQregisterEventProc(conn, myEventProc, "mydata_proc",
        NULL))
    {
        fprintf(stderr, "Cannot register PGEventProc\n");
        PQfinish(conn);
        return 1;
    }

    /* conn instanceData is available */
    data = PQinstanceData(conn, myEventProc);

    /* Sends a PGEVT_RESULTCREATE to myEventProc */
    res = PQexec(conn, "SELECT 1 + 1");

    /* result instanceData is available */
    data = PQresultInstanceData(res, myEventProc);

    /* If PG_COPYRES_EVENTS is used, sends a PGEVT_RESULTCOPY to
    myEventProc */

```

```
    res_copy = PQcopyResult(res, PG_COPYRES_TUPLES |
PG_COPYRES_EVENTS);

    /* result instanceData is available if PG_COPYRES_EVENTS was
    * used during the PQcopyResult call.
    */
    data = PQresultInstanceData(res_copy, myEventProc);

    /* Both clears send a PGEVT_RESULTDESTROY to myEventProc */
    PQclear(res);
    PQclear(res_copy);

    /* Sends a PGEVT_CONNDESTROY to myEventProc */
    PQfinish(conn);

    return 0;
}

static int
myEventProc(PGEventId evtId, void *evtInfo, void *passThrough)
{
    switch (evtId)
    {
        case PGEVT_REGISTER:
        {
            PGEventRegister *e = (PGEventRegister *)evtInfo;
            mydata *data = get_mydata(e->conn);

            /* associate app specific data with connection */
            PQsetInstanceData(e->conn, myEventProc, data);
            break;
        }

        case PGEVT_CONNRESET:
        {
            PGEventConnReset *e = (PGEventConnReset *)evtInfo;
            mydata *data = PQinstanceData(e->conn, myEventProc);

            if (data)
                memset(data, 0, sizeof(mydata));
            break;
        }

        case PGEVT_CONNDESTROY:
        {
            PGEventConnDestroy *e = (PGEventConnDestroy *)evtInfo;
            mydata *data = PQinstanceData(e->conn, myEventProc);

            /* free instance data because the conn is being
            destroyed */
            if (data)
                free_mydata(data);
            break;
        }

        case PGEVT_RESULTCREATE:
        {
```

```

        PGEventResultCreate *e = (PGEventResultCreate
*)evtInfo;
        mydata *conn_data = PQinstanceData(e->conn,
myEventProc);
        mydata *res_data = dup_mydata(conn_data);

        /* associate app specific data with result (copy it
from conn) */
        PQsetResultInstanceData(e->result, myEventProc,
res_data);
        break;
    }

    case PGEVT_RESULTCOPY:
    {
        PGEventResultCopy *e = (PGEventResultCopy *)evtInfo;
        mydata *src_data = PQresultInstanceData(e->src,
myEventProc);
        mydata *dest_data = dup_mydata(src_data);

        /* associate app specific data with result (copy it
from a result) */
        PQsetResultInstanceData(e->dest, myEventProc,
dest_data);
        break;
    }

    case PGEVT_RESULTDESTROY:
    {
        PGEventResultDestroy *e = (PGEventResultDestroy
*)evtInfo;
        mydata *data = PQresultInstanceData(e->result,
myEventProc);

        /* free instance data because the result is being
destroyed */
        if (data)
            free_mydata(data);
        break;
    }

    /* unknown event ID, just return true. */
    default:
        break;
}

return true; /* event processing succeeded */
}

```

33.14. Environment Variables

The following environment variables can be used to select default connection parameter values, which will be used by `PQconnectdb`, `PQsetdbLogin` and `PQsetdb` if no value is directly specified by the calling code. These are useful to avoid hard-coding database connection information into simple client applications, for example.

- `PGHOST` behaves the same as the host connection parameter.

- `PGHOSTADDR` behaves the same as the `hostaddr` connection parameter. This can be set instead of or in addition to `PGHOST` to avoid DNS lookup overhead.
- `PGPORT` behaves the same as the `port` connection parameter.
- `PGDATABASE` behaves the same as the `dbname` connection parameter.
- `PGUSER` behaves the same as the `user` connection parameter.
- `PGPASSWORD` behaves the same as the `password` connection parameter. Use of this environment variable is not recommended for security reasons, as some operating systems allow non-root users to see process environment variables via `ps`; instead consider using a password file (see Section 33.15).
- `PGPASSFILE` behaves the same as the `passfile` connection parameter.
- `PGSERVICE` behaves the same as the `service` connection parameter.
- `PGSERVICEFILE` specifies the name of the per-user connection service file. If not set, it defaults to `~/.pg_service.conf` (see Section 33.16).
- `PGOPTIONS` behaves the same as the `options` connection parameter.
- `PGAPPNAME` behaves the same as the `application_name` connection parameter.
- `PGSSLMODE` behaves the same as the `sslmode` connection parameter.
- `PGREQUIRESSL` behaves the same as the `requiressl` connection parameter. This environment variable is deprecated in favor of the `PGSSLMODE` variable; setting both variables suppresses the effect of this one.
- `PGSSLCOMPRESSION` behaves the same as the `sslcompression` connection parameter.
- `PGSSLCERT` behaves the same as the `sslcert` connection parameter.
- `PGSSLKEY` behaves the same as the `sslkey` connection parameter.
- `PGSSLROOTCERT` behaves the same as the `sslrootcert` connection parameter.
- `PGSSLCRL` behaves the same as the `sslcrf` connection parameter.
- `PGREQUIREPEER` behaves the same as the `requirepeer` connection parameter.
- `PGGSSENCMODE` behaves the same as the `gssencmode` connection parameter.
- `PGKRBSRVNAME` behaves the same as the `krbsrvname` connection parameter.
- `PGGSSLIB` behaves the same as the `gsslib` connection parameter.
- `PGCONNECT_TIMEOUT` behaves the same as the `connect_timeout` connection parameter.
- `PGCLIENTENCODING` behaves the same as the `client_encoding` connection parameter.
- `PGTARGETSESSIONATTRS` behaves the same as the `target_session_attrs` connection parameter.

The following environment variables can be used to specify default behavior for each PostgreSQL session. (See also the `ALTER ROLE` and `ALTER DATABASE` commands for ways to set default behavior on a per-user or per-database basis.)

- `PGDATESTYLE` sets the default style of date/time representation. (Equivalent to `SET datestyle TO ...`.)
- `PGTZ` sets the default time zone. (Equivalent to `SET timezone TO ...`.)
- `PGGEQO` sets the default mode for the genetic query optimizer. (Equivalent to `SET geqo TO ...`.)

Refer to the SQL command `SET` for information on correct values for these environment variables.

The following environment variables determine internal behavior of libpq; they override compiled-in defaults.

- `PGSYSCONFDIR` sets the directory containing the `pg_service.conf` file and in a future version possibly other system-wide configuration files.
- `PGLOCALEDIR` sets the directory containing the `locale` files for message localization.

33.15. The Password File

The file `.pgpass` in a user's home directory can contain passwords to be used if the connection requires a password (and no password has been specified otherwise). On Microsoft Windows the file is named `%APPDATA%\postgresql\pgpass.conf` (where `%APPDATA%` refers to the Application Data subdirectory in the user's profile). Alternatively, a password file can be specified using the connection parameter `passfile` or the environment variable `PGPASSFILE`.

This file should contain lines of the following format:

```
hostname:port:database:username:password
```

(You can add a reminder comment to the file by copying the line above and preceding it with `#`.) Each of the first four fields can be a literal value, or `*`, which matches anything. The password field from the first line that matches the current connection parameters will be used. (Therefore, put more-specific entries first when you are using wildcards.) If an entry needs to contain `:` or `\`, escape this character with `\`. The host name field is matched to the `host` connection parameter if that is specified, otherwise to the `hostaddr` parameter if that is specified; if neither are given then the host name `localhost` is searched for. The host name `localhost` is also searched for when the connection is a Unix-domain socket connection and the `host` parameter matches libpq's default socket directory path. In a standby server, a database field of `replication` matches streaming replication connections made to the master server. The database field is of limited usefulness otherwise, because users have the same password for all databases in the same cluster.

On Unix systems, the permissions on a password file must disallow any access to world or group; achieve this by a command such as `chmod 0600 ~/.pgpass`. If the permissions are less strict than this, the file will be ignored. On Microsoft Windows, it is assumed that the file is stored in a directory that is secure, so no special permissions check is made.

33.16. The Connection Service File

The connection service file allows libpq connection parameters to be associated with a single service name. That service name can then be specified by a libpq connection, and the associated settings will be used. This allows connection parameters to be modified without requiring a recompile of the libpq application. The service name can also be specified using the `PGSERVICE` environment variable.

The connection service file can be a per-user service file at `~/.pg_service.conf` or the location specified by the environment variable `PGSERVICEFILE`, or it can be a system-wide file at ``pg_config --sysconfdir`/pg_service.conf` or in the directory specified by the environment variable `PGSYSCONFDIR`. If service definitions with the same name exist in the user and the system file, the user file takes precedence.

The file uses an “INI file” format where the section name is the service name and the parameters are connection parameters; see Section 33.1.2 for a list. For example:

```
# comment
[mydb]
host=somehost
port=5433
user=admin
```

An example file is provided at `share/pg_service.conf.sample`.

33.17. LDAP Lookup of Connection Parameters

If libpq has been compiled with LDAP support (option `--with-ldap` for `configure`) it is possible to retrieve connection options like `host` or `dbname` via LDAP from a central server. The advantage is that if the connection parameters for a database change, the connection information doesn't have to be updated on all client machines.

LDAP connection parameter lookup uses the connection service file `pg_service.conf` (see Section 33.16). A line in a `pg_service.conf` stanza that starts with `ldap://` will be recognized as an LDAP URL and an LDAP query will be performed. The result must be a list of `keyword = value` pairs which will be used to set connection options. The URL must conform to RFC 1959 and be of the form

```
ldap://[hostname[:port]]/search_base?attribute?search_scope?filter
```

where `hostname` defaults to `localhost` and `port` defaults to `389`.

Processing of `pg_service.conf` is terminated after a successful LDAP lookup, but is continued if the LDAP server cannot be contacted. This is to provide a fallback with further LDAP URL lines that point to different LDAP servers, classical `keyword = value` pairs, or default connection options. If you would rather get an error message in this case, add a syntactically incorrect line after the LDAP URL.

A sample LDAP entry that has been created with the LDIF file

```
version:1
dn:cn=mydatabase,dc=mycompany,dc=com
changetype:add
objectclass:top
objectclass:device
cn:mydatabase
description:host=dbserver.mycompany.com
description:port=5439
description:dbname=mydb
description:user=mydb_user
description:sslmode=require
```

might be queried with the following LDAP URL:

```
ldap://ldap.mycompany.com/dc=mycompany,dc=com?description?one?
(cn=mydatabase)
```

You can also mix regular service file entries with LDAP lookups. A complete example for a stanza in `pg_service.conf` would be:

```
# only host and port are stored in LDAP, specify dbname and user
explicitly
[customerdb]
dbname=customer
user=appuser
ldap://ldap.acme.com/cn=dbserver,cn=hosts?pgconnectinfo?base?
(objectclass=*)
```

33.18. SSL Support

PostgreSQL has native support for using SSL connections to encrypt client/server communications for increased security. See Section 18.9 for details about the server-side SSL functionality.

libpq reads the system-wide OpenSSL configuration file. By default, this file is named `openssl.cnf` and is located in the directory reported by `openssl version -d`. This default can be overridden by setting environment variable `OPENSSL_CONF` to the name of the desired configuration file.

33.18.1. Client Verification of Server Certificates

By default, PostgreSQL will not perform any verification of the server certificate. This means that it is possible to spoof the server identity (for example by modifying a DNS record or by taking over the server IP address) without the client knowing. In order to prevent spoofing, the client must be able to verify the server's identity via a chain of trust. A chain of trust is established by placing a root (self-signed) certificate authority (CA) certificate on one computer and a leaf certificate *signed* by the root certificate on another computer. It is also possible to use an “intermediate” certificate which is signed by the root certificate and signs leaf certificates.

To allow the client to verify the identity of the server, place a root certificate on the client and a leaf certificate signed by the root certificate on the server. To allow the server to verify the identity of the client, place a root certificate on the server and a leaf certificate signed by the root certificate on the client. One or more intermediate certificates (usually stored with the leaf certificate) can also be used to link the leaf certificate to the root certificate.

Once a chain of trust has been established, there are two ways for the client to validate the leaf certificate sent by the server. If the parameter `sslmode` is set to `verify-ca`, libpq will verify that the server is trustworthy by checking the certificate chain up to the root certificate stored on the client. If `sslmode` is set to `verify-full`, libpq will *also* verify that the server host name matches the name stored in the server certificate. The SSL connection will fail if the server certificate cannot be verified. `verify-full` is recommended in most security-sensitive environments.

In `verify-full` mode, the host name is matched against the certificate's Subject Alternative Name attribute(s), or against the Common Name attribute if no Subject Alternative Name of type `dnsName` is present. If the certificate's name attribute starts with an asterisk (*), the asterisk will be treated as a wildcard, which will match all characters *except* a dot (.). This means the certificate will not match subdomains. If the connection is made using an IP address instead of a host name, the IP address will be matched (without doing any DNS lookups).

To allow server certificate verification, one or more root certificates must be placed in the file `~/.postgresql/root.crt` in the user's home directory. (On Microsoft Windows the file is named `%APPDATA%\postgresql\root.crt`.) Intermediate certificates should also be added to the file if they are needed to link the certificate chain sent by the server to the root certificates stored on the client.

Certificate Revocation List (CRL) entries are also checked if the file `~/.postgresql/root.crl` exists (`%APPDATA%\postgresql\root.crl` on Microsoft Windows).

The location of the root certificate file and the CRL can be changed by setting the connection parameters `sslrootcert` and `sslcrl` or the environment variables `PGSSLROOTCERT` and `PGSSLCRL`.

Note

For backwards compatibility with earlier versions of PostgreSQL, if a root CA file exists, the behavior of `sslmode=require` will be the same as that of `verify-ca`, meaning the server certificate is validated against the CA. Relying on this behavior is discouraged, and applications that need certificate validation should always use `verify-ca` or `verify-full`.

33.18.2. Client Certificates

If the server attempts to verify the identity of the client by requesting the client's leaf certificate, libpq will send the certificates stored in file `~/.postgresql/postgresql.crt` in the user's home directory. The certificates must chain to the root certificate trusted by the server. A matching private key file `~/.postgresql/postgresql.key` must also be present. The private key file must not allow any access to world or group; achieve this by the command `chmod 0600 ~/.postgresql/postgresql.key`. On Microsoft Windows these files are named `%APPDATA%\postgresql\postgresql.crt` and `%APPDATA%\postgresql\postgresql.key`, and there is no special permissions check since the directory is presumed secure. The location of the certificate and key files can be overridden by the connection parameters `sslcert` and `sslkey` or the environment variables `PGSSLCERT` and `PGSSLKEY`.

The first certificate in `postgresql.crt` must be the client's certificate because it must match the client's private key. "Intermediate" certificates can be optionally appended to the file — doing so avoids requiring storage of intermediate certificates on the server (`ssl_ca_file`).

For instructions on creating certificates, see Section 18.9.5.

33.18.3. Protection Provided in Different Modes

The different values for the `sslmode` parameter provide different levels of protection. SSL can provide protection against three types of attacks:

Eavesdropping

If a third party can examine the network traffic between the client and the server, it can read both connection information (including the user name and password) and the data that is passed. SSL uses encryption to prevent this.

Man in the middle (MITM)

If a third party can modify the data while passing between the client and server, it can pretend to be the server and therefore see and modify data *even if it is encrypted*. The third party can then forward the connection information and data to the original server, making it impossible to detect this attack. Common vectors to do this include DNS poisoning and address hijacking, whereby the client is directed to a different server than intended. There are also several other attack methods that can accomplish this. SSL uses certificate verification to prevent this, by authenticating the server to the client.

Impersonation

If a third party can pretend to be an authorized client, it can simply access data it should not have access to. Typically this can happen through insecure password management. SSL uses client certificates to prevent this, by making sure that only holders of valid certificates can access the server.

For a connection to be known SSL-secured, SSL usage must be configured on *both the client and the server* before the connection is made. If it is only configured on the server, the client may end up sending sensitive information (e.g. passwords) before it knows that the server requires high security. In libpq, secure connections can be ensured by setting the `sslmode` parameter to `verify-full` or `verify-ca`, and providing the system with a root certificate to verify against. This is analogous to using an `https` URL for encrypted web browsing.

Once the server has been authenticated, the client can pass sensitive data. This means that up until this point, the client does not need to know if certificates will be used for authentication, making it safe to specify that only in the server configuration.

All SSL options carry overhead in the form of encryption and key-exchange, so there is a trade-off that has to be made between performance and security. Table 33.1 illustrates the risks the different `sslmode` values protect against, and what statement they make about security and overhead.

Table 33.1. SSL Mode Descriptions

<code>sslmode</code>	Eavesdropping protection	MITM protection	Statement
<code>disable</code>	No	No	I don't care about security, and I don't want to pay the overhead of encryption.
<code>allow</code>	Maybe	No	I don't care about security, but I will pay the overhead of encryption if the server insists on it.
<code>prefer</code>	Maybe	No	I don't care about encryption, but I wish to pay the overhead of encryption if the server supports it.
<code>require</code>	Yes	No	I want my data to be encrypted, and I accept the overhead. I trust that the network will make sure I always connect to the server I want.
<code>verify-ca</code>	Yes	Depends on CA-policy	I want my data encrypted, and I accept the overhead. I want to be sure that I connect to a server that I trust.
<code>verify-full</code>	Yes	Yes	I want my data encrypted, and I accept the overhead. I want to be sure that I connect to a server I trust, and that it's the one I specify.

The difference between `verify-ca` and `verify-full` depends on the policy of the root CA. If a public CA is used, `verify-ca` allows connections to a server that *somebody else* may have registered with the CA. In this case, `verify-full` should always be used. If a local CA is used, or even a self-signed certificate, using `verify-ca` often provides enough protection.

The default value for `sslmode` is `prefer`. As is shown in the table, this makes no sense from a security point of view, and it only promises performance overhead if possible. It is only provided as the default for backward compatibility, and is not recommended in secure deployments.

33.18.4. SSL Client File Usage

Table 33.2 summarizes the files that are relevant to the SSL setup on the client.

Table 33.2. Libpq/Client SSL File Usage

File	Contents	Effect
<code>~/.postgresql/postgresql.crt</code>	client certificate	requested by server
<code>~/.postgresql/postgresql.key</code>	client private key	proves client certificate sent by owner; does not indicate certificate owner is trustworthy

File	Contents	Effect
~/.postgresql/root.crt	trusted certificate authorities	checks that server certificate is signed by a trusted certificate authority
~/.postgresql/root.crl	certificates revoked by certificate authorities	server certificate must not be on this list

33.18.5. SSL Library Initialization

If your application initializes `libssl` and/or `libcrypto` libraries and `libpq` is built with SSL support, you should call `PQinitOpenSSL` to tell `libpq` that the `libssl` and/or `libcrypto` libraries have been initialized by your application, so that `libpq` will not also initialize those libraries. See http://h41379.www4.hp.com/doc/83final/ba554_90007/ch04.html for details on the SSL API.

`PQinitOpenSSL`

Allows applications to select which security libraries to initialize.

```
void PQinitOpenSSL(int do_ssl, int do_crypto);
```

When `do_ssl` is non-zero, `libpq` will initialize the OpenSSL library before first opening a database connection. When `do_crypto` is non-zero, the `libcrypto` library will be initialized. By default (if `PQinitOpenSSL` is not called), both libraries are initialized. When SSL support is not compiled in, this function is present but does nothing.

If your application uses and initializes either OpenSSL or its underlying `libcrypto` library, you *must* call this function with zeroes for the appropriate parameter(s) before first opening a database connection. Also be sure that you have done that initialization before opening a database connection.

`PQinitSSL`

Allows applications to select which security libraries to initialize.

```
void PQinitSSL(int do_ssl);
```

This function is equivalent to `PQinitOpenSSL(do_ssl, do_ssl)`. It is sufficient for applications that initialize both or neither of OpenSSL and `libcrypto`.

`PQinitSSL` has been present since PostgreSQL 8.0, while `PQinitOpenSSL` was added in PostgreSQL 8.4, so `PQinitSSL` might be preferable for applications that need to work with older versions of `libpq`.

33.19. Behavior in Threaded Programs

`libpq` is reentrant and thread-safe by default. You might need to use special compiler command-line options when you compile your application code. Refer to your system's documentation for information about how to build thread-enabled applications, or look in `src/Makefile.global` for `PTHREAD_CFLAGS` and `PTHREAD_LIBS`. This function allows the querying of `libpq`'s thread-safe status:

`PQisthreadsafe`

Returns the thread safety status of the `libpq` library.

```
int PQisthreadsafe();
```

Returns 1 if the libpq is thread-safe and 0 if it is not.

One thread restriction is that no two threads attempt to manipulate the same `PGconn` object at the same time. In particular, you cannot issue concurrent commands from different threads through the same connection object. (If you need to run concurrent commands, use multiple connections.)

`PGresult` objects are normally read-only after creation, and so can be passed around freely between threads. However, if you use any of the `PGresult`-modifying functions described in Section 33.11 or Section 33.13, it's up to you to avoid concurrent operations on the same `PGresult`, too.

The deprecated functions `PQrequestCancel` and `PQoidStatus` are not thread-safe and should not be used in multithread programs. `PQrequestCancel` can be replaced by `PQcancel`. `PQoidStatus` can be replaced by `PQoidValue`.

If you are using Kerberos inside your application (in addition to inside libpq), you will need to do locking around Kerberos calls because Kerberos functions are not thread-safe. See function `PQregisterThreadLock` in the libpq source code for a way to do cooperative locking between libpq and your application.

If you experience problems with threaded applications, run the program in `src/tools/thread` to see if your platform has thread-unsafe functions. This program is run by `configure`, but for binary distributions your library might not match the library used to build the binaries.

33.20. Building libpq Programs

To build (i.e., compile and link) a program using libpq you need to do all of the following things:

- Include the `libpq-fe.h` header file:

```
#include <libpq-fe.h>
```

If you failed to do that then you will normally get error messages from your compiler similar to:

```
foo.c: In function `main':
foo.c:34: `PGconn' undeclared (first use in this function)
foo.c:35: `PGresult' undeclared (first use in this function)
foo.c:54: `CONNECTION_BAD' undeclared (first use in this
function)
foo.c:68: `PGRES_COMMAND_OK' undeclared (first use in this
function)
foo.c:95: `PGRES_TUPLES_OK' undeclared (first use in this
function)
```

- Point your compiler to the directory where the PostgreSQL header files were installed, by supplying the `-Idirectory` option to your compiler. (In some cases the compiler will look into the directory in question by default, so you can omit this option.) For instance, your compile command line could look like:

```
cc -c -I/usr/local/pgsql/include testprog.c
```

If you are using makefiles then add the option to the `CPPFLAGS` variable:

```
CPPFLAGS += -I/usr/local/pgsql/include
```

If there is any chance that your program might be compiled by other users then you should not hardcode the directory location like that. Instead, you can run the utility `pg_config` to find out where the header files are on the local system:

```
$ pg_config --includedir
/usr/local/include
```

If you have `pkg-config` installed, you can run instead:

```
$ pkg-config --cflags libpq
-I/usr/local/include
```

Note that this will already include the `-I` in front of the path.

Failure to specify the correct option to the compiler will result in an error message such as:

```
testlibpq.c:8:22: libpq-fe.h: No such file or directory
```

- When linking the final program, specify the option `-lpq` so that the `libpq` library gets pulled in, as well as the option `-Ldirectory` to point the compiler to the directory where the `libpq` library resides. (Again, the compiler will search some directories by default.) For maximum portability, put the `-L` option before the `-lpq` option. For example:

```
cc -o testprog testprog1.o testprog2.o -L/usr/local/pgsql/lib -lpq
```

You can find out the library directory using `pg_config` as well:

```
$ pg_config --libdir
/usr/local/pgsql/lib
```

Or again use `pkg-config`:

```
$ pkg-config --libs libpq
-L/usr/local/pgsql/lib -lpq
```

Note again that this prints the full options, not only the path.

Error messages that point to problems in this area could look like the following:

```
testlibpq.o: In function `main':
testlibpq.o(.text+0x60): undefined reference to `PQsetdbLogin'
testlibpq.o(.text+0x71): undefined reference to `PQstatus'
testlibpq.o(.text+0xa4): undefined reference to `PQerrorMessage'
```

This means you forgot `-lpq`.

```
/usr/bin/ld: cannot find -lpq
```

This means you forgot the `-L` option or did not specify the right directory.

33.21. Example Programs

These examples and others can be found in the directory `src/test/examples` in the source code distribution.

Example 33.1. libpq Example Program 1

```
/*
 * src/test/examples/testlibpq.c
 *
 *
 * testlibpq.c
 *
 *      Test the C version of libpq, the PostgreSQL frontend
 *      library.
 */
#include <stdio.h>
#include <stdlib.h>
#include "libpq-fe.h"

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
    int        nFields;
    int        i,
              j;

    /*
     * If the user supplies a parameter on the command line, use it
     * as the
     * conninfo string; otherwise default to setting
     * dbname=postgres and using
     * environment variables or defaults for all other connection
     * parameters.
     */
    if (argc > 1)
        conninfo = argv[1];
    else
        conninfo = "dbname = postgres";

    /* Make a connection to the database */
    conn = PQconnectdb(conninfo);

    /* Check to see that the backend connection was successfully
     * made */
    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
                PQerrorMessage(conn));
        exit_nicely(conn);
    }
}
```

```
    /* Set always-secure search path, so malicious users can't take
control. */
    res = PQexec(conn,
                  "SELECT pg_catalog.set_config('search_path', '',
false)");
    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
        fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    /*
    * Should PQclear PGresult whenever it is no longer needed to
avoid memory
    * leaks
    */
    PQclear(res);

    /*
    * Our test case here involves using a cursor, for which we
must be inside
    * a transaction block. We could do the whole thing with a
single
    * PQexec() of "select * from pg_database", but that's too
trivial to make
    * a good example.
    */

    /* Start a transaction block */
    res = PQexec(conn, "BEGIN");
    if (PQresultStatus(res) != PGRES_COMMAND_OK)
    {
        fprintf(stderr, "BEGIN command failed: %s",
PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }
    PQclear(res);

    /*
    * Fetch rows from pg_database, the system catalog of databases
    */
    res = PQexec(conn, "DECLARE myportal CURSOR FOR select * from
pg_database");
    if (PQresultStatus(res) != PGRES_COMMAND_OK)
    {
        fprintf(stderr, "DECLARE CURSOR failed: %s",
PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }
    PQclear(res);

    res = PQexec(conn, "FETCH ALL in myportal");
    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
```

```
        fprintf(stderr, "FETCH ALL failed: %s",
PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    /* first, print out the attribute names */
    nFields = PQnfields(res);
    for (i = 0; i < nFields; i++)
        printf("%-15s", PQfname(res, i));
    printf("\n\n");

    /* next, print out the rows */
    for (i = 0; i < PQntuples(res); i++)
    {
        for (j = 0; j < nFields; j++)
            printf("%-15s", PQgetvalue(res, i, j));
        printf("\n");
    }

    PQclear(res);

    /* close the portal ... we don't bother to check for errors ...
*/
    res = PQexec(conn, "CLOSE myportal");
    PQclear(res);

    /* end the transaction */
    res = PQexec(conn, "END");
    PQclear(res);

    /* close the connection to the database and cleanup */
    PQfinish(conn);

    return 0;
}
```

Example 33.2. libpq Example Program 2

```
/*
* src/test/examples/testlibpq2.c
*
*
* testlibpq2.c
*     Test of the asynchronous notification interface
*
* Start this program, then from psql in another window do
*     NOTIFY TBL2;
* Repeat four times to get this program to exit.
*
* Or, if you want to get fancy, try this:
* populate a database with the following commands
* (provided in src/test/examples/testlibpq2.sql):
*
*     CREATE SCHEMA TESTLIBPQ2;
```

```
* SET search_path = TESTLIBPQ2;
* CREATE TABLE TBL1 (i int4);
* CREATE TABLE TBL2 (i int4);
* CREATE RULE r1 AS ON INSERT TO TBL1 DO
*   (INSERT INTO TBL2 VALUES (new.i); NOTIFY TBL2);
*
* Start this program, then from psql do this four times:
*
* INSERT INTO TESTLIBPQ2.TBL1 VALUES (10);
*/

#ifdef WIN32
#include <windows.h>
#endif
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <errno.h>
#include <sys/time.h>
#include <sys/types.h>
#ifdef HAVE_SYS_SELECT_H
#include <sys/select.h>
#endif

#include "libpq-fe.h"

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn      *conn;
    PGresult     *res;
    PGnotify     *notify;
    int          nnotifies;

    /*
     * If the user supplies a parameter on the command line, use it
     * as the
     * conninfo string; otherwise default to setting
     * dbname=postgres and using
     * environment variables or defaults for all other connection
     * parameters.
     */
    if (argc > 1)
        conninfo = argv[1];
    else
        conninfo = "dbname = postgres";

    /* Make a connection to the database */
    conn = PQconnectdb(conninfo);
```

```
/* Check to see that the backend connection was successfully
made */
if (PQstatus(conn) != CONNECTION_OK)
{
    fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
    exit_nicely(conn);
}

/* Set always-secure search path, so malicious users can't take
control. */
res = PQexec(conn,
              "SELECT pg_catalog.set_config('search_path', '',
false)");
if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

/*
 * Should PQclear PGresult whenever it is no longer needed to
avoid memory
 * leaks
 */
PQclear(res);

/*
 * Issue LISTEN command to enable notifications from the rule's
NOTIFY.
 */
res = PQexec(conn, "LISTEN TBL2");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "LISTEN command failed: %s",
PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

/* Quit after four notifies are received. */
nnotifies = 0;
while (nnotifies < 4)
{
    /*
     * Sleep until something happens on the connection. We use
select(2)
     * to wait for input, but you could also use poll() or
similar
     * facilities.
     */
    int sock;
    fd_set input_mask;

    sock = PQsocket(conn);
```

```

    if (sock < 0)
        break;                /* shouldn't happen */

    FD_ZERO(&input_mask);
    FD_SET(sock, &input_mask);

    if (select(sock + 1, &input_mask, NULL, NULL, NULL) < 0)
    {
        fprintf(stderr, "select() failed: %s\n",
strerror(errno));
        exit_nicely(conn);
    }

    /* Now check for input */
    PQconsumeInput(conn);
    while ((notify = PQnotifies(conn)) != NULL)
    {
        fprintf(stderr,
            "ASYNC NOTIFY of '%s' received from backend PID
%d\n",
                notify->relname, notify->be_pid);
        PQfreemem(notify);
        nnotifies++;
        PQconsumeInput(conn);
    }
}

fprintf(stderr, "Done.\n");

/* close the connection to the database and cleanup */
PQfinish(conn);

return 0;
}

```

Example 33.3. libpq Example Program 3

```

/*
 * src/test/examples/testlibpq3.c
 *
 *
 * testlibpq3.c
 *     Test out-of-line parameters and binary I/O.
 *
 * Before running this, populate a database with the following
 * commands
 * (provided in src/test/examples/testlibpq3.sql):
 *
 * CREATE SCHEMA testlibpq3;
 * SET search_path = testlibpq3;
 * CREATE TABLE test1 (i int4, t text, b bytea);
 * INSERT INTO test1 values (1, 'joe's place', '\\000\\001\\002\\
\\003\\004');
 * INSERT INTO test1 values (2, 'ho there', '\\004\\003\\002\\001\\
\\000');

```

```
*
* The expected output is:
*
* tuple 0: got
* i = (4 bytes) 1
* t = (11 bytes) 'joe's place'
* b = (5 bytes) \000\001\002\003\004
*
* tuple 0: got
* i = (4 bytes) 2
* t = (8 bytes) 'ho there'
* b = (5 bytes) \004\003\002\001\000
*/

#ifdef WIN32
#include <windows.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <string.h>
#include <sys/types.h>
#include "libpq-fe.h"

/* for ntohs/htons */
#include <netinet/in.h>
#include <arpa/inet.h>

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

/*
 * This function prints a query result that is a binary-format
 * fetch from
 * a table defined as in the comment above. We split it out
 * because the
 * main() function uses it twice.
 */
static void
show_binary_results(PGresult *res)
{
    int          i,
                j;
    int          i_fnum,
                t_fnum,
                b_fnum;

    /* Use PQfnumber to avoid assumptions about field order in
    result */
    i_fnum = PQfnumber(res, "i");
    t_fnum = PQfnumber(res, "t");
    b_fnum = PQfnumber(res, "b");
```

```

    for (i = 0; i < PQntuples(res); i++)
    {
        char        *iptr;
        char        *tptr;
        char        *bptr;
        int         blen;
        int         ival;

        /* Get the field values (we ignore possibility they are
null!) */
        iptr = PQgetvalue(res, i, i_fnum);
        tptr = PQgetvalue(res, i, t_fnum);
        bptr = PQgetvalue(res, i, b_fnum);

        /*
         * The binary representation of INT4 is in network byte
order, which
         * we'd better coerce to the local byte order.
         */
        ival = ntohl(*(uint32_t *) iptr);

        /*
         * The binary representation of TEXT is, well, text, and
since libpq
         * was nice enough to append a zero byte to it, it'll work
just fine
         * as a C string.
         *
         * The binary representation of BYTEA is a bunch of bytes,
which could
         * include embedded nulls so we have to pay attention to
field length.
         */
        blen = PQgetlength(res, i, b_fnum);

        printf("tuple %d: got\n", i);
        printf(" i = (%d bytes) %d\n",
            PQgetlength(res, i, i_fnum), ival);
        printf(" t = (%d bytes) '%s'\n",
            PQgetlength(res, i, t_fnum), tptr);
        printf(" b = (%d bytes) ", blen);
        for (j = 0; j < blen; j++)
            printf("\\%03o", bptr[j]);
        printf("\n\n");
    }
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
    const char *paramValues[1];
    int        paramLengths[1];
    int        paramFormats[1];
    uint32_t   binaryIntVal;

```

```
/*
 * If the user supplies a parameter on the command line, use it
as the
 * conninfo string; otherwise default to setting
dbname=postgres and using
 * environment variables or defaults for all other connection
parameters.
 */
if (argc > 1)
    conninfo = argv[1];
else
    conninfo = "dbname = postgres";

/* Make a connection to the database */
conn = PQconnectdb(conninfo);

/* Check to see that the backend connection was successfully
made */
if (PQstatus(conn) != CONNECTION_OK)
{
    fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
    exit_nicely(conn);
}

/* Set always-secure search path, so malicious users can't take
control. */
res = PQexec(conn, "SET search_path = testlibpq3");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

/*
 * The point of this program is to illustrate use of
PQexecParams() with
 * out-of-line parameters, as well as binary transmission of
data.
 *
 * This first example transmits the parameters as text, but
receives the
 * results in binary format. By using out-of-line parameters
we can avoid
 * a lot of tedious mucking about with quoting and escaping,
even though
 * the data is text. Notice how we don't have to do anything
special with
 * the quote mark in the parameter value.
 */

/* Here is our out-of-line parameter value */
paramValues[0] = "joe's place";

res = PQexecParams(conn,
```

```
        "SELECT * FROM test1 WHERE t = $1",
        1,          /* one param */
        NULL,      /* let the backend deduce param
type */

        paramValues,
        NULL,      /* don't need param lengths since
text */

        NULL,      /* default to all text params */
        1);       /* ask for binary results */

    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
        fprintf(stderr, "SELECT failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    show_binary_results(res);

    PQclear(res);

    /*
     * In this second example we transmit an integer parameter in
    binary form,
     * and again retrieve the results in binary form.
     *
     * Although we tell PQexecParams we are letting the backend
    deduce
     * parameter type, we really force the decision by casting the
    parameter
     * symbol in the query text. This is a good safety measure
    when sending
     * binary parameters.
     */

    /* Convert integer value "2" to network byte order */
    binaryIntVal = htonl((uint32_t) 2);

    /* Set up parameter arrays for PQexecParams */
    paramValues[0] = (char *) &binaryIntVal;
    paramLengths[0] = sizeof(binaryIntVal);
    paramFormats[0] = 1;          /* binary */

    res = PQexecParams(conn,
        "SELECT * FROM test1 WHERE i = $1::int4",
        1,          /* one param */
        NULL,      /* let the backend deduce param
type */

        paramValues,
        paramLengths,
        paramFormats,
        1);       /* ask for binary results */

    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
        fprintf(stderr, "SELECT failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

```

```
    }  
  
    show_binary_results(res);  
  
    PQclear(res);  
  
    /* close the connection to the database and cleanup */  
    PQfinish(conn);  
  
    return 0;  
}
```

Chapter 34. Large Objects

PostgreSQL has a *large object* facility, which provides stream-style access to user data that is stored in a special large-object structure. Streaming access is useful when working with data values that are too large to manipulate conveniently as a whole.

This chapter describes the implementation and the programming and query language interfaces to PostgreSQL large object data. We use the libpq C library for the examples in this chapter, but most programming interfaces native to PostgreSQL support equivalent functionality. Other interfaces might use the large object interface internally to provide generic support for large values. This is not described here.

34.1. Introduction

All large objects are stored in a single system table named `pg_largeobject`. Each large object also has an entry in the system table `pg_largeobject_metadata`. Large objects can be created, modified, and deleted using a read/write API that is similar to standard operations on files.

PostgreSQL also supports a storage system called “TOAST”, which automatically stores values larger than a single database page into a secondary storage area per table. This makes the large object facility partially obsolete. One remaining advantage of the large object facility is that it allows values up to 4 TB in size, whereas TOASTed fields can be at most 1 GB. Also, reading and updating portions of a large object can be done efficiently, while most operations on a TOASTed field will read or write the whole value as a unit.

34.2. Implementation Features

The large object implementation breaks large objects up into “chunks” and stores the chunks in rows in the database. A B-tree index guarantees fast searches for the correct chunk number when doing random access reads and writes.

The chunks stored for a large object do not have to be contiguous. For example, if an application opens a new large object, seeks to offset 1000000, and writes a few bytes there, this does not result in allocation of 1000000 bytes worth of storage; only of chunks covering the range of data bytes actually written. A read operation will, however, read out zeroes for any unallocated locations preceding the last existing chunk. This corresponds to the common behavior of “sparsely allocated” files in Unix file systems.

As of PostgreSQL 9.0, large objects have an owner and a set of access permissions, which can be managed using `GRANT` and `REVOKE`. `SELECT` privileges are required to read a large object, and `UPDATE` privileges are required to write or truncate it. Only the large object's owner (or a database superuser) can delete, comment on, or change the owner of a large object. To adjust this behavior for compatibility with prior releases, see the `lo_compat_privileges` run-time parameter.

34.3. Client Interfaces

This section describes the facilities that PostgreSQL's libpq client interface library provides for accessing large objects. The PostgreSQL large object interface is modeled after the Unix file-system interface, with analogues of `open`, `read`, `write`, `lseek`, etc.

All large object manipulation using these functions *must* take place within an SQL transaction block, since large object file descriptors are only valid for the duration of a transaction.

If an error occurs while executing any one of these functions, the function will return an otherwise-impossible value, typically 0 or -1. A message describing the error is stored in the connection object and can be retrieved with `PQerrorMessage`.

Client applications that use these functions should include the header file `libpq/libpq-fs.h` and link with the `libpq` library.

34.3.1. Creating a Large Object

The function

```
Oid lo_creat(PGconn *conn, int mode);
```

creates a new large object. The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure. *mode* is unused and ignored as of PostgreSQL 8.1; however, for backward compatibility with earlier releases it is best to set it to `INV_READ`, `INV_WRITE`, or `INV_READ | INV_WRITE`. (These symbolic constants are defined in the header file `libpq/libpq-fs.h`.)

An example:

```
inv_oid = lo_creat(conn, INV_READ | INV_WRITE);
```

The function

```
Oid lo_create(PGconn *conn, Oid lobjId);
```

also creates a new large object. The OID to be assigned can be specified by *lobjId*; if so, failure occurs if that OID is already in use for some large object. If *lobjId* is `InvalidOid` (zero) then `lo_create` assigns an unused OID (this is the same behavior as `lo_creat`). The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure.

`lo_create` is new as of PostgreSQL 8.1; if this function is run against an older server version, it will fail and return `InvalidOid`.

An example:

```
inv_oid = lo_create(conn, desired_oid);
```

34.3.2. Importing a Large Object

To import an operating system file as a large object, call

```
Oid lo_import(PGconn *conn, const char *filename);
```

filename specifies the operating system name of the file to be imported as a large object. The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure. Note that the file is read by the client interface library, not by the server; so it must exist in the client file system and be readable by the client application.

The function

```
Oid lo_import_with_oid(PGconn *conn, const char *filename, Oid lobjId);
```

also imports a new large object. The OID to be assigned can be specified by *lobjId*; if so, failure occurs if that OID is already in use for some large object. If *lobjId* is `InvalidOid` (zero) then `lo_import_with_oid` assigns an unused OID (this is the same behavior as `lo_import`). The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure.

`lo_import_with_oid` is new as of PostgreSQL 8.4 and uses `lo_create` internally which is new in 8.1; if this function is run against 8.0 or before, it will fail and return `InvalidOid`.

34.3.3. Exporting a Large Object

To export a large object into an operating system file, call

```
int lo_export(PGconn *conn, Oid lobjId, const char *filename);
```

The `lobjId` argument specifies the OID of the large object to export and the `filename` argument specifies the operating system name of the file. Note that the file is written by the client interface library, not by the server. Returns 1 on success, -1 on failure.

34.3.4. Opening an Existing Large Object

To open an existing large object for reading or writing, call

```
int lo_open(PGconn *conn, Oid lobjId, int mode);
```

The `lobjId` argument specifies the OID of the large object to open. The `mode` bits control whether the object is opened for reading (`INV_READ`), writing (`INV_WRITE`), or both. (These symbolic constants are defined in the header file `libpq/libpq-fs.h`.) `lo_open` returns a (non-negative) large object descriptor for later use in `lo_read`, `lo_write`, `lo_lseek`, `lo_lseek64`, `lo_tell`, `lo_tell64`, `lo_truncate`, `lo_truncate64`, and `lo_close`. The descriptor is only valid for the duration of the current transaction. On failure, -1 is returned.

The server currently does not distinguish between modes `INV_WRITE` and `INV_READ | INV_WRITE`: you are allowed to read from the descriptor in either case. However there is a significant difference between these modes and `INV_READ` alone: with `INV_READ` you cannot write on the descriptor, and the data read from it will reflect the contents of the large object at the time of the transaction snapshot that was active when `lo_open` was executed, regardless of later writes by this or other transactions. Reading from a descriptor opened with `INV_WRITE` returns data that reflects all writes of other committed transactions as well as writes of the current transaction. This is similar to the behavior of `REPEATABLE READ` versus `READ COMMITTED` transaction modes for ordinary SQL `SELECT` commands.

`lo_open` will fail if `SELECT` privilege is not available for the large object, or if `INV_WRITE` is specified and `UPDATE` privilege is not available. (Prior to PostgreSQL 11, these privilege checks were instead performed at the first actual read or write call using the descriptor.) These privilege checks can be disabled with the `lo_compat_privileges` run-time parameter.

An example:

```
inv_fd = lo_open(conn, inv_oid, INV_READ|INV_WRITE);
```

34.3.5. Writing Data to a Large Object

The function

```
int lo_write(PGconn *conn, int fd, const char *buf, size_t len);
```

writes `len` bytes from `buf` (which must be of size `len`) to large object descriptor `fd`. The `fd` argument must have been returned by a previous `lo_open`. The number of bytes actually written is returned (in the current implementation, this will always equal `len` unless there is an error). In the event of an error, the return value is -1.

Although the *len* parameter is declared as `size_t`, this function will reject length values larger than `INT_MAX`. In practice, it's best to transfer data in chunks of at most a few megabytes anyway.

34.3.6. Reading Data from a Large Object

The function

```
int lo_read(PGconn *conn, int fd, char *buf, size_t len);
```

reads up to *len* bytes from large object descriptor *fd* into *buf* (which must be of size *len*). The *fd* argument must have been returned by a previous `lo_open`. The number of bytes actually read is returned; this will be less than *len* if the end of the large object is reached first. In the event of an error, the return value is -1.

Although the *len* parameter is declared as `size_t`, this function will reject length values larger than `INT_MAX`. In practice, it's best to transfer data in chunks of at most a few megabytes anyway.

34.3.7. Seeking in a Large Object

To change the current read or write location associated with a large object descriptor, call

```
int lo_lseek(PGconn *conn, int fd, int offset, int whence);
```

This function moves the current location pointer for the large object descriptor identified by *fd* to the new location specified by *offset*. The valid values for *whence* are `SEEK_SET` (seek from object start), `SEEK_CUR` (seek from current position), and `SEEK_END` (seek from object end). The return value is the new location pointer, or -1 on error.

When dealing with large objects that might exceed 2GB in size, instead use

```
pg_int64 lo_lseek64(PGconn *conn, int fd, pg_int64 offset, int whence);
```

This function has the same behavior as `lo_lseek`, but it can accept an *offset* larger than 2GB and/or deliver a result larger than 2GB. Note that `lo_lseek` will fail if the new location pointer would be greater than 2GB.

`lo_lseek64` is new as of PostgreSQL 9.3. If this function is run against an older server version, it will fail and return -1.

34.3.8. Obtaining the Seek Position of a Large Object

To obtain the current read or write location of a large object descriptor, call

```
int lo_tell(PGconn *conn, int fd);
```

If there is an error, the return value is -1.

When dealing with large objects that might exceed 2GB in size, instead use

```
pg_int64 lo_tell64(PGconn *conn, int fd);
```

This function has the same behavior as `lo_tell`, but it can deliver a result larger than 2GB. Note that `lo_tell` will fail if the current read/write location is greater than 2GB.

`lo_tell64` is new as of PostgreSQL 9.3. If this function is run against an older server version, it will fail and return -1.

34.3.9. Truncating a Large Object

To truncate a large object to a given length, call

```
int lo_truncate(PGconn *conn, int fd, size_t len);
```

This function truncates the large object descriptor *fd* to length *len*. The *fd* argument must have been returned by a previous `lo_open`. If *len* is greater than the large object's current length, the large object is extended to the specified length with null bytes ('\0'). On success, `lo_truncate` returns zero. On error, the return value is -1.

The read/write location associated with the descriptor *fd* is not changed.

Although the *len* parameter is declared as `size_t`, `lo_truncate` will reject length values larger than `INT_MAX`.

When dealing with large objects that might exceed 2GB in size, instead use

```
int lo_truncate64(PGconn *conn, int fd, pg_int64 len);
```

This function has the same behavior as `lo_truncate`, but it can accept a *len* value exceeding 2GB.

`lo_truncate` is new as of PostgreSQL 8.3; if this function is run against an older server version, it will fail and return -1.

`lo_truncate64` is new as of PostgreSQL 9.3; if this function is run against an older server version, it will fail and return -1.

34.3.10. Closing a Large Object Descriptor

A large object descriptor can be closed by calling

```
int lo_close(PGconn *conn, int fd);
```

where *fd* is a large object descriptor returned by `lo_open`. On success, `lo_close` returns zero. On error, the return value is -1.

Any large object descriptors that remain open at the end of a transaction will be closed automatically.

34.3.11. Removing a Large Object

To remove a large object from the database, call

```
int lo_unlink(PGconn *conn, Oid loObjId);
```

The *loObjId* argument specifies the OID of the large object to remove. Returns 1 if successful, -1 on failure.

34.4. Server-Side Functions

Server-side functions tailored for manipulating large objects from SQL are listed in Table 34.1.

Table 34.1. SQL-Oriented Large Object Functions

Function	Return Type	Description	Example	Result
<code>lo_from_bytea</code> (<i>loid</i>	<code>oid</code>	Create a large object and store da-	<code>lo_from_bytea('\\\\x\xff\xff\xff00')</code>	204528

Function	Return Type	Description	Example	Result
<code>oid, string bytea)</code>		ta there, returning its OID. Pass 0 to have the system choose an OID.		
<code>lo_put(loid oid, offset bigint, str bytea)</code>	void	Write data at the given offset.	<code>lo_put(24528, 1, '\xaa')</code>	
<code>lo_get(loid oid [, from bigint, for int])</code>	bytea	Extract contents or a substring thereof.	<code>lo_get(24528, 0, 3)</code>	<code>\xffaaff</code>

There are additional server-side functions corresponding to each of the client-side functions described earlier; indeed, for the most part the client-side functions are simply interfaces to the equivalent server-side functions. The ones just as convenient to call via SQL commands are `lo_creat`, `lo_create`, `lo_unlink`, `lo_import`, and `lo_export`. Here are examples of their use:

```
CREATE TABLE image (
    name          text,
    raster        oid
);

SELECT lo_creat(-1);          -- returns OID of new, empty large
object

SELECT lo_create(43213);     -- attempts to create large object with
OID 43213

SELECT lo_unlink(173454);    -- deletes large object with OID 173454

INSERT INTO image (name, raster)
VALUES ('beautiful image', lo_import('/etc/motd'));

INSERT INTO image (name, raster) -- same as above, but specify OID
to use
VALUES ('beautiful image', lo_import('/etc/motd', 68583));

SELECT lo_export(image.raster, '/tmp/motd') FROM image
WHERE name = 'beautiful image';
```

The server-side `lo_import` and `lo_export` functions behave considerably differently from their client-side analogs. These two functions read and write files in the server's file system, using the permissions of the database's owning user. Therefore, by default their use is restricted to superusers. In contrast, the client-side import and export functions read and write files in the client's file system, using the permissions of the client program. The client-side functions do not require any database privileges, except the privilege to read or write the large object in question.

Caution

It is possible to GRANT use of the server-side `lo_import` and `lo_export` functions to non-superusers, but careful consideration of the security implications is required. A malicious user of such privileges could easily parlay them into becoming superuser (for example by rewriting server configuration files), or could attack the rest of the server's file system without bothering to obtain database superuser privileges

as such. *Access to roles having such privilege must therefore be guarded just as carefully as access to superuser roles.* Nonetheless, if use of server-side `lo_import` or `lo_export` is needed for some routine task, it's safer to use a role with such privileges than one with full superuser privileges, as that helps to reduce the risk of damage from accidental errors.

The functionality of `lo_read` and `lo_write` is also available via server-side calls, but the names of the server-side functions differ from the client side interfaces in that they do not contain underscores. You must call these functions as `loread` and `lowrite`.

34.5. Example Program

Example 34.1 is a sample program which shows how the large object interface in `libpq` can be used. Parts of the program are commented out but are left in the source for the reader's benefit. This program can also be found in `src/test/examples/testlo.c` in the source distribution.

Example 34.1. Large Objects with `libpq` Example Program

```

/
*-----
*
* testlo.c
*   test using large objects with libpq
*
* Portions Copyright (c) 1996-2019, PostgreSQL Global Development
Group
* Portions Copyright (c) 1994, Regents of the University of
California
*
*
* IDENTIFICATION
*   src/test/examples/testlo.c
*
*-----
*/
#include <stdio.h>
#include <stdlib.h>

#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>

#include "libpq-fe.h"
#include "libpq/libpq-fs.h"

#define BUFSIZE          1024

/*
 * importFile -
 *   import file "in_filename" into database as large object
 * "lobjOid"
 *
 */
static Oid
importFile(PGconn *conn, char *filename)

```

```

{
    Oid          lobjId;
    int          lobj_fd;
    char         buf[BUFSIZE];
    int          nbytes,
                tmp;
    int          fd;

    /*
     * open the file to be read in
     */
    fd = open(filename, O_RDONLY, 0666);
    if (fd < 0)
    {
        /* error */
        fprintf(stderr, "cannot open unix file \"%s\"\n", filename);
    }

    /*
     * create the large object
     */
    lobjId = lo_creat(conn, INV_READ | INV_WRITE);
    if (lobjId == 0)
        fprintf(stderr, "cannot create large object");

    lobj_fd = lo_open(conn, lobjId, INV_WRITE);

    /*
     * read in from the Unix file and write to the inversion file
     */
    while ((nbytes = read(fd, buf, BUFSIZE)) > 0)
    {
        tmp = lo_write(conn, lobj_fd, buf, nbytes);
        if (tmp < nbytes)
            fprintf(stderr, "error while reading \"%s\"",
filename);
    }

    close(fd);
    lo_close(conn, lobj_fd);

    return lobjId;
}

static void
pickout(PGconn *conn, Oid lobjId, int start, int len)
{
    int          lobj_fd;
    char         *buf;
    int          nbytes;
    int          nread;

    lobj_fd = lo_open(conn, lobjId, INV_READ);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    lo_lseek(conn, lobj_fd, start, SEEK_SET);
    buf = malloc(len + 1);

```

```

nread = 0;
while (len - nread > 0)
{
    nbytes = lo_read(conn, lobj_fd, buf, len - nread);
    buf[nbytes] = '\\0';
    fprintf(stderr, ">>> %s", buf);
    nread += nbytes;
    if (nbytes <= 0)
        break;          /* no more data? */
}
free(buf);
fprintf(stderr, "\\n");
lo_close(conn, lobj_fd);
}

static void
overwrite(PGconn *conn, Oid lobjId, int start, int len)
{
    int         lobj_fd;
    char        *buf;
    int         nbytes;
    int         nwritten;
    int         i;

    lobj_fd = lo_open(conn, lobjId, INV_WRITE);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    lo_lseek(conn, lobj_fd, start, SEEK_SET);
    buf = malloc(len + 1);

    for (i = 0; i < len; i++)
        buf[i] = 'X';
    buf[i] = '\\0';

    nwritten = 0;
    while (len - nwritten > 0)
    {
        nbytes = lo_write(conn, lobj_fd, buf + nwritten, len -
nwritten);
        nwritten += nbytes;
        if (nbytes <= 0)
        {
            fprintf(stderr, "\\nWRITE FAILED!\\n");
            break;
        }
    }
    free(buf);
    fprintf(stderr, "\\n");
    lo_close(conn, lobj_fd);
}

/*
 * exportFile -
 *   export large object "lobjOid" to file "out_filename"
 *
 */

```

```
static void
exportFile(PGconn *conn, Oid lobjId, char *filename)
{
    int          lobj_fd;
    char         buf[BUFSIZE];
    int          nbytes,
               tmp;
    int          fd;

    /*
     * open the large object
     */
    lobj_fd = lo_open(conn, lobjId, INV_READ);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    /*
     * open the file to be written to
     */
    fd = open(filename, O_CREAT | O_WRONLY | O_TRUNC, 0666);
    if (fd < 0)
    {
        /* error */
        fprintf(stderr, "cannot open unix file \"%s\"",
                filename);
    }

    /*
     * read in from the inversion file and write to the Unix file
     */
    while ((nbytes = lo_read(conn, lobj_fd, buf, BUFSIZE)) > 0)
    {
        tmp = write(fd, buf, nbytes);
        if (tmp < nbytes)
        {
            fprintf(stderr, "error while writing \"%s\"",
                    filename);
        }
    }

    lo_close(conn, lobj_fd);
    close(fd);

    return;
}

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    char         *in_filename,
               *out_filename;
    char         *database;
```

```

Oid      lobjOid;
PGconn   *conn;
PGresult *res;

if (argc != 4)
{
    fprintf(stderr, "Usage: %s database_name in_filename
out_filename\n",
            argv[0]);
    exit(1);
}

database = argv[1];
in_filename = argv[2];
out_filename = argv[3];

/*
 * set up the connection
 */
conn = PQsetdb(NULL, NULL, NULL, NULL, database);

/* check to see that the backend connection was successfully
made */
if (PQstatus(conn) != CONNECTION_OK)
{
    fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
    exit_nicely(conn);
}

/* Set always-secure search path, so malicious users can't take
control. */
res = PQexec(conn,
             "SELECT pg_catalog.set_config('search_path', '',
false)");
if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SET failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

res = PQexec(conn, "begin");
PQclear(res);
printf("importing file \"%s\" ... \n", in_filename);
/* lobjOid = importFile(conn, in_filename); */
lobjOid = lo_import(conn, in_filename);
if (lobjOid == 0)
    fprintf(stderr, "%s\n", PQerrorMessage(conn));
else
{
    printf("\tas large object %u.\n", lobjOid);

    printf("picking out bytes 1000-2000 of the large object
\n");
    pickout(conn, lobjOid, 1000, 1000);
}

```

```
        printf("overwriting bytes 1000-2000 of the large object
with X's\n");
        overwrite(conn, lobjOid, 1000, 1000);

        printf("exporting large object to file \"%s\" ...\n",
out_filename);
/*      exportFile(conn, lobjOid, out_filename); */
        if (lo_export(conn, lobjOid, out_filename) < 0)
            fprintf(stderr, "%s\n", PQerrorMessage(conn));
    }

    res = PQexec(conn, "end");
    PQclear(res);
    PQfinish(conn);
    return 0;
}
```

Chapter 35. ECPG - Embedded SQL in C

This chapter describes the embedded SQL package for PostgreSQL. It was written by Linus Tolke (<linus@epact.se>) and Michael Meskes (<meskes@postgresql.org>). Originally it was written to work with C. It also works with C++, but it does not recognize all C++ constructs yet.

This documentation is quite incomplete. But since this interface is standardized, additional information can be found in many resources about SQL.

35.1. The Concept

An embedded SQL program consists of code written in an ordinary programming language, in this case C, mixed with SQL commands in specially marked sections. To build the program, the source code (*.pgc) is first passed through the embedded SQL preprocessor, which converts it to an ordinary C program (*.c), and afterwards it can be processed by a C compiler. (For details about the compiling and linking see Section 35.10). Converted ECPG applications call functions in the libpq library through the embedded SQL library (ecpglib), and communicate with the PostgreSQL server using the normal frontend-backend protocol.

Embedded SQL has advantages over other methods for handling SQL commands from C code. First, it takes care of the tedious passing of information to and from variables in your C program. Second, the SQL code in the program is checked at build time for syntactical correctness. Third, embedded SQL in C is specified in the SQL standard and supported by many other SQL database systems. The PostgreSQL implementation is designed to match this standard as much as possible, and it is usually possible to port embedded SQL programs written for other SQL databases to PostgreSQL with relative ease.

As already stated, programs written for the embedded SQL interface are normal C programs with special code inserted to perform database-related actions. This special code always has the form:

```
EXEC SQL ... ;
```

These statements syntactically take the place of a C statement. Depending on the particular statement, they can appear at the global level or within a function. Embedded SQL statements follow the case-sensitivity rules of normal SQL code, and not those of C. Also they allow nested C-style comments that are part of the SQL standard. The C part of the program, however, follows the C standard of not accepting nested comments.

The following sections explain all the embedded SQL statements.

35.2. Managing Database Connections

This section describes how to open, close, and switch database connections.

35.2.1. Connecting to the Database Server

One connects to a database using the following statement:

```
EXEC SQL CONNECT TO target [AS connection-name] [USER user-name];
```

The *target* can be specified in the following ways:

- *dbname*[@*hostname*][:*port*]

- `tcp:postgresql://hostname[:port][/dbname][?options]`
- `unix:postgresql://hostname[:port][/dbname][?options]`
- an SQL string literal containing one of the above forms
- a reference to a character variable containing one of the above forms (see examples)
- `DEFAULT`

If you specify the connection target literally (that is, not through a variable reference) and you don't quote the value, then the case-insensitivity rules of normal SQL are applied. In that case you can also double-quote the individual parameters separately as needed. In practice, it is probably less error-prone to use a (single-quoted) string literal or a variable reference. The connection target `DEFAULT` initiates a connection to the default database under the default user name. No separate user name or connection name can be specified in that case.

There are also different ways to specify the user name:

- `username`
- `username/password`
- `username IDENTIFIED BY password`
- `username USING password`

As above, the parameters `username` and `password` can be an SQL identifier, an SQL string literal, or a reference to a character variable.

If the connection target includes any *options*, those consist of `keyword=value` specifications separated by ampersands (&). The allowed key words are the same ones recognized by libpq (see Section 33.1.2). Spaces are ignored before any *keyword* or *value*, though not within or after one. Note that there is no way to write & within a *value*.

The *connection-name* is used to handle multiple connections in one program. It can be omitted if a program uses only one connection. The most recently opened connection becomes the current connection, which is used by default when an SQL statement is to be executed (see later in this chapter).

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin each session by removing publicly-writable schemas from `search_path`. For example, add `options=-c search_path=` to *options*, or issue `EXEC SQL SELECT pg_catalog.set_config('search_path', '', false);` after connecting. This consideration is not specific to ECPG; it applies to every interface for executing arbitrary SQL commands.

Here are some examples of `CONNECT` statements:

```
EXEC SQL CONNECT TO mydb@sql.mydomain.com;

EXEC SQL CONNECT TO unix:postgresql://sql.mydomain.com/mydb AS
myconnection USER john;

EXEC SQL BEGIN DECLARE SECTION;
const char *target = "mydb@sql.mydomain.com";
const char *user = "john";
const char *passwd = "secret";
EXEC SQL END DECLARE SECTION;
...
EXEC SQL CONNECT TO :target USER :user USING :passwd;
/* or EXEC SQL CONNECT TO :target USER :user/:passwd; */
```

The last form makes use of the variant referred to above as character variable reference. You will see in later sections how C variables can be used in SQL statements when you prefix them with a colon.

Be advised that the format of the connection target is not specified in the SQL standard. So if you want to develop portable applications, you might want to use something based on the last example above to encapsulate the connection target string somewhere.

35.2.2. Choosing a Connection

SQL statements in embedded SQL programs are by default executed on the current connection, that is, the most recently opened one. If an application needs to manage multiple connections, then there are two ways to handle this.

The first option is to explicitly choose a connection for each SQL statement, for example:

```
EXEC SQL AT connection-name SELECT ...;
```

This option is particularly suitable if the application needs to use several connections in mixed order.

If your application uses multiple threads of execution, they cannot share a connection concurrently. You must either explicitly control access to the connection (using mutexes) or use a connection for each thread.

The second option is to execute a statement to switch the current connection. That statement is:

```
EXEC SQL SET CONNECTION connection-name;
```

This option is particularly convenient if many statements are to be executed on the same connection.

Here is an example program managing multiple database connections:

```
#include <stdio.h>

EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
EXEC SQL END DECLARE SECTION;

int
main()
{
    EXEC SQL CONNECT TO testdb1 AS con1 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL CONNECT TO testdb2 AS con2 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL CONNECT TO testdb3 AS con3 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    /* This query would be executed in the last opened database
"testdb3". */
    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb3)\n", dbname);

    /* Using "AT" to run a query in "testdb2" */
    EXEC SQL AT con2 SELECT current_database() INTO :dbname;
```

```
printf("current=%s (should be testdb2)\n", dbname);

/* Switch the current connection to "testdb1". */
EXEC SQL SET CONNECTION con1;

EXEC SQL SELECT current_database() INTO :dbname;
printf("current=%s (should be testdb1)\n", dbname);

EXEC SQL DISCONNECT ALL;
return 0;
}
```

This example would produce this output:

```
current=testdb3 (should be testdb3)
current=testdb2 (should be testdb2)
current=testdb1 (should be testdb1)
```

35.2.3. Closing a Connection

To close a connection, use the following statement:

```
EXEC SQL DISCONNECT [connection];
```

The *connection* can be specified in the following ways:

- *connection-name*
- DEFAULT
- CURRENT
- ALL

If no connection name is specified, the current connection is closed.

It is good style that an application always explicitly disconnect from every connection it opened.

35.3. Running SQL Commands

Any SQL command can be run from within an embedded SQL application. Below are some examples of how to do that.

35.3.1. Executing SQL Statements

Creating a table:

```
EXEC SQL CREATE TABLE foo (number integer, ascii char(16));
EXEC SQL CREATE UNIQUE INDEX num1 ON foo(number);
EXEC SQL COMMIT;
```

Inserting rows:

```
EXEC SQL INSERT INTO foo (number, ascii) VALUES (9999, 'doodad');
EXEC SQL COMMIT;
```

Deleting rows:

```
EXEC SQL DELETE FROM foo WHERE number = 9999;
EXEC SQL COMMIT;
```

Updates:

```
EXEC SQL UPDATE foo
    SET ascii = 'foobar'
    WHERE number = 9999;
EXEC SQL COMMIT;
```

SELECT statements that return a single result row can also be executed using EXEC SQL directly. To handle result sets with multiple rows, an application has to use a cursor; see Section 35.3.2 below. (As a special case, an application can fetch multiple rows at once into an array host variable; see Section 35.4.4.3.1.)

Single-row select:

```
EXEC SQL SELECT foo INTO :FooBar FROM table1 WHERE ascii =
    'doodad';
```

Also, a configuration parameter can be retrieved with the SHOW command:

```
EXEC SQL SHOW search_path INTO :var;
```

The tokens of the form *:something* are *host variables*, that is, they refer to variables in the C program. They are explained in Section 35.4.

35.3.2. Using Cursors

To retrieve a result set holding multiple rows, an application has to declare a cursor and fetch each row from the cursor. The steps to use a cursor are the following: declare a cursor, open it, fetch a row from the cursor, repeat, and finally close it.

Select using cursors:

```
EXEC SQL DECLARE foo_bar CURSOR FOR
    SELECT number, ascii FROM foo
    ORDER BY ascii;
EXEC SQL OPEN foo_bar;
EXEC SQL FETCH foo_bar INTO :FooBar, DooDad;
...
EXEC SQL CLOSE foo_bar;
EXEC SQL COMMIT;
```

For more details about declaration of the cursor, see DECLARE, and see FETCH for FETCH command details.

Note

The ECPG DECLARE command does not actually cause a statement to be sent to the PostgreSQL backend. The cursor is opened in the backend (using the backend's DECLARE command) at the point when the OPEN command is executed.

35.3.3. Managing Transactions

In the default mode, statements are committed only when `EXEC SQL COMMIT` is issued. The embedded SQL interface also supports autocommit of transactions (similar to `psql`'s default behavior) via the `-t` command-line option to `ecpg` (see `ecpg`) or via the `EXEC SQL SET AUTOCOMMIT TO ON` statement. In autocommit mode, each command is automatically committed unless it is inside an explicit transaction block. This mode can be explicitly turned off using `EXEC SQL SET AUTOCOMMIT TO OFF`.

The following transaction management commands are available:

```
EXEC SQL COMMIT
```

Commit an in-progress transaction.

```
EXEC SQL ROLLBACK
```

Roll back an in-progress transaction.

```
EXEC SQL PREPARE TRANSACTION transaction_id
```

Prepare the current transaction for two-phase commit.

```
EXEC SQL COMMIT PREPARED transaction_id
```

Commit a transaction that is in prepared state.

```
EXEC SQL ROLLBACK PREPARED transaction_id
```

Roll back a transaction that is in prepared state.

```
EXEC SQL SET AUTOCOMMIT TO ON
```

Enable autocommit mode.

```
EXEC SQL SET AUTOCOMMIT TO OFF
```

Disable autocommit mode. This is the default.

35.3.4. Prepared Statements

When the values to be passed to an SQL statement are not known at compile time, or the same statement is going to be used many times, then prepared statements can be useful.

The statement is prepared using the command `PREPARE`. For the values that are not known yet, use the placeholder “?”:

```
EXEC SQL PREPARE stmt1 FROM "SELECT oid, datname FROM pg_database
WHERE oid = ?";
```

If a statement returns a single row, the application can call `EXECUTE` after `PREPARE` to execute the statement, supplying the actual values for the placeholders with a `USING` clause:

```
EXEC SQL EXECUTE stmt1 INTO :dboid, :dbname USING 1;
```

If a statement returns multiple rows, the application can use a cursor declared based on the prepared statement. To bind input parameters, the cursor must be opened with a `USING` clause:

```
EXEC SQL PREPARE stmt1 FROM "SELECT oid,datname FROM pg_database
WHERE oid > ?";
EXEC SQL DECLARE foo_bar CURSOR FOR stmt1;

/* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

EXEC SQL OPEN foo_bar USING 100;
...
while (1)
{
    EXEC SQL FETCH NEXT FROM foo_bar INTO :dboid, :dbname;
    ...
}
EXEC SQL CLOSE foo_bar;
```

When you don't need the prepared statement anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE PREPARE name;
```

For more details about `PREPARE`, see `PREPARE`. Also see Section 35.5 for more details about using placeholders and input parameters.

35.4. Using Host Variables

In Section 35.3 you saw how you can execute SQL statements from an embedded SQL program. Some of those statements only used fixed values and did not provide a way to insert user-supplied values into statements or have the program process the values returned by the query. Those kinds of statements are not really useful in real applications. This section explains in detail how you can pass data between your C program and the embedded SQL statements using a simple mechanism called *host variables*. In an embedded SQL program we consider the SQL statements to be *guests* in the C program code which is the *host language*. Therefore the variables of the C program are called *host variables*.

Another way to exchange values between PostgreSQL backends and ECPG applications is the use of SQL descriptors, described in Section 35.7.

35.4.1. Overview

Passing data between the C program and the SQL statements is particularly simple in embedded SQL. Instead of having the program paste the data into the statement, which entails various complications, such as properly quoting the value, you can simply write the name of a C variable into the SQL statement, prefixed by a colon. For example:

```
EXEC SQL INSERT INTO sometable VALUES (:v1, 'foo', :v2);
```

This statement refers to two C variables named `v1` and `v2` and also uses a regular SQL string literal, to illustrate that you are not restricted to use one kind of data or the other.

This style of inserting C variables in SQL statements works anywhere a value expression is expected in an SQL statement.

35.4.2. Declare Sections

To pass data from the program to the database, for example as parameters in a query, or to pass data from the database back to the program, the C variables that are intended to contain this data need to be declared in specially marked sections, so the embedded SQL preprocessor is made aware of them.

This section starts with:

```
EXEC SQL BEGIN DECLARE SECTION;
```

and ends with:

```
EXEC SQL END DECLARE SECTION;
```

Between those lines, there must be normal C variable declarations, such as:

```
int    x = 4;
char   foo[16], bar[16];
```

As you can see, you can optionally assign an initial value to the variable. The variable's scope is determined by the location of its declaring section within the program. You can also declare variables with the following syntax which implicitly creates a declare section:

```
EXEC SQL int i = 4;
```

You can have as many declare sections in a program as you like.

The declarations are also echoed to the output file as normal C variables, so there's no need to declare them again. Variables that are not intended to be used in SQL commands can be declared normally outside these special sections.

The definition of a structure or union also must be listed inside a DECLARE section. Otherwise the preprocessor cannot handle these types since it does not know the definition.

35.4.3. Retrieving Query Results

Now you should be able to pass data generated by your program into an SQL command. But how do you retrieve the results of a query? For that purpose, embedded SQL provides special variants of the usual commands `SELECT` and `FETCH`. These commands have a special `INTO` clause that specifies which host variables the retrieved values are to be stored in. `SELECT` is used for a query that returns only single row, and `FETCH` is used for a query that returns multiple rows, using a cursor.

Here is an example:

```
/*
 * assume this table:
 * CREATE TABLE test1 (a int, b varchar(50));
 */

EXEC SQL BEGIN DECLARE SECTION;
int v1;
VARCHAR v2;
EXEC SQL END DECLARE SECTION;

...

EXEC SQL SELECT a, b INTO :v1, :v2 FROM test;
```

So the `INTO` clause appears between the select list and the `FROM` clause. The number of elements in the select list and the list after `INTO` (also called the target list) must be equal.

Here is an example using the command `FETCH`:

```
EXEC SQL BEGIN DECLARE SECTION;
int v1;
VARCHAR v2;
EXEC SQL END DECLARE SECTION;

...

EXEC SQL DECLARE foo CURSOR FOR SELECT a, b FROM test;

...

do
{
    ...
    EXEC SQL FETCH NEXT FROM foo INTO :v1, :v2;
    ...
} while (...);
```

Here the `INTO` clause appears after all the normal clauses.

35.4.4. Type Mapping

When ECPG applications exchange values between the PostgreSQL server and the C application, such as when retrieving query results from the server or executing SQL statements with input parameters, the values need to be converted between PostgreSQL data types and host language variable types (C language data types, concretely). One of the main points of ECPG is that it takes care of this automatically in most cases.

In this respect, there are two kinds of data types: Some simple PostgreSQL data types, such as `integer` and `text`, can be read and written by the application directly. Other PostgreSQL data types, such as `timestamp` and `numeric` can only be accessed through special library functions; see Section 35.4.4.2.

Table 35.1 shows which PostgreSQL data types correspond to which C data types. When you wish to send or receive a value of a given PostgreSQL data type, you should declare a C variable of the corresponding C data type in the declare section.

Table 35.1. Mapping Between PostgreSQL Data Types and C Variable Types

PostgreSQL data type	Host variable type
<code>smallint</code>	<code>short</code>
<code>integer</code>	<code>int</code>
<code>bigint</code>	<code>long long int</code>
<code>decimal</code>	<code>decimal^a</code>
<code>numeric</code>	<code>numeric^a</code>
<code>real</code>	<code>float</code>
<code>double precision</code>	<code>double</code>
<code>smallserial</code>	<code>short</code>
<code>serial</code>	<code>int</code>
<code>bigserial</code>	<code>long long int</code>
<code>oid</code>	<code>unsigned int</code>

PostgreSQL data type	Host variable type
<code>character(n)</code> , <code>varchar(n)</code> , <code>text</code>	<code>char[n+1]</code> , <code>VARCHAR[n+1]</code>
<code>name</code>	<code>char[NAMEDATALEN]</code>
<code>timestamp</code>	<code>timestamp^a</code>
<code>interval</code>	<code>interval^a</code>
<code>date</code>	<code>date^a</code>
<code>boolean</code>	<code>bool^b</code>
<code>bytea</code>	<code>char*</code> , <code>bytea[n]</code>

^aThis type can only be accessed through special library functions; see Section 35.4.4.2.

^bdeclared in `ecpglib.h` if not native

35.4.4.1. Handling Character Strings

To handle SQL character string data types, such as `varchar` and `text`, there are two possible ways to declare the host variables.

One way is using `char[]`, an array of `char`, which is the most common way to handle character data in C.

```
EXEC SQL BEGIN DECLARE SECTION;
    char str[50];
EXEC SQL END DECLARE SECTION;
```

Note that you have to take care of the length yourself. If you use this host variable as the target variable of a query which returns a string with more than 49 characters, a buffer overflow occurs.

The other way is using the `VARCHAR` type, which is a special type provided by ECPG. The definition on an array of type `VARCHAR` is converted into a named `struct` for every variable. A declaration like:

```
VARCHAR var[180];
```

is converted into:

```
struct varchar_var { int len; char arr[180]; } var;
```

The member `arr` hosts the string including a terminating zero byte. Thus, to store a string in a `VARCHAR` host variable, the host variable has to be declared with the length including the zero byte terminator. The member `len` holds the length of the string stored in the `arr` without the terminating zero byte. When a host variable is used as input for a query, if `strlen(arr)` and `len` are different, the shorter one is used.

`VARCHAR` can be written in upper or lower case, but not in mixed case.

`char` and `VARCHAR` host variables can also hold values of other SQL types, which will be stored in their string forms.

35.4.4.2. Accessing Special Data Types

ECPG contains some special types that help you to interact easily with some special data types from the PostgreSQL server. In particular, it has implemented support for the `numeric`, `decimal`, `date`, `timestamp`, and `interval` types. These data types cannot usefully be mapped to primitive host variable types (such as `int`, `long long int`, or `char[]`), because they have a complex internal structure. Applications deal with these types by declaring host variables in special types and accessing them using functions in the `pgtypes` library. The `pgtypes` library, described in detail in Section 35.6

contains basic functions to deal with those types, such that you do not need to send a query to the SQL server just for adding an interval to a time stamp for example.

The follow subsections describe these special data types. For more details about pgtypes library functions, see Section 35.6.

35.4.4.2.1. timestamp, date

Here is a pattern for handling `timestamp` variables in the ECPG host application.

First, the program has to include the header file for the `timestamp` type:

```
#include <pgtypes_timestamp.h>
```

Next, declare a host variable as type `timestamp` in the declare section:

```
EXEC SQL BEGIN DECLARE SECTION;
timestamp ts;
EXEC SQL END DECLARE SECTION;
```

And after reading a value into the host variable, process it using `pgtypes` library functions. In following example, the `timestamp` value is converted into text (ASCII) form with the `PGTYPEStimestamp_to_asc()` function:

```
EXEC SQL SELECT now()::timestamp INTO :ts;

printf("ts = %s\n", PGTYPEStimestamp_to_asc(ts));
```

This example will show some result like following:

```
ts = 2010-06-27 18:03:56.949343
```

In addition, the `DATE` type can be handled in the same way. The program has to include `pgtypes_date.h`, declare a host variable as the date type and convert a `DATE` value into a text form using `PGTYPESdate_to_asc()` function. For more details about the `pgtypes` library functions, see Section 35.6.

35.4.4.2.2. interval

The handling of the `interval` type is also similar to the `timestamp` and `date` types. It is required, however, to allocate memory for an `interval` type value explicitly. In other words, the memory space for the variable has to be allocated in the heap memory, not in the stack memory.

Here is an example program:

```
#include <stdio.h>
#include <stdlib.h>
#include <pgtypes_interval.h>

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    interval *in;
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL CONNECT TO testdb;
EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

in = PGTYPEStinterval_new();
EXEC SQL SELECT '1 min'::interval INTO :in;
printf("interval = %s\n", PGTYPEStinterval_to_asc(in));
PGTYPEStinterval_free(in);

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
return 0;
}
```

35.4.4.2.3. numeric, decimal

The handling of the `numeric` and `decimal` types is similar to the `interval` type: It requires defining a pointer, allocating some memory space on the heap, and accessing the variable using the `pgtypes` library functions. For more details about the `pgtypes` library functions, see Section 35.6.

No functions are provided specifically for the `decimal` type. An application has to convert it to a `numeric` variable using a `pgtypes` library function to do further processing.

Here is an example program handling `numeric` and `decimal` type variables.

```
#include <stdio.h>
#include <stdlib.h>
#include <pgtypes_numeric.h>

EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    numeric *num;
    numeric *num2;
    decimal *dec;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    num = PGTYPEStnumeric_new();
    dec = PGTYPEStdecimal_new();

    EXEC SQL SELECT 12.345::numeric(4,2), 23.456::decimal(4,2)
INTO :num, :dec;

    printf("numeric = %s\n", PGTYPEStnumeric_to_asc(num, 0));
    printf("numeric = %s\n", PGTYPEStnumeric_to_asc(num, 1));
    printf("numeric = %s\n", PGTYPEStnumeric_to_asc(num, 2));

    /* Convert decimal to numeric to show a decimal value. */
    num2 = PGTYPEStnumeric_new();
    PGTYPEStnumeric_from_decimal(dec, num2);
}
```

```

printf("decimal = %s\n", PGTYPEStoasc(num2, 0));
printf("decimal = %s\n", PGTYPEStoasc(num2, 1));
printf("decimal = %s\n", PGTYPEStoasc(num2, 2));

PGTYPEStoasc_free(num2);
PGTYPEStoasc_free(dec);
PGTYPEStoasc_free(num);

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
return 0;
}

```

35.4.4.2.4. bytea

The handling of the `bytea` type is similar to that of `VARCHAR`. The definition on an array of type `bytea` is converted into a named struct for every variable. A declaration like:

```
bytea var[180];
```

is converted into:

```
struct bytea_var { int len; char arr[180]; } var;
```

The member `arr` hosts binary format data. It can also handle `'\0'` as part of data, unlike `VARCHAR`. The data is converted from/to hex format and sent/received by `ecpglib`.

Note

`bytea` variable can be used only when `bytea_output` is set to `hex`.

35.4.4.3. Host Variables with Nonprimitive Types

As a host variable you can also use arrays, typedefs, structs, and pointers.

35.4.4.3.1. Arrays

There are two use cases for arrays as host variables. The first is a way to store some text string in `char[]` or `VARCHAR[]`, as explained in Section 35.4.4.1. The second use case is to retrieve multiple rows from a query result without using a cursor. Without an array, to process a query result consisting of multiple rows, it is required to use a cursor and the `FETCH` command. But with array host variables, multiple rows can be received at once. The length of the array has to be defined to be able to accommodate all rows, otherwise a buffer overflow will likely occur.

Following example scans the `pg_database` system table and shows all OIDs and names of the available databases:

```

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    int dbid[8];
    char dbname[8][16];
    int i;

```

```
EXEC SQL END DECLARE SECTION;

    memset(dbname, 0, sizeof(char)* 16 * 8);
    memset(dbid, 0, sizeof(int) * 8);

    EXEC SQL CONNECT TO testdb;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    /* Retrieve multiple rows into arrays at once. */
    EXEC SQL SELECT oid,datname INTO :dbid, :dbname FROM
pg_database;

    for (i = 0; i < 8; i++)
        printf("oid=%d, dbname=%s\n", dbid[i], dbname[i]);

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

This example shows following result. (The exact values depend on local circumstances.)

```
oid=1, dbname=template1
oid=11510, dbname=template0
oid=11511, dbname=postgres
oid=313780, dbname=testdb
oid=0, dbname=
oid=0, dbname=
oid=0, dbname=
```

35.4.4.3.2. Structures

A structure whose member names match the column names of a query result, can be used to retrieve multiple columns at once. The structure enables handling multiple column values in a single host variable.

The following example retrieves OIDs, names, and sizes of the available databases from the `pg_database` system table and using the `pg_database_size()` function. In this example, a structure variable `dbinfo_t` with members whose names match each column in the `SELECT` result is used to retrieve one result row without putting multiple host variables in the `FETCH` statement.

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef struct
    {
        int oid;
        char datname[65];
        long long int size;
    } dbinfo_t;

    dbinfo_t dbval;
EXEC SQL END DECLARE SECTION;

    memset(&dbval, 0, sizeof(dbinfo_t));

    EXEC SQL DECLARE curl CURSOR FOR SELECT oid, datname,
pg_database_size(oid) AS size FROM pg_database;
```

```
EXEC SQL OPEN curl;

/* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Fetch multiple columns into one structure. */
    EXEC SQL FETCH FROM curl INTO :dbval;

    /* Print members of the structure. */
    printf("oid=%d, datname=%s, size=%lld\n", dbval.oid,
dbval.datname, dbval.size);
}

EXEC SQL CLOSE curl;
```

This example shows following result. (The exact values depend on local circumstances.)

```
oid=1, datname=templatel, size=4324580
oid=11510, datname=template0, size=4243460
oid=11511, datname=postgres, size=4324580
oid=313780, datname=testdb, size=8183012
```

Structure host variables “absorb” as many columns as the structure as fields. Additional columns can be assigned to other host variables. For example, the above program could also be restructured like this, with the size variable outside the structure:

```
EXEC SQL BEGIN DECLARE SECTION;
typedef struct
{
    int oid;
    char datname[65];
} dbinfo_t;

dbinfo_t dbval;
long long int size;
EXEC SQL END DECLARE SECTION;

memset(&dbval, 0, sizeof(dbinfo_t));

EXEC SQL DECLARE curl CURSOR FOR SELECT oid, datname,
pg_database_size(oid) AS size FROM pg_database;
EXEC SQL OPEN curl;

/* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Fetch multiple columns into one structure. */
    EXEC SQL FETCH FROM curl INTO :dbval, :size;

    /* Print members of the structure. */
    printf("oid=%d, datname=%s, size=%lld\n", dbval.oid,
dbval.datname, size);
}
```

```
EXEC SQL CLOSE curl;
```

35.4.4.3.3. Typedefs

Use the `typedef` keyword to map new types to already existing types.

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef char mychartype[40];
    typedef long serial_t;
EXEC SQL END DECLARE SECTION;
```

Note that you could also use:

```
EXEC SQL TYPE serial_t IS long;
```

This declaration does not need to be part of a declare section.

35.4.4.3.4. Pointers

You can declare pointers to the most common types. Note however that you cannot use pointers as target variables of queries without auto-allocation. See Section 35.7 for more information on auto-allocation.

```
EXEC SQL BEGIN DECLARE SECTION;
    int    *intp;
    char  **charp;
EXEC SQL END DECLARE SECTION;
```

35.4.5. Handling Nonprimitive SQL Data Types

This section contains information on how to handle nonscalar and user-defined SQL-level data types in ECPG applications. Note that this is distinct from the handling of host variables of nonprimitive types, described in the previous section.

35.4.5.1. Arrays

Multi-dimensional SQL-level arrays are not directly supported in ECPG. One-dimensional SQL-level arrays can be mapped into C array host variables and vice-versa. However, when creating a statement `ecpg` does not know the types of the columns, so that it cannot check if a C array is input into a corresponding SQL-level array. When processing the output of a SQL statement, `ecpg` has the necessary information and thus checks if both are arrays.

If a query accesses *elements* of an array separately, then this avoids the use of arrays in ECPG. Then, a host variable with a type that can be mapped to the element type should be used. For example, if a column type is array of `integer`, a host variable of type `int` can be used. Also if the element type is `varchar` or `text`, a host variable of type `char[]` or `VARCHAR[]` can be used.

Here is an example. Assume the following table:

```
CREATE TABLE t3 (
    ii integer[]
);

testdb=> SELECT * FROM t3;
```

```
      ii
-----
{1,2,3,4,5}
(1 row)
```

The following example program retrieves the 4th element of the array and stores it into a host variable of type int:

```
EXEC SQL BEGIN DECLARE SECTION;
int ii;
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii[4] FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1 INTO :ii ;
    printf("ii=%d\n", ii);
}

EXEC SQL CLOSE cur1;
```

This example shows the following result:

```
ii=4
```

To map multiple array elements to the multiple elements in an array type host variables each element of array column and each element of the host variable array have to be managed separately, for example:

```
EXEC SQL BEGIN DECLARE SECTION;
int ii_a[8];
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii[1], ii[2], ii[3], ii[4]
FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1
    INTO :ii_a[0], :ii_a[1], :ii_a[2], :ii_a[3];
    ...
}

```

Note again that

```
EXEC SQL BEGIN DECLARE SECTION;
int ii_a[8];
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii FROM t3;
```

```
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* WRONG */
    EXEC SQL FETCH FROM cur1 INTO :ii_a;
    ...
}
```

would not work correctly in this case, because you cannot map an array type column to an array host variable directly.

Another workaround is to store arrays in their external string representation in host variables of type `char[]` or `VARCHAR[]`. For more details about this representation, see Section 8.15.2. Note that this means that the array cannot be accessed naturally as an array in the host program (without further processing that parses the text representation).

35.4.5.2. Composite Types

Composite types are not directly supported in ECPG, but an easy workaround is possible. The available workarounds are similar to the ones described for arrays above: Either access each attribute separately or use the external string representation.

For the following examples, assume the following type and table:

```
CREATE TYPE comp_t AS (intval integer, textval varchar(32));
CREATE TABLE t4 (compval comp_t);
INSERT INTO t4 VALUES ( (256, 'PostgreSQL') );
```

The most obvious solution is to access each attribute separately. The following program retrieves data from the example table by selecting each attribute of the type `comp_t` separately:

```
EXEC SQL BEGIN DECLARE SECTION;
int intval;
varchar textval[33];
EXEC SQL END DECLARE SECTION;

/* Put each element of the composite type column in the SELECT
list. */
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).intval,
(compval).textval FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Fetch each element of the composite type column into host
variables. */
    EXEC SQL FETCH FROM cur1 INTO :intval, :textval;

    printf("intval=%d, textval=%s\n", intval, textval.arr);
}

EXEC SQL CLOSE cur1;
```

To enhance this example, the host variables to store values in the `FETCH` command can be gathered into one structure. For more details about the host variable in the structure form, see Section 35.4.4.3.2. To switch to the structure, the example can be modified as below. The two host variables, `intval` and `textval`, become members of the `comp_t` structure, and the structure is specified on the `FETCH` command.

```
EXEC SQL BEGIN DECLARE SECTION;
typedef struct
{
    int intval;
    varchar textval[33];
} comp_t;

comp_t compval;
EXEC SQL END DECLARE SECTION;

/* Put each element of the composite type column in the SELECT
list. */
EXEC SQL DECLARE curl CURSOR FOR SELECT (compval).intval,
(compval).textval FROM t4;
EXEC SQL OPEN curl;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Put all values in the SELECT list into one structure. */
    EXEC SQL FETCH FROM curl INTO :compval;

    printf("intval=%d, textval=%s\n", compval.intval,
compval.textval.arr);
}

EXEC SQL CLOSE curl;
```

Although a structure is used in the `FETCH` command, the attribute names in the `SELECT` clause are specified one by one. This can be enhanced by using a `*` to ask for all attributes of the composite type value.

```
...
EXEC SQL DECLARE curl CURSOR FOR SELECT (compval).* FROM t4;
EXEC SQL OPEN curl;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Put all values in the SELECT list into one structure. */
    EXEC SQL FETCH FROM curl INTO :compval;

    printf("intval=%d, textval=%s\n", compval.intval,
compval.textval.arr);
}
...
```

This way, composite types can be mapped into structures almost seamlessly, even though ECPG does not understand the composite type itself.

Finally, it is also possible to store composite type values in their external string representation in host variables of type `char []` or `VARCHAR[]`. But that way, it is not easily possible to access the fields of the value from the host program.

35.4.5.3. User-Defined Base Types

New user-defined base types are not directly supported by ECPG. You can use the external string representation and host variables of type `char []` or `VARCHAR[]`, and this solution is indeed appropriate and sufficient for many types.

Here is an example using the data type `complex` from the example in Section 37.13. The external string representation of that type is `(%f,%f)`, which is defined in the functions `complex_in()` and `complex_out()` functions in Section 37.13. The following example inserts the `complex` type values `(1,1)` and `(3,3)` into the columns `a` and `b`, and select them from the table after that.

```
EXEC SQL BEGIN DECLARE SECTION;
    varchar a[64];
    varchar b[64];
EXEC SQL END DECLARE SECTION;

EXEC SQL INSERT INTO test_complex VALUES ('(1,1)', '(3,3)');

EXEC SQL DECLARE cur1 CURSOR FOR SELECT a, b FROM test_complex;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1 INTO :a, :b;
    printf("a=%s, b=%s\n", a.arr, b.arr);
}

EXEC SQL CLOSE cur1;
```

This example shows following result:

```
a=(1,1), b=(3,3)
```

Another workaround is avoiding the direct use of the user-defined types in ECPG and instead create a function or cast that converts between the user-defined type and a primitive type that ECPG can handle. Note, however, that type casts, especially implicit ones, should be introduced into the type system very carefully.

For example,

```
CREATE FUNCTION create_complex(r double, i double) RETURNS complex
LANGUAGE SQL
IMMUTABLE
AS $$ SELECT $1 * complex '(1,0)' + $2 * complex '(0,1)' $$;
```

After this definition, the following

```
EXEC SQL BEGIN DECLARE SECTION;
double a, b, c, d;
EXEC SQL END DECLARE SECTION;
```

```
a = 1;
b = 2;
c = 3;
d = 4;
```

```
EXEC SQL INSERT INTO test_complex VALUES (create_complex(:a, :b),
      create_complex(:c, :d));
```

has the same effect as

```
EXEC SQL INSERT INTO test_complex VALUES ('(1,2)', '(3,4)');
```

35.4.6. Indicators

The examples above do not handle null values. In fact, the retrieval examples will raise an error if they fetch a null value from the database. To be able to pass null values to the database or retrieve null values from the database, you need to append a second host variable specification to each host variable that contains data. This second host variable is called the *indicator* and contains a flag that tells whether the datum is null, in which case the value of the real host variable is ignored. Here is an example that handles the retrieval of null values correctly:

```
EXEC SQL BEGIN DECLARE SECTION;
VARCHAR val;
int val_ind;
EXEC SQL END DECLARE SECTION;

...

EXEC SQL SELECT b INTO :val :val_ind FROM test1;
```

The indicator variable `val_ind` will be zero if the value was not null, and it will be negative if the value was null.

The indicator has another function: if the indicator value is positive, it means that the value is not null, but it was truncated when it was stored in the host variable.

If the argument `-r no_indicator` is passed to the preprocessor `ecpg`, it works in “no-indicator” mode. In no-indicator mode, if no indicator variable is specified, null values are signaled (on input and output) for character string types as empty string and for integer types as the lowest possible value for type (for example, `INT_MIN` for `int`).

35.5. Dynamic SQL

In many cases, the particular SQL statements that an application has to execute are known at the time the application is written. In some cases, however, the SQL statements are composed at run time or provided by an external source. In these cases you cannot embed the SQL statements directly into the C source code, but there is a facility that allows you to call arbitrary SQL statements that you provide in a string variable.

35.5.1. Executing Statements without a Result Set

The simplest way to execute an arbitrary SQL statement is to use the command `EXECUTE IMMEDIATE`. For example:

```
EXEC SQL BEGIN DECLARE SECTION;
```

```
const char *stmt = "CREATE TABLE test1 (...);";
EXEC SQL END DECLARE SECTION;

EXEC SQL EXECUTE IMMEDIATE :stmt;
```

EXECUTE IMMEDIATE can be used for SQL statements that do not return a result set (e.g., DDL, INSERT, UPDATE, DELETE). You cannot execute statements that retrieve data (e.g., SELECT) this way. The next section describes how to do that.

35.5.2. Executing a Statement with Input Parameters

A more powerful way to execute arbitrary SQL statements is to prepare them once and execute the prepared statement as often as you like. It is also possible to prepare a generalized version of a statement and then execute specific versions of it by substituting parameters. When preparing the statement, write question marks where you want to substitute parameters later. For example:

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "INSERT INTO test1 VALUES(?, ?)";
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE mystmt FROM :stmt;
...
EXEC SQL EXECUTE mystmt USING 42, 'foobar';
```

When you don't need the prepared statement anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE PREPARE name;
```

35.5.3. Executing a Statement with a Result Set

To execute an SQL statement with a single result row, EXECUTE can be used. To save the result, add an INTO clause.

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "SELECT a, b, c FROM test1 WHERE a > ?";
int v1, v2;
VARCHAR v3[50];
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE mystmt FROM :stmt;
...
EXEC SQL EXECUTE mystmt INTO :v1, :v2, :v3 USING 37;
```

An EXECUTE command can have an INTO clause, a USING clause, both, or neither.

If a query is expected to return more than one result row, a cursor should be used, as in the following example. (See Section 35.3.2 for more details about the cursor.)

```
EXEC SQL BEGIN DECLARE SECTION;
char dbaname[128];
char datname[128];
char *stmt = "SELECT u.username as dbaname, d.datname "
            " FROM pg_database d, pg_user u "
            " WHERE d.datdba = u.usesysid";
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL CONNECT TO testdb AS con1 USER testuser;
EXEC SQL SELECT pg_catalog.set_config('search_path', '', false);
EXEC SQL COMMIT;

EXEC SQL PREPARE stmt1 FROM :stmt;

EXEC SQL DECLARE cursor1 CURSOR FOR stmt1;
EXEC SQL OPEN cursor1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH cursor1 INTO :dbaname,:datname;
    printf("dbaname=%s, datname=%s\n", dbaname, datname);
}

EXEC SQL CLOSE cursor1;

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
```

35.6. pgtypes Library

The `pgtypes` library maps PostgreSQL database types to C equivalents that can be used in C programs. It also offers functions to do basic calculations with those types within C, i.e., without the help of the PostgreSQL server. See the following example:

```
EXEC SQL BEGIN DECLARE SECTION;
    date datel;
    timestamp ts1, tsout;
    interval iv1;
    char *out;
EXEC SQL END DECLARE SECTION;

PGTYPESdate_today(&datel);
EXEC SQL SELECT started, duration INTO :ts1, :iv1 FROM datetbl
    WHERE d=:datel;
PGTYPEStimestamp_add_interval(&ts1, &iv1, &tsout);
out = PGTYPEStimestamp_to_asc(&tsout);
printf("Started + duration: %s\n", out);
PGTYPESchar_free(out);
```

35.6.1. Character Strings

Some functions such as `PGTYPESnumeric_to_asc` return a pointer to a freshly allocated character string. These results should be freed with `PGTYPESchar_free` instead of `free`. (This is important only on Windows, where memory allocation and release sometimes need to be done by the same library.)

35.6.2. The numeric Type

The numeric type offers to do calculations with arbitrary precision. See Section 8.1 for the equivalent type in the PostgreSQL server. Because of the arbitrary precision this variable needs to be able

to expand and shrink dynamically. That's why you can only create numeric variables on the heap, by means of the `PGTYPESnumeric_new` and `PGTYPESnumeric_free` functions. The decimal type, which is similar but limited in precision, can be created on the stack as well as on the heap.

The following functions can be used to work with the numeric type:

`PGTYPESnumeric_new`

Request a pointer to a newly allocated numeric variable.

```
numeric *PGTYPESnumeric_new(void);
```

`PGTYPESnumeric_free`

Free a numeric type, release all of its memory.

```
void PGTYPESnumeric_free(numeric *var);
```

`PGTYPESnumeric_from_asc`

Parse a numeric type from its string notation.

```
numeric *PGTYPESnumeric_from_asc(char *str, char **endptr);
```

Valid formats are for example: `-2`, `.794`, `+3.44`, `592.49E07` or `-32.84e-4`. If the value could be parsed successfully, a valid pointer is returned, else the NULL pointer. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to NULL.

`PGTYPESnumeric_to_asc`

Returns a pointer to a string allocated by `malloc` that contains the string representation of the numeric type `num`.

```
char *PGTYPESnumeric_to_asc(numeric *num, int dscale);
```

The numeric value will be printed with `dscale` decimal digits, with rounding applied if necessary. The result must be freed with `PGTYPESchar_free()`.

`PGTYPESnumeric_add`

Add two numeric variables into a third one.

```
int PGTYPESnumeric_add(numeric *var1, numeric *var2, numeric *result);
```

The function adds the variables `var1` and `var2` into the result variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_sub`

Subtract two numeric variables and return the result in a third one.

```
int PGTYPESnumeric_sub(numeric *var1, numeric *var2, numeric *result);
```

The function subtracts the variable `var2` from the variable `var1`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_mul`

Multiply two numeric variables and return the result in a third one.

```
int PGTYPESnumeric_mul(numeric *var1, numeric *var2, numeric
    *result);
```

The function multiplies the variables `var1` and `var2`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_div`

Divide two numeric variables and return the result in a third one.

```
int PGTYPESnumeric_div(numeric *var1, numeric *var2, numeric
    *result);
```

The function divides the variables `var1` by `var2`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_cmp`

Compare two numeric variables.

```
int PGTYPESnumeric_cmp(numeric *var1, numeric *var2)
```

This function compares two numeric variables. In case of error, `INT_MAX` is returned. On success, the function returns one of three possible results:

- 1, if `var1` is bigger than `var2`
- -1, if `var1` is smaller than `var2`
- 0, if `var1` and `var2` are equal

`PGTYPESnumeric_from_int`

Convert an int variable to a numeric variable.

```
int PGTYPESnumeric_from_int(signed int int_val, numeric *var);
```

This function accepts a variable of type `signed int` and stores it in the numeric variable `var`. Upon success, 0 is returned and -1 in case of a failure.

`PGTYPESnumeric_from_long`

Convert a long int variable to a numeric variable.

```
int PGTYPESnumeric_from_long(signed long int long_val, numeric
    *var);
```

This function accepts a variable of type `signed long int` and stores it in the numeric variable `var`. Upon success, 0 is returned and -1 in case of a failure.

PGTYPESnumeric_copy

Copy over one numeric variable into another one.

```
int PGTYPESnumeric_copy(numeric *src, numeric *dst);
```

This function copies over the value of the variable that `src` points to into the variable that `dst` points to. It returns 0 on success and -1 if an error occurs.

PGTYPESnumeric_from_double

Convert a variable of type double to a numeric.

```
int PGTYPESnumeric_from_double(double d, numeric *dst);
```

This function accepts a variable of type double and stores the result in the variable that `dst` points to. It returns 0 on success and -1 if an error occurs.

PGTYPESnumeric_to_double

Convert a variable of type numeric to double.

```
int PGTYPESnumeric_to_double(numeric *nv, double *dp)
```

The function converts the numeric value from the variable that `nv` points to into the double variable that `dp` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

PGTYPESnumeric_to_int

Convert a variable of type numeric to int.

```
int PGTYPESnumeric_to_int(numeric *nv, int *ip);
```

The function converts the numeric value from the variable that `nv` points to into the integer variable that `ip` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

PGTYPESnumeric_to_long

Convert a variable of type numeric to long.

```
int PGTYPESnumeric_to_long(numeric *nv, long *lp);
```

The function converts the numeric value from the variable that `nv` points to into the long integer variable that `lp` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

PGTYPESnumeric_to_decimal

Convert a variable of type numeric to decimal.

```
int PGTYPESnumeric_to_decimal(numeric *src, decimal *dst);
```

The function converts the numeric value from the variable that `src` points to into the decimal variable that `dst` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_from_decimal`

Convert a variable of type decimal to numeric.

```
int PGTYPESnumeric_from_decimal(decimal *src, numeric *dst);
```

The function converts the decimal value from the variable that `src` points to into the numeric variable that `dst` points to. It returns 0 on success and -1 if an error occurs. Since the decimal type is implemented as a limited version of the numeric type, overflow cannot occur with this conversion.

35.6.3. The date Type

The date type in C enables your programs to deal with data of the SQL type date. See Section 8.5 for the equivalent type in the PostgreSQL server.

The following functions can be used to work with the date type:

`PGTYPESdate_from_timestamp`

Extract the date part from a timestamp.

```
date PGTYPESdate_from_timestamp(timestamp dt);
```

The function receives a timestamp as its only argument and returns the extracted date part from this timestamp.

`PGTYPESdate_from_asc`

Parse a date from its textual representation.

```
date PGTYPESdate_from_asc(char *str, char **endptr);
```

The function receives a C `char*` string `str` and a pointer to a C `char*` string `endptr`. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to `NULL`.

Note that the function always assumes MDY-formatted dates and there is currently no variable to change that within ECPG.

Table 35.2 shows the allowed input formats.

Table 35.2. Valid Input Formats for `PGTYPESdate_from_asc`

Input	Result
January 8, 1999	January 8, 1999
1999-01-08	January 8, 1999
1/8/1999	January 8, 1999
1/18/1999	January 18, 1999
01/02/03	February 1, 2003
1999-Jan-08	January 8, 1999
Jan-08-1999	January 8, 1999
08-Jan-1999	January 8, 1999

Input	Result
99-Jan-08	January 8, 1999
08-Jan-99	January 8, 1999
08-Jan-06	January 8, 2006
Jan-08-99	January 8, 1999
19990108	ISO 8601; January 8, 1999
990108	ISO 8601; January 8, 1999
1999.008	year and day of year
J2451187	Julian day
January 8, 99 BC	year 99 before the Common Era

PGTYPEdate_to_asc

Return the textual representation of a date variable.

```
char *PGTYPEdate_to_asc(date dDate);
```

The function receives the date `dDate` as its only parameter. It will output the date in the form 1999-01-18, i.e., in the YYYY-MM-DD format. The result must be freed with `PGTYPE-Schar_free()`.

PGTYPEdate_julmdy

Extract the values for the day, the month and the year from a variable of type date.

```
void PGTYPEdate_julmdy(date d, int *mdy);
```

The function receives the date `d` and a pointer to an array of 3 integer values `mdy`. The variable name indicates the sequential order: `mdy[0]` will be set to contain the number of the month, `mdy[1]` will be set to the value of the day and `mdy[2]` will contain the year.

PGTYPEdate_mdyjul

Create a date value from an array of 3 integers that specify the day, the month and the year of the date.

```
void PGTYPEdate_mdyjul(int *mdy, date *jdate);
```

The function receives the array of the 3 integers (`mdy`) as its first argument and as its second argument a pointer to a variable of type date that should hold the result of the operation.

PGTYPEdate_dayofweek

Return a number representing the day of the week for a date value.

```
int PGTYPEdate_dayofweek(date d);
```

The function receives the date variable `d` as its only argument and returns an integer that indicates the day of the week for this date.

- 0 - Sunday
- 1 - Monday

- 2 - Tuesday
- 3 - Wednesday
- 4 - Thursday
- 5 - Friday
- 6 - Saturday

`PGTYPESdate_today`

Get the current date.

```
void PGTYPESdate_today(date *d);
```

The function receives a pointer to a date variable (d) that it sets to the current date.

`PGTYPESdate_fmt_asc`

Convert a variable of type date to its textual representation using a format mask.

```
int PGTYPESdate_fmt_asc(date dDate, char *fmtstring, char *outbuf);
```

The function receives the date to convert (dDate), the format mask (fmtstring) and the string that will hold the textual representation of the date (outbuf).

On success, 0 is returned and a negative value if an error occurred.

The following literals are the field specifiers you can use:

- dd - The number of the day of the month.
- mm - The number of the month of the year.
- yy - The number of the year as a two digit number.
- yyyy - The number of the year as a four digit number.
- ddd - The name of the day (abbreviated).
- mmm - The name of the month (abbreviated).

All other characters are copied 1:1 to the output string.

Table 35.3 indicates a few possible formats. This will give you an idea of how to use this function. All output lines are based on the same date: November 23, 1959.

Table 35.3. Valid Input Formats for PGTYPESdate_fmt_asc

Format	Result
mmddy	112359
ddmmyy	231159
yyymmdd	591123
yy/mm/dd	59/11/23
yy mm dd	59 11 23
yy.mm.dd	59.11.23

Format	Result
.mm.yyyy.dd.	.11.1959.23.
mmm. dd, yyyy	Nov. 23, 1959
mmm dd yyyy	Nov 23 1959
yyyy dd mm	1959 23 11
ddd, mmm. dd, yyyy	Mon, Nov. 23, 1959
(ddd) mmm. dd, yyyy	(Mon) Nov. 23, 1959

PGTYPESdate_defmt_asc

Use a format mask to convert a C char* string to a value of type date.

```
int PGTYPESdate_defmt_asc(date *d, char *fmt, char *str);
```

The function receives a pointer to the date value that should hold the result of the operation (*d*), the format mask to use for parsing the date (*fmt*) and the C char* string containing the textual representation of the date (*str*). The textual representation is expected to match the format mask. However you do not need to have a 1:1 mapping of the string to the format mask. The function only analyzes the sequential order and looks for the literals *yy* or *yyyy* that indicate the position of the year, *mm* to indicate the position of the month and *dd* to indicate the position of the day.

Table 35.4 indicates a few possible formats. This will give you an idea of how to use this function.

Table 35.4. Valid Input Formats for rdefmtdate

Format	String	Result
ddmmyy	21-2-54	1954-02-21
ddmmyy	2-12-54	1954-12-02
ddmmyy	20111954	1954-11-20
ddmmyy	130464	1964-04-13
mmm.dd.yyyy	MAR-12-1967	1967-03-12
yy/mm/dd	1954, February 3rd	1954-02-03
mmm.dd.yyyy	041269	1969-04-12
yy/mm/dd	In the year 2525, in the month of July, mankind will be alive on the 28th day	2525-07-28
dd-mm-yy	I said on the 28th of July in the year 2525	2525-07-28
mmm.dd.yyyy	9/14/58	1958-09-14
yy/mm/dd	47/03/29	1947-03-29
mmm.dd.yyyy	oct 28 1975	1975-10-28
mmddy	Nov 14th, 1985	1985-11-14

35.6.4. The timestamp Type

The timestamp type in C enables your programs to deal with data of the SQL type timestamp. See Section 8.5 for the equivalent type in the PostgreSQL server.

The following functions can be used to work with the timestamp type:

`PGTYPEStimestamp_from_asc`

Parse a timestamp from its textual representation into a timestamp variable.

```
timestamp PGTYPEStimestamp_from_asc(char *str, char **endptr);
```

The function receives the string to parse (`str`) and a pointer to a C `char*` (`endptr`). At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to `NULL`.

The function returns the parsed timestamp on success. On error, `PGTYPEStimestamp` is returned and `errno` is set to `PGTYPEStimestamp_TS_BAD_TIMESTAMP`. See `PGTYPEStimestampInvalidTimestamp` for important notes on this value.

In general, the input string can contain any combination of an allowed date specification, a white-space character and an allowed time specification. Note that time zones are not supported by ECPG. It can parse them but does not apply any calculation as the PostgreSQL server does for example. Timezone specifiers are silently discarded.

Table 35.5 contains a few examples for input strings.

Table 35.5. Valid Input Formats for `PGTYPEStimestamp_from_asc`

Input	Result
1999-01-08 04:05:06	1999-01-08 04:05:06
January 8 04:05:06 1999 PST	1999-01-08 04:05:06
1999-Jan-08 04:05:06.789-8	1999-01-08 04:05:06.789 (time zone specifier ignored)
J2451187 04:05-08:00	1999-01-08 04:05:00 (time zone specifier ignored)

`PGTYPEStimestamp_to_asc`

Converts a date to a C `char*` string.

```
char *PGTYPEStimestamp_to_asc(timestamp tstamp);
```

The function receives the timestamp `tstamp` as its only argument and returns an allocated string that contains the textual representation of the timestamp. The result must be freed with `PGTYPEStimestamp_free()`.

`PGTYPEStimestamp_current`

Retrieve the current timestamp.

```
void PGTYPEStimestamp_current(timestamp *ts);
```

The function retrieves the current timestamp and saves it into the timestamp variable that `ts` points to.

`PGTYPEStimestamp_fmt_asc`

Convert a timestamp variable to a C `char*` using a format mask.

```
int PGTYPEStimestamp_fmt_asc(timestamp *ts, char *output, int str_len, char *fmtstr);
```

The function receives a pointer to the timestamp to convert as its first argument (`ts`), a pointer to the output buffer (`output`), the maximal length that has been allocated for the output buffer (`str_len`) and the format mask to use for the conversion (`fmtstr`).

Upon success, the function returns 0 and a negative value if an error occurred.

You can use the following format specifiers for the format mask. The format specifiers are the same ones that are used in the `strftime` function in `libc`. Any non-format specifier will be copied into the output buffer.

- `%A` - is replaced by national representation of the full weekday name.
- `%a` - is replaced by national representation of the abbreviated weekday name.
- `%B` - is replaced by national representation of the full month name.
- `%b` - is replaced by national representation of the abbreviated month name.
- `%C` - is replaced by (year / 100) as decimal number; single digits are preceded by a zero.
- `%c` - is replaced by national representation of time and date.
- `%D` - is equivalent to `%m/%d/%y`.
- `%d` - is replaced by the day of the month as a decimal number (01-31).
- `%E*` `%O*` - POSIX locale extensions. The sequences `%Ec %EC %Ex %EX %Ey %EY %Od %Oe %OH %OI %Om %OM %OS %Ou %OU %OV %Ow %OW %Oy` are supposed to provide alternative representations.

Additionally `%OB` implemented to represent alternative months names (used standalone, without day mentioned).

- `%e` - is replaced by the day of month as a decimal number (1-31); single digits are preceded by a blank.
- `%F` - is equivalent to `%Y-%m-%d`.
- `%G` - is replaced by a year as a decimal number with century. This year is the one that contains the greater part of the week (Monday as the first day of the week).
- `%g` - is replaced by the same year as in `%G`, but as a decimal number without century (00-99).
- `%H` - is replaced by the hour (24-hour clock) as a decimal number (00-23).
- `%h` - the same as `%b`.
- `%I` - is replaced by the hour (12-hour clock) as a decimal number (01-12).
- `%j` - is replaced by the day of the year as a decimal number (001-366).
- `%k` - is replaced by the hour (24-hour clock) as a decimal number (0-23); single digits are preceded by a blank.
- `%l` - is replaced by the hour (12-hour clock) as a decimal number (1-12); single digits are preceded by a blank.
- `%M` - is replaced by the minute as a decimal number (00-59).
- `%m` - is replaced by the month as a decimal number (01-12).
- `%n` - is replaced by a newline.

- %O* - the same as %E*.
- %p - is replaced by national representation of either “ante meridiem” or “post meridiem” as appropriate.
- %R - is equivalent to %H:%M.
- %r - is equivalent to %I:%M:%S %p.
- %S - is replaced by the second as a decimal number (00-60).
- %s - is replaced by the number of seconds since the Epoch, UTC.
- %T - is equivalent to %H:%M:%S
- %t - is replaced by a tab.
- %U - is replaced by the week number of the year (Sunday as the first day of the week) as a decimal number (00-53).
- %u - is replaced by the weekday (Monday as the first day of the week) as a decimal number (1-7).
- %V - is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (01-53). If the week containing January 1 has four or more days in the new year, then it is week 1; otherwise it is the last week of the previous year, and the next week is week 1.
- %v - is equivalent to %e-%b-%Y.
- %W - is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (00-53).
- %w - is replaced by the weekday (Sunday as the first day of the week) as a decimal number (0-6).
- %X - is replaced by national representation of the time.
- %x - is replaced by national representation of the date.
- %Y - is replaced by the year with century as a decimal number.
- %y - is replaced by the year without century as a decimal number (00-99).
- %Z - is replaced by the time zone name.
- %z - is replaced by the time zone offset from UTC; a leading plus sign stands for east of UTC, a minus sign for west of UTC, hours and minutes follow with two digits each and no delimiter between them (common form for RFC 822 date headers).
- %+ - is replaced by national representation of the date and time.
- %-* - GNU libc extension. Do not do any padding when performing numerical outputs.
- \$_* - GNU libc extension. Explicitly specify space for padding.
- %0* - GNU libc extension. Explicitly specify zero for padding.
- %% - is replaced by %.

PGTYPEStimestamp_sub

Subtract one timestamp from another one and save the result in a variable of type interval.

```
int PGTYPEStimestamp_sub(timestamp *ts1, timestamp *ts2,
    interval *iv);
```

The function will subtract the timestamp variable that `ts2` points to from the timestamp variable that `ts1` points to and will store the result in the interval variable that `iv` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

`PGTYPEStimestamp_defmt_asc`

Parse a timestamp value from its textual representation using a formatting mask.

```
int PGTYPEStimestamp_defmt_asc(char *str, char *fmt, timestamp
    *d);
```

The function receives the textual representation of a timestamp in the variable `str` as well as the formatting mask to use in the variable `fmt`. The result will be stored in the variable that `d` points to.

If the formatting mask `fmt` is `NULL`, the function will fall back to the default formatting mask which is `%Y-%m-%d %H:%M:%S`.

This is the reverse function to `PGTYPEStimestamp_fmt_asc`. See the documentation there in order to find out about the possible formatting mask entries.

`PGTYPEStimestamp_add_interval`

Add an interval variable to a timestamp variable.

```
int PGTYPEStimestamp_add_interval(timestamp *tin, interval
    *span, timestamp *tout);
```

The function receives a pointer to a timestamp variable `tin` and a pointer to an interval variable `span`. It adds the interval to the timestamp and saves the resulting timestamp in the variable that `tout` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

`PGTYPEStimestamp_sub_interval`

Subtract an interval variable from a timestamp variable.

```
int PGTYPEStimestamp_sub_interval(timestamp *tin, interval
    *span, timestamp *tout);
```

The function subtracts the interval variable that `span` points to from the timestamp variable that `tin` points to and saves the result into the variable that `tout` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

35.6.5. The interval Type

The interval type in C enables your programs to deal with data of the SQL type interval. See Section 8.5 for the equivalent type in the PostgreSQL server.

The following functions can be used to work with the interval type:

`PGTYPEStinterval_new`

Return a pointer to a newly allocated interval variable.

```
interval *PGTYPEInterval_new(void);
```

PGTYPEInterval_free

Release the memory of a previously allocated interval variable.

```
void PGTYPEInterval_new(interval *intvl);
```

PGTYPEInterval_from_asc

Parse an interval from its textual representation.

```
interval *PGTYPEInterval_from_asc(char *str, char **endptr);
```

The function parses the input string `str` and returns a pointer to an allocated interval variable. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to `NULL`.

PGTYPEInterval_to_asc

Convert a variable of type interval to its textual representation.

```
char *PGTYPEInterval_to_asc(interval *span);
```

The function converts the interval variable that `span` points to into a C `char*`. The output looks like this example: `@ 1 day 12 hours 59 mins 10 secs`. The result must be freed with `PGTYPEchar_free()`.

PGTYPEInterval_copy

Copy a variable of type interval.

```
int PGTYPEInterval_copy(interval *intvlsrc, interval *intvldest);
```

The function copies the interval variable that `intvlsrc` points to into the variable that `intvldest` points to. Note that you need to allocate the memory for the destination variable before.

35.6.6. The decimal Type

The decimal type is similar to the numeric type. However it is limited to a maximum precision of 30 significant digits. In contrast to the numeric type which can be created on the heap only, the decimal type can be created either on the stack or on the heap (by means of the functions `PGTYPEdecimal_new` and `PGTYPEdecimal_free`). There are a lot of other functions that deal with the decimal type in the Informix compatibility mode described in Section 35.15.

The following functions can be used to work with the decimal type and are not only contained in the `libcompat` library.

PGTYPEdecimal_new

Request a pointer to a newly allocated decimal variable.

```
decimal *PGTYPEdecimal_new(void);
```

PGTYPESdecimal_free

Free a decimal type, release all of its memory.

```
void PGTYPESdecimal_free(decimal *var);
```

35.6.7. errno Values of pgtypeslib

PGTYPES_NUM_BAD_NUMERIC

An argument should contain a numeric variable (or point to a numeric variable) but in fact its in-memory representation was invalid.

PGTYPES_NUM_OVERFLOW

An overflow occurred. Since the numeric type can deal with almost arbitrary precision, converting a numeric variable into other types might cause overflow.

PGTYPES_NUM_UNDERFLOW

An underflow occurred. Since the numeric type can deal with almost arbitrary precision, converting a numeric variable into other types might cause underflow.

PGTYPES_NUM_DIVIDE_ZERO

A division by zero has been attempted.

PGTYPES_DATE_BAD_DATE

An invalid date string was passed to the PGTYPESdate_from_asc function.

PGTYPES_DATE_ERR_EARGS

Invalid arguments were passed to the PGTYPESdate_defmt_asc function.

PGTYPES_DATE_ERR_ENOSHORTDATE

An invalid token in the input string was found by the PGTYPESdate_defmt_asc function.

PGTYPES_INTVL_BAD_INTERVAL

An invalid interval string was passed to the PGTYPESinterval_from_asc function, or an invalid interval value was passed to the PGTYPESinterval_to_asc function.

PGTYPES_DATE_ERR_ENOTDMY

There was a mismatch in the day/month/year assignment in the PGTYPESdate_defmt_asc function.

PGTYPES_DATE_BAD_DAY

An invalid day of the month value was found by the PGTYPESdate_defmt_asc function.

PGTYPES_DATE_BAD_MONTH

An invalid month value was found by the PGTYPESdate_defmt_asc function.

PGTYPES_TS_BAD_TIMESTAMP

An invalid timestamp string pass passed to the PGTYPEStimestamp_from_asc function, or an invalid timestamp value was passed to the PGTYPEStimestamp_to_asc function.

PGTYPES_TS_ERR_EINFTIME

An infinite timestamp value was encountered in a context that cannot handle it.

35.6.8. Special Constants of pgtypeslib

PGTYPESInvalidTimestamp

A value of type timestamp representing an invalid time stamp. This is returned by the function `PGTYPEStimestamp_from_asc` on parse error. Note that due to the internal representation of the `timestamp` data type, `PGTYPESInvalidTimestamp` is also a valid timestamp at the same time. It is set to `1899-12-31 23:59:59`. In order to detect errors, make sure that your application does not only test for `PGTYPESInvalidTimestamp` but also for `errno != 0` after each call to `PGTYPEStimestamp_from_asc`.

35.7. Using Descriptor Areas

An SQL descriptor area is a more sophisticated method for processing the result of a `SELECT`, `FETCH` or a `DESCRIBE` statement. An SQL descriptor area groups the data of one row of data together with metadata items into one data structure. The metadata is particularly useful when executing dynamic SQL statements, where the nature of the result columns might not be known ahead of time. PostgreSQL provides two ways to use Descriptor Areas: the named SQL Descriptor Areas and the C-structure SQLDAs.

35.7.1. Named SQL Descriptor Areas

A named SQL descriptor area consists of a header, which contains information concerning the entire descriptor, and one or more item descriptor areas, which basically each describe one column in the result row.

Before you can use an SQL descriptor area, you need to allocate one:

```
EXEC SQL ALLOCATE DESCRIPTOR identifier;
```

The identifier serves as the “variable name” of the descriptor area. When you don't need the descriptor anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE DESCRIPTOR identifier;
```

To use a descriptor area, specify it as the storage target in an `INTO` clause, instead of listing host variables:

```
EXEC SQL FETCH NEXT FROM mycursor INTO SQL DESCRIPTOR mydesc;
```

If the result set is empty, the Descriptor Area will still contain the metadata from the query, i.e. the field names.

For not yet executed prepared queries, the `DESCRIBE` statement can be used to get the metadata of the result set:

```
EXEC SQL BEGIN DECLARE SECTION;  
char *sql_stmt = "SELECT * FROM table1";  
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL PREPARE stmt1 FROM :sql_stmt;
EXEC SQL DESCRIBE stmt1 INTO SQL DESCRIPTOR mydesc;
```

Before PostgreSQL 9.0, the SQL keyword was optional, so using DESCRIBE and SQL DESCRIP-
TOR produced named SQL Descriptor Areas. Now it is mandatory, omitting the SQL keyword pro-
duces SQLDA Descriptor Areas, see Section 35.7.2.

In DESCRIBE and FETCH statements, the INTO and USING keywords can be used to similarly: they
produce the result set and the metadata in a Descriptor Area.

Now how do you get the data out of the descriptor area? You can think of the descriptor area as a
structure with named fields. To retrieve the value of a field from the header and store it into a host
variable, use the following command:

```
EXEC SQL GET DESCRIPTOR name :hostvar = field;
```

Currently, there is only one header field defined: *COUNT*, which tells how many item descriptor areas
exist (that is, how many columns are contained in the result). The host variable needs to be of an
integer type. To get a field from the item descriptor area, use the following command:

```
EXEC SQL GET DESCRIPTOR name VALUE num :hostvar = field;
```

num can be a literal integer or a host variable containing an integer. Possible fields are:

CARDINALITY (integer)

number of rows in the result set

DATA

actual data item (therefore, the data type of this field depends on the query)

DATETIME_INTERVAL_CODE (integer)

When TYPE is 9, DATETIME_INTERVAL_CODE will have a value of 1 for DATE, 2 for TIME,
3 for TIMESTAMP, 4 for TIME WITH TIME ZONE, or 5 for TIMESTAMP WITH TIME ZONE.

DATETIME_INTERVAL_PRECISION (integer)

not implemented

INDICATOR (integer)

the indicator (indicating a null value or a value truncation)

KEY_MEMBER (integer)

not implemented

LENGTH (integer)

length of the datum in characters

NAME (string)

name of the column

NULLABLE (integer)

not implemented

OCTET_LENGTH (integer)

length of the character representation of the datum in bytes

PRECISION (integer)

precision (for type numeric)

RETURNED_LENGTH (integer)

length of the datum in characters

RETURNED_OCTET_LENGTH (integer)

length of the character representation of the datum in bytes

SCALE (integer)

scale (for type numeric)

TYPE (integer)

numeric code of the data type of the column

In EXECUTE, DECLARE and OPEN statements, the effect of the INTO and USING keywords are different. A Descriptor Area can also be manually built to provide the input parameters for a query or a cursor and USING SQL DESCRIPTOR *name* is the way to pass the input parameters into a parameterized query. The statement to build a named SQL Descriptor Area is below:

```
EXEC SQL SET DESCRIPTOR name VALUE num field = :hostvar;
```

PostgreSQL supports retrieving more than one record in one FETCH statement and storing the data in host variables in this case assumes that the variable is an array. E.g.:

```
EXEC SQL BEGIN DECLARE SECTION;
int id[5];
EXEC SQL END DECLARE SECTION;

EXEC SQL FETCH 5 FROM mycursor INTO SQL DESCRIPTOR mydesc;

EXEC SQL GET DESCRIPTOR mydesc VALUE 1 :id = DATA;
```

35.7.2. SQLDA Descriptor Areas

An SQLDA Descriptor Area is a C language structure which can be also used to get the result set and the metadata of a query. One structure stores one record from the result set.

```
EXEC SQL include sqllda.h;
sqllda_t      *mysqlda;

EXEC SQL FETCH 3 FROM mycursor INTO DESCRIPTOR mysqlda;
```

Note that the SQL keyword is omitted. The paragraphs about the use cases of the INTO and USING keywords in Section 35.7.1 also apply here with an addition. In a DESCRIBE statement the DESCRIPTOR keyword can be completely omitted if the INTO keyword is used:

```
EXEC SQL DESCRIBE prepared_statement INTO mysqlda;
```

The general flow of a program that uses SQLDA is:

1. Prepare a query, and declare a cursor for it.
2. Declare an SQLDA for the result rows.
3. Declare an SQLDA for the input parameters, and initialize them (memory allocation, parameter settings).
4. Open a cursor with the input SQLDA.
5. Fetch rows from the cursor, and store them into an output SQLDA.
6. Read values from the output SQLDA into the host variables (with conversion if necessary).
7. Close the cursor.
8. Free the memory area allocated for the input SQLDA.

35.7.2.1. SQLDA Data Structure

SQLDA uses three data structure types: `sqllda_t`, `sqlvar_t`, and `struct sqlname`.

Tip

PostgreSQL's SQLDA has a similar data structure to the one in IBM DB2 Universal Database, so some technical information on DB2's SQLDA could help understanding PostgreSQL's one better.

35.7.2.1.1. `sqllda_t` Structure

The structure type `sqllda_t` is the type of the actual SQLDA. It holds one record. And two or more `sqllda_t` structures can be connected in a linked list with the pointer in the `desc_next` field, thus representing an ordered collection of rows. So, when two or more rows are fetched, the application can read them by following the `desc_next` pointer in each `sqllda_t` node.

The definition of `sqllda_t` is:

```
struct sqllda_struct
{
    char          sqldaid[8];
    long          sqldabc;
    short        sqln;
    short        sqld;
    struct sqllda_struct *desc_next;
    struct sqlvar_struct sqlvar[1];
};

typedef struct sqllda_struct sqllda_t;
```

The meaning of the fields is:

`sqldaid`

It contains the literal string "SQLDA".

`sqldabc`

It contains the size of the allocated space in bytes.

`sqln`

It contains the number of input parameters for a parameterized query in case it's passed into `OPEN`, `DECLARE` or `EXECUTE` statements using the `USING` keyword. In case it's used as output of `SELECT`, `EXECUTE` or `FETCH` statements, its value is the same as `sqld` statement

`sqld`

It contains the number of fields in a result set.

`desc_next`

If the query returns more than one record, multiple linked `SQLDA` structures are returned, and `desc_next` holds a pointer to the next entry in the list.

`sqlvar`

This is the array of the columns in the result set.

35.7.2.1.2. `sqlvar_t` Structure

The structure type `sqlvar_t` holds a column value and metadata such as type and length. The definition of the type is:

```
struct sqlvar_struct
{
    short          sqltype;
    short          sqllen;
    char           *sqldata;
    short          *sqlind;
    struct sqlname sqlname;
};

typedef struct sqlvar_struct sqlvar_t;
```

The meaning of the fields is:

`sqltype`

Contains the type identifier of the field. For values, see enum `ECPGttype` in `ecpgtype.h`.

`sqllen`

Contains the binary length of the field. e.g. 4 bytes for `ECPGt_int`.

`sqldata`

Points to the data. The format of the data is described in Section 35.4.4.

`sqlind`

Points to the null indicator. 0 means not null, -1 means null.

`sqlname`

The name of the field.

35.7.2.1.3. `struct sqlname` Structure

A `struct sqlname` structure holds a column name. It is used as a member of the `sqlvar_t` structure. The definition of the structure is:

```
#define NAMEDATALEN 64

struct sqlname
{
    short      length;
    char      data[NAMEDATALEN];
};
```

The meaning of the fields is:

`length`

Contains the length of the field name.

`data`

Contains the actual field name.

35.7.2.2. Retrieving a Result Set Using an SQLDA

The general steps to retrieve a query result set through an SQLDA are:

1. Declare an `sqlda_t` structure to receive the result set.
2. Execute `FETCH/EXECUTE/DESCRIBE` commands to process a query specifying the declared SQLDA.
3. Check the number of records in the result set by looking at `sqln`, a member of the `sqlda_t` structure.
4. Get the values of each column from `sqlvar[0]`, `sqlvar[1]`, etc., members of the `sqlda_t` structure.
5. Go to next row (`sqlda_t` structure) by following the `desc_next` pointer, a member of the `sqlda_t` structure.
6. Repeat above as you need.

Here is an example retrieving a result set through an SQLDA.

First, declare a `sqlda_t` structure to receive the result set.

```
sqlda_t *sqlda1;
```

Next, specify the SQLDA in a command. This is a `FETCH` command example.

```
EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;
```

Run a loop following the linked list to retrieve the rows.

```
sqlda_t *cur_sqlda;

for (cur_sqlda = sqlda1;
     cur_sqlda != NULL;
     cur_sqlda = cur_sqlda->desc_next)
{
    ...
}
```

```
}

```

Inside the loop, run another loop to retrieve each column data (`sqlvar_t` structure) of the row.

```
for (i = 0; i < cur_sqlda->sqlld; i++)
{
    sqlvar_t v = cur_sqlda->sqlvar[i];
    char *sqldata = v.sqldata;
    short sqlllen = v.sqlllen;
    ...
}
```

To get a column value, check the `sqltype` value, a member of the `sqlvar_t` structure. Then, switch to an appropriate way, depending on the column type, to copy data from the `sqlvar` field to a host variable.

```
char var_buf[1024];

switch (v.sqltype)
{
    case ECPGt_char:
        memset(&var_buf, 0, sizeof(var_buf));
        memcpy(&var_buf, sqldata, (sizeof(var_buf) <= sqlllen ?
sizeof(var_buf) - 1 : sqlllen));
        break;

    case ECPGt_int: /* integer */
        memcpy(&intval, sqldata, sqlllen);
        snprintf(var_buf, sizeof(var_buf), "%d", intval);
        break;

    ...
}
```

35.7.2.3. Passing Query Parameters Using an SQLDA

The general steps to use an SQLDA to pass input parameters to a prepared query are:

1. Create a prepared query (prepared statement)
2. Declare a `sqlda_t` structure as an input SQLDA.
3. Allocate memory area (as `sqlda_t` structure) for the input SQLDA.
4. Set (copy) input values in the allocated memory.
5. Open a cursor with specifying the input SQLDA.

Here is an example.

First, create a prepared statement.

```
EXEC SQL BEGIN DECLARE SECTION;
char query[1024] = "SELECT d.oid, * FROM pg_database d,
pg_stat_database s WHERE d.oid = s.datid AND (d.datname = ? OR
d.oid = ?)";
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL PREPARE stmt1 FROM :query;
```

Next, allocate memory for an `SQLDA`, and set the number of input parameters in `sqln`, a member variable of the `sqlda_t` structure. When two or more input parameters are required for the prepared query, the application has to allocate additional memory space which is calculated by $(nr. \text{ of params} - 1) * \text{sizeof}(\text{sqlvar_t})$. The example shown here allocates memory space for two input parameters.

```
sqlda_t *sqlda2;
```

```
sqlda2 = (sqlda_t *) malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));  
memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
```

```
sqlda2->sqln = 2; /* number of input variables */
```

After memory allocation, store the parameter values into the `sqlvar[]` array. (This is same array used for retrieving column values when the `SQLDA` is receiving a result set.) In this example, the input parameters are "postgres", having a string type, and 1, having an integer type.

```
sqlda2->sqlvar[0].sqltype = ECPGt_char;  
sqlda2->sqlvar[0].sqldata = "postgres";  
sqlda2->sqlvar[0].sqlllen = 8;
```

```
int intval = 1;  
sqlda2->sqlvar[1].sqltype = ECPGt_int;  
sqlda2->sqlvar[1].sqldata = (char *) &intval;  
sqlda2->sqlvar[1].sqlllen = sizeof(intval);
```

By opening a cursor and specifying the `SQLDA` that was set up beforehand, the input parameters are passed to the prepared statement.

```
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;
```

Finally, after using input `SQLDAs`, the allocated memory space must be freed explicitly, unlike `SQLDAs` used for receiving query results.

```
free(sqlda2);
```

35.7.2.4. A Sample Application Using `SQLDA`

Here is an example program, which describes how to fetch access statistics of the databases, specified by the input parameters, from the system catalogs.

This application joins two system tables, `pg_database` and `pg_stat_database` on the database `OID`, and also fetches and shows the database statistics which are retrieved by two input parameters (a database `postgres`, and `OID 1`).

First, declare an `SQLDA` for input and an `SQLDA` for output.

```
EXEC SQL include sqlda.h;
```

```
sqlda_t *sqlda1; /* an output descriptor */  
sqlda_t *sqlda2; /* an input descriptor */
```

Next, connect to the database, prepare a statement, and declare a cursor for the prepared statement.

```

int
main(void)
{
    EXEC SQL BEGIN DECLARE SECTION;
    char query[1024] = "SELECT d.oid,* FROM pg_database d,
pg_stat_database s WHERE d.oid=s.datid AND ( d.datname=? OR
d.oid=? )";
    EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    EXEC SQL PREPARE stmt1 FROM :query;
    EXEC SQL DECLARE cur1 CURSOR FOR stmt1;

```

Next, put some values in the input SQLDA for the input parameters. Allocate memory for the input SQLDA, and set the number of input parameters to `sqln`. Store type, value, and value length into `sqltype`, `sqldata`, and `sqlllen` in the `sqlvar` structure.

```

/* Create SQLDA structure for input parameters. */
sqlda2 = (sqlda_t *) malloc(sizeof(sqlda_t) +
sizeof(sqlvar_t));
memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
sqlda2->sqln = 2; /* number of input variables */

sqlda2->sqlvar[0].sqltype = ECPGt_char;
sqlda2->sqlvar[0].sqldata = "postgres";
sqlda2->sqlvar[0].sqlllen = 8;

intval = 1;
sqlda2->sqlvar[1].sqltype = ECPGt_int;
sqlda2->sqlvar[1].sqldata = (char *)&intval
sqlda2->sqlvar[1].sqlllen = sizeof(intval);

```

After setting up the input SQLDA, open a cursor with the input SQLDA.

```

/* Open a cursor with input parameters. */
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;

```

Fetch rows into the output SQLDA from the opened cursor. (Generally, you have to call `FETCH` repeatedly in the loop, to fetch all rows in the result set.)

```

while (1)
{
    sqlda_t *cur_sqlda;

    /* Assign descriptor to the cursor */
    EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;

```

Next, retrieve the fetched records from the SQLDA, by following the linked list of the `sqlda_t` structure.

```

for (cur_sqlda = sqlda1 ;

```

```

    cur_sqlda != NULL ;
    cur_sqlda = cur_sqlda->desc_next)
{
    ...

```

Read each columns in the first record. The number of columns is stored in `sqld`, the actual data of the first column is stored in `sqlvar[0]`, both members of the `sqlda_t` structure.

```

/* Print every column in a row. */
for (i = 0; i < sqlda1->sqld; i++)
{
    sqlvar_t v = sqlda1->sqlvar[i];
    char *sqldata = v.sqldata;
    short sqllen = v.sqlllen;

    strncpy(name_buf, v.sqlname.data, v.sqlname.length);
    name_buf[v.sqlname.length] = '\0';

```

Now, the column data is stored in the variable `v`. Copy every datum into host variables, looking at `v.sqltype` for the type of the column.

```

    switch (v.sqltype) {
        int intval;
        double doubleval;
        unsigned long long int longlongval;

        case ECPGt_char:
            memset(&var_buf, 0, sizeof(var_buf));
            memcpy(&var_buf, sqldata, (sizeof(var_buf) <=
sqlllen ? sizeof(var_buf)-1 : sqllen));
            break;

        case ECPGt_int: /* integer */
            memcpy(&intval, sqldata, sqllen);
            snprintf(var_buf, sizeof(var_buf), "%d",
intval);
            break;

        ...

        default:
            ...
    }

    printf("%s = %s (type: %d)\n", name_buf, var_buf,
v.sqltype);
}

```

Close the cursor after processing all of records, and disconnect from the database.

```

EXEC SQL CLOSE cur1;
EXEC SQL COMMIT;

EXEC SQL DISCONNECT ALL;

```

The whole program is shown in Example 35.1.

Example 35.1. Example SQLDA Program

```

#include <stdlib.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>
#include <unistd.h>

EXEC SQL include sqlda.h;

sqlda_t *sqlda1; /* descriptor for output */
sqlda_t *sqlda2; /* descriptor for input */

EXEC SQL WHENEVER NOT FOUND DO BREAK;
EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
    EXEC SQL BEGIN DECLARE SECTION;
    char query[1024] = "SELECT d.oid,* FROM pg_database d,
pg_stat_database s WHERE d.oid=s.datid AND ( d.datname=? OR
d.oid=? )";

    int intval;
    unsigned long long int longlongval;
    EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO uptimedb AS con1 USER uptime;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    EXEC SQL PREPARE stmt1 FROM :query;
    EXEC SQL DECLARE cur1 CURSOR FOR stmt1;

    /* Create a SQLDA structure for an input parameter */
    sqlda2 = (sqlda_t *)malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));
    memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
    sqlda2->sqln = 2; /* a number of input variables */

    sqlda2->sqlvar[0].sqltype = ECPGt_char;
    sqlda2->sqlvar[0].sqldata = "postgres";
    sqlda2->sqlvar[0].sqlllen = 8;

    intval = 1;
    sqlda2->sqlvar[1].sqltype = ECPGt_int;
    sqlda2->sqlvar[1].sqldata = (char *) &intval;
    sqlda2->sqlvar[1].sqlllen = sizeof(intval);

    /* Open a cursor with input parameters. */
    EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;

    while (1)
    {
        sqlda_t *cur_sqlda;

        /* Assign descriptor to the cursor */

```

```

EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;

for (cur_sqlda = sqlda1 ;
     cur_sqlda != NULL ;
     cur_sqlda = cur_sqlda->desc_next)
{
    int i;
    char name_buf[1024];
    char var_buf[1024];

    /* Print every column in a row. */
    for (i=0 ; i<cur_sqlda->sqld ; i++)
    {
        sqlvar_t v = cur_sqlda->sqlvar[i];
        char *sqldata = v.sqldata;
        short sqllen = v.sqllen;

        strncpy(name_buf, v.sqlname.data,
v.sqlname.length);
        name_buf[v.sqlname.length] = '\0';

        switch (v.sqltype)
        {
            case ECPGt_char:
                memset(&var_buf, 0, sizeof(var_buf));
                memcpy(&var_buf, sqldata,
(sizeof(var_buf)<=sqllen ? sizeof(var_buf)-1 : sqllen) );
                break;

            case ECPGt_int: /* integer */
                memcpy(&intval, sqldata, sqllen);
                sprintf(var_buf, sizeof(var_buf), "%d",
intval);
                break;

            case ECPGt_long_long: /* bigint */
                memcpy(&longlongval, sqldata, sqllen);
                sprintf(var_buf, sizeof(var_buf), "%lld",
longlongval);
                break;

            default:
                {
                    int i;
                    memset(var_buf, 0, sizeof(var_buf));
                    for (i = 0; i < sqllen; i++)
                    {
                        char tmpbuf[16];
                        sprintf(tmpbuf, sizeof(tmpbuf), "%02x",
(unsigned char) sqldata[i]);
                        strcat(var_buf, tmpbuf,
sizeof(var_buf));
                    }
                }
                break;
        }
    }
}

```

```

        printf("%s = %s (type: %d)\n", name_buf, var_buf,
v.sqltype);
    }

    printf("\n");
}

EXEC SQL CLOSE curl;
EXEC SQL COMMIT;

EXEC SQL DISCONNECT ALL;

return 0;
}

```

The output of this example should look something like the following (some numbers will vary).

```

oid = 1 (type: 1)
datname = templatel (type: 1)
datdba = 10 (type: 1)
encoding = 0 (type: 5)
datistemplate = t (type: 1)
datallowconn = t (type: 1)
datconlimit = -1 (type: 5)
datlastsysoid = 11510 (type: 1)
datfrozenxid = 379 (type: 1)
dattablespace = 1663 (type: 1)
datconfig = (type: 1)
datacl = {=c/uptime,uptime=CTc/uptime} (type: 1)
datid = 1 (type: 1)
datname = templatel (type: 1)
numbackends = 0 (type: 5)
xact_commit = 113606 (type: 9)
xact_rollback = 0 (type: 9)
blks_read = 130 (type: 9)
blks_hit = 7341714 (type: 9)
tup_returned = 38262679 (type: 9)
tup_fetched = 1836281 (type: 9)
tup_inserted = 0 (type: 9)
tup_updated = 0 (type: 9)
tup_deleted = 0 (type: 9)

oid = 11511 (type: 1)
datname = postgres (type: 1)
datdba = 10 (type: 1)
encoding = 0 (type: 5)
datistemplate = f (type: 1)
datallowconn = t (type: 1)
datconlimit = -1 (type: 5)
datlastsysoid = 11510 (type: 1)
datfrozenxid = 379 (type: 1)
dattablespace = 1663 (type: 1)
datconfig = (type: 1)
datacl = (type: 1)
datid = 11511 (type: 1)
datname = postgres (type: 1)

```

```

numbackends = 0 (type: 5)
xact_commit = 221069 (type: 9)
xact_rollback = 18 (type: 9)
blks_read = 1176 (type: 9)
blks_hit = 13943750 (type: 9)
tup_returned = 77410091 (type: 9)
tup_fetched = 3253694 (type: 9)
tup_inserted = 0 (type: 9)
tup_updated = 0 (type: 9)
tup_deleted = 0 (type: 9)

```

35.8. Error Handling

This section describes how you can handle exceptional conditions and warnings in an embedded SQL program. There are two nonexclusive facilities for this.

- Callbacks can be configured to handle warning and error conditions using the `WHENEVER` command.
- Detailed information about the error or warning can be obtained from the `sqlca` variable.

35.8.1. Setting Callbacks

One simple method to catch errors and warnings is to set a specific action to be executed whenever a particular condition occurs. In general:

```
EXEC SQL WHENEVER condition action;
```

condition can be one of the following:

SQLERROR

The specified action is called whenever an error occurs during the execution of an SQL statement.

SQLWARNING

The specified action is called whenever a warning occurs during the execution of an SQL statement.

NOT FOUND

The specified action is called whenever an SQL statement retrieves or affects zero rows. (This condition is not an error, but you might be interested in handling it specially.)

action can be one of the following:

CONTINUE

This effectively means that the condition is ignored. This is the default.

GOTO *label*

GO TO *label*

Jump to the specified label (using a C `goto` statement).

SQLPRINT

Print a message to standard error. This is useful for simple programs or during prototyping. The details of the message cannot be configured.

STOP

Call `exit(1)`, which will terminate the program.

DO BREAK

Execute the C statement `break`. This should only be used in loops or `switch` statements.

DO CONTINUE

Execute the C statement `continue`. This should only be used in loops statements. If executed, will cause the flow of control to return to the top of the loop.

CALL *name* (*args*)

DO *name* (*args*)

Call the specified C functions with the specified arguments. (This use is different from the meaning of `CALL` and `DO` in the normal PostgreSQL grammar.)

The SQL standard only provides for the actions `CONTINUE` and `GOTO` (and `GO TO`).

Here is an example that you might want to use in a simple program. It prints a simple message when a warning occurs and aborts the program when an error happens:

```
EXEC SQL WHENEVER SQLWARNING SQLPRINT;  
EXEC SQL WHENEVER SQLERROR STOP;
```

The statement `EXEC SQL WHENEVER` is a directive of the SQL preprocessor, not a C statement. The error or warning actions that it sets apply to all embedded SQL statements that appear below the point where the handler is set, unless a different action was set for the same condition between the first `EXEC SQL WHENEVER` and the SQL statement causing the condition, regardless of the flow of control in the C program. So neither of the two following C program excerpts will have the desired effect:

```
/*  
 * WRONG  
 */  
int main(int argc, char *argv[])  
{  
    ...  
    if (verbose) {  
        EXEC SQL WHENEVER SQLWARNING SQLPRINT;  
    }  
    ...  
    EXEC SQL SELECT ...;  
    ...  
}
```

```
/*  
 * WRONG  
 */  
int main(int argc, char *argv[])  
{  
    ...  
    set_error_handler();  
    ...  
    EXEC SQL SELECT ...;  
}
```

```
    ...  
}  
  
static void set_error_handler(void)  
{  
    EXEC SQL WHENEVER SQLERROR STOP;  
}
```

35.8.2. sqlca

For more powerful error handling, the embedded SQL interface provides a global variable with the name `sqlca` (SQL communication area) that has the following structure:

```
struct  
{  
    char sqlcaid[8];  
    long sqlabc;  
    long sqlcode;  
    struct  
    {  
        int sqlerrml;  
        char sqlerrmc[SQLERRMC_LEN];  
    } sqlerrm;  
    char sqlerrp[8];  
    long sqlerrd[6];  
    char sqlwarn[8];  
    char sqlstate[5];  
} sqlca;
```

(In a multithreaded program, every thread automatically gets its own copy of `sqlca`. This works similarly to the handling of the standard C global variable `errno`.)

`sqlca` covers both warnings and errors. If multiple warnings or errors occur during the execution of a statement, then `sqlca` will only contain information about the last one.

If no error occurred in the last SQL statement, `sqlca.sqlcode` will be 0 and `sqlca.sqlstate` will be "00000". If a warning or error occurred, then `sqlca.sqlcode` will be negative and `sqlca.sqlstate` will be different from "00000". A positive `sqlca.sqlcode` indicates a harmless condition, such as that the last query returned zero rows. `sqlcode` and `sqlstate` are two different error code schemes; details appear below.

If the last SQL statement was successful, then `sqlca.sqlerrd[1]` contains the OID of the processed row, if applicable, and `sqlca.sqlerrd[2]` contains the number of processed or returned rows, if applicable to the command.

In case of an error or warning, `sqlca.sqlerrm.sqlerrmc` will contain a string that describes the error. The field `sqlca.sqlerrm.sqlerrml` contains the length of the error message that is stored in `sqlca.sqlerrm.sqlerrmc` (the result of `strlen()`, not really interesting for a C programmer). Note that some messages are too long to fit in the fixed-size `sqlerrmc` array; they will be truncated.

In case of a warning, `sqlca.sqlwarn[2]` is set to W. (In all other cases, it is set to something different from W.) If `sqlca.sqlwarn[1]` is set to W, then a value was truncated when it was stored in a host variable. `sqlca.sqlwarn[0]` is set to W if any of the other elements are set to indicate a warning.

The fields `sqlcaid`, `sqlabc`, `sqlerrp`, and the remaining elements of `sqlerrd` and `sqlwarn` currently contain no useful information.

The structure `sqlca` is not defined in the SQL standard, but is implemented in several other SQL database systems. The definitions are similar at the core, but if you want to write portable applications, then you should investigate the different implementations carefully.

Here is one example that combines the use of `WHENEVER` and `sqlca`, printing out the contents of `sqlca` when an error occurs. This is perhaps useful for debugging or prototyping applications, before installing a more “user-friendly” error handler.

```
EXEC SQL WHENEVER SQLERROR CALL print_sqlca();

void
print_sqlca()
{
    fprintf(stderr, "==== sqlca ====\\n");
    fprintf(stderr, "sqlcode: %ld\\n", sqlca.sqlcode);
    fprintf(stderr, "sqlerrm.sqlerrml: %d\\n",
sqlca.sqlerrm.sqlerrml);
    fprintf(stderr, "sqlerrm.sqlerrmc: %s\\n",
sqlca.sqlerrm.sqlerrmc);
    fprintf(stderr, "sqlerrd: %ld %ld %ld %ld %ld %ld\\n",
sqlca.sqlerrd[0], sqlca.sqlerrd[1], sqlca.sqlerrd[2],

sqlca.sqlerrd[3], sqlca.sqlerrd[4], sqlca.sqlerrd[5]);
    fprintf(stderr, "sqlwarn: %d %d %d %d %d %d %d %d\\n",
sqlca.sqlwarn[0], sqlca.sqlwarn[1], sqlca.sqlwarn[2],

sqlca.sqlwarn[3], sqlca.sqlwarn[4], sqlca.sqlwarn[5],

sqlca.sqlwarn[6], sqlca.sqlwarn[7]);
    fprintf(stderr, "sqlstate: %5s\\n", sqlca.sqlstate);
    fprintf(stderr, "====\\n");
}
```

The result could look as follows (here an error due to a misspelled table name):

```
==== sqlca ====
sqlcode: -400
sqlerrm.sqlerrml: 49
sqlerrm.sqlerrmc: relation "pg_databasep" does not exist on line 38
sqlerrd: 0 0 0 0 0 0
sqlwarn: 0 0 0 0 0 0 0 0
sqlstate: 42P01
=====
```

35.8.3. SQLSTATE VS. SQLCODE

The fields `sqlca.sqlstate` and `sqlca.sqlcode` are two different schemes that provide error codes. Both are derived from the SQL standard, but `SQLCODE` has been marked deprecated in the SQL-92 edition of the standard and has been dropped in later editions. Therefore, new applications are strongly encouraged to use `SQLSTATE`.

`SQLSTATE` is a five-character array. The five characters contain digits or upper-case letters that represent codes of various error and warning conditions. `SQLSTATE` has a hierarchical scheme: the first two characters indicate the general class of the condition, the last three characters indicate a subclass of the general condition. A successful state is indicated by the code `00000`. The `SQLSTATE` codes are for the most part defined in the SQL standard. The PostgreSQL server natively supports `SQLSTATE`

error codes; therefore a high degree of consistency can be achieved by using this error code scheme throughout all applications. For further information see Appendix A.

SQLCODE, the deprecated error code scheme, is a simple integer. A value of 0 indicates success, a positive value indicates success with additional information, a negative value indicates an error. The SQL standard only defines the positive value +100, which indicates that the last command returned or affected zero rows, and no specific negative values. Therefore, this scheme can only achieve poor portability and does not have a hierarchical code assignment. Historically, the embedded SQL processor for PostgreSQL has assigned some specific SQLCODE values for its use, which are listed below with their numeric value and their symbolic name. Remember that these are not portable to other SQL implementations. To simplify the porting of applications to the SQLSTATE scheme, the corresponding SQLSTATE is also listed. There is, however, no one-to-one or one-to-many mapping between the two schemes (indeed it is many-to-many), so you should consult the global SQLSTATE listing in Appendix A in each case.

These are the assigned SQLCODE values:

0 (ECPG_NO_ERROR)

Indicates no error. (SQLSTATE 00000)

100 (ECPG_NOT_FOUND)

This is a harmless condition indicating that the last command retrieved or processed zero rows, or that you are at the end of the cursor. (SQLSTATE 02000)

When processing a cursor in a loop, you could use this code as a way to detect when to abort the loop, like this:

```
while (1)
{
    EXEC SQL FETCH ... ;
    if (sqlca.sqlcode == ECPG_NOT_FOUND)
        break;
}
```

But WHENEVER NOT FOUND DO BREAK effectively does this internally, so there is usually no advantage in writing this out explicitly.

-12 (ECPG_OUT_OF_MEMORY)

Indicates that your virtual memory is exhausted. The numeric value is defined as -ENOMEM. (SQLSTATE YE001)

-200 (ECPG_UNSUPPORTED)

Indicates the preprocessor has generated something that the library does not know about. Perhaps you are running incompatible versions of the preprocessor and the library. (SQLSTATE YE002)

-201 (ECPG_TOO_MANY_ARGUMENTS)

This means that the command specified more host variables than the command expected. (SQLSTATE 07001 or 07002)

-202 (ECPG_TOO_FEW_ARGUMENTS)

This means that the command specified fewer host variables than the command expected. (SQLSTATE 07001 or 07002)

-203 (ECPG_TOO_MANY_MATCHES)

This means a query has returned multiple rows but the statement was only prepared to store one result row (for example, because the specified variables are not arrays). (SQLSTATE 21000)

-204 (ECPG_INT_FORMAT)

The host variable is of type `int` and the datum in the database is of a different type and contains a value that cannot be interpreted as an `int`. The library uses `strtol()` for this conversion. (SQLSTATE 42804)

-205 (ECPG_UINT_FORMAT)

The host variable is of type `unsigned int` and the datum in the database is of a different type and contains a value that cannot be interpreted as an `unsigned int`. The library uses `strtoul()` for this conversion. (SQLSTATE 42804)

-206 (ECPG_FLOAT_FORMAT)

The host variable is of type `float` and the datum in the database is of another type and contains a value that cannot be interpreted as a `float`. The library uses `strtod()` for this conversion. (SQLSTATE 42804)

-207 (ECPG_NUMERIC_FORMAT)

The host variable is of type `numeric` and the datum in the database is of another type and contains a value that cannot be interpreted as a `numeric` value. (SQLSTATE 42804)

-208 (ECPG_INTERVAL_FORMAT)

The host variable is of type `interval` and the datum in the database is of another type and contains a value that cannot be interpreted as an `interval` value. (SQLSTATE 42804)

-209 (ECPG_DATE_FORMAT)

The host variable is of type `date` and the datum in the database is of another type and contains a value that cannot be interpreted as a `date` value. (SQLSTATE 42804)

-210 (ECPG_TIMESTAMP_FORMAT)

The host variable is of type `timestamp` and the datum in the database is of another type and contains a value that cannot be interpreted as a `timestamp` value. (SQLSTATE 42804)

-211 (ECPG_CONVERT_BOOL)

This means the host variable is of type `bool` and the datum in the database is neither `'t'` nor `'f'`. (SQLSTATE 42804)

-212 (ECPG_EMPTY)

The statement sent to the PostgreSQL server was empty. (This cannot normally happen in an embedded SQL program, so it might point to an internal error.) (SQLSTATE YE002)

-213 (ECPG_MISSING_INDICATOR)

A null value was returned and no null indicator variable was supplied. (SQLSTATE 22002)

-214 (ECPG_NO_ARRAY)

An ordinary variable was used in a place that requires an array. (SQLSTATE 42804)

-215 (ECPG_DATA_NOT_ARRAY)

The database returned an ordinary variable in a place that requires array value. (SQLSTATE 42804)

-216 (ECPG_ARRAY_INSERT)

The value could not be inserted into the array. (SQLSTATE 42804)

-220 (ECPG_NO_CONN)

The program tried to access a connection that does not exist. (SQLSTATE 08003)

-221 (ECPG_NOT_CONN)

The program tried to access a connection that does exist but is not open. (This is an internal error.) (SQLSTATE YE002)

-230 (ECPG_INVALID_STMT)

The statement you are trying to use has not been prepared. (SQLSTATE 26000)

-239 (ECPG_INFORMIX_DUPLICATE_KEY)

Duplicate key error, violation of unique constraint (Informix compatibility mode). (SQLSTATE 23505)

-240 (ECPG_UNKNOWN_DESCRIPTOR)

The descriptor specified was not found. The statement you are trying to use has not been prepared. (SQLSTATE 33000)

-241 (ECPG_INVALID_DESCRIPTOR_INDEX)

The descriptor index specified was out of range. (SQLSTATE 07009)

-242 (ECPG_UNKNOWN_DESCRIPTOR_ITEM)

An invalid descriptor item was requested. (This is an internal error.) (SQLSTATE YE002)

-243 (ECPG_VAR_NOT_NUMERIC)

During the execution of a dynamic statement, the database returned a numeric value and the host variable was not numeric. (SQLSTATE 07006)

-244 (ECPG_VAR_NOT_CHAR)

During the execution of a dynamic statement, the database returned a non-numeric value and the host variable was numeric. (SQLSTATE 07006)

-284 (ECPG_INFORMIX_SUBSELECT_NOT_ONE)

A result of the subquery is not single row (Informix compatibility mode). (SQLSTATE 21000)

-400 (ECPG_PGSQL)

Some error caused by the PostgreSQL server. The message contains the error message from the PostgreSQL server.

-401 (ECPG_TRANS)

The PostgreSQL server signaled that we cannot start, commit, or rollback the transaction. (SQLSTATE 08007)

-402 (ECPG_CONNECT)

The connection attempt to the database did not succeed. (SQLSTATE 08001)

-403 (ECPG_DUPLICATE_KEY)

Duplicate key error, violation of unique constraint. (SQLSTATE 23505)

-404 (ECPG_SUBSELECT_NOT_ONE)

A result for the subquery is not single row. (SQLSTATE 21000)

-602 (ECPG_WARNING_UNKNOWN_PORTAL)

An invalid cursor name was specified. (SQLSTATE 34000)

-603 (ECPG_WARNING_IN_TRANSACTION)

Transaction is in progress. (SQLSTATE 25001)

-604 (ECPG_WARNING_NO_TRANSACTION)

There is no active (in-progress) transaction. (SQLSTATE 25P01)

-605 (ECPG_WARNING_PORTAL_EXISTS)

An existing cursor name was specified. (SQLSTATE 42P03)

35.9. Preprocessor Directives

Several preprocessor directives are available that modify how the `ecpg` preprocessor parses and processes a file.

35.9.1. Including Files

To include an external file into your embedded SQL program, use:

```
EXEC SQL INCLUDE filename;  
EXEC SQL INCLUDE <filename>;  
EXEC SQL INCLUDE "filename";
```

The embedded SQL preprocessor will look for a file named `filename.h`, preprocess it, and include it in the resulting C output. Thus, embedded SQL statements in the included file are handled correctly.

The `ecpg` preprocessor will search a file at several directories in following order:

- current directory
- `/usr/local/include`
- PostgreSQL include directory, defined at build time (e.g., `/usr/local/pgsql/include`)
- `/usr/include`

But when `EXEC SQL INCLUDE "filename"` is used, only the current directory is searched.

In each directory, the preprocessor will first look for the file name as given, and if not found will append `.h` to the file name and try again (unless the specified file name already has that suffix).

Note that `EXEC SQL INCLUDE` is *not* the same as:

```
#include <filename.h>
```

because this file would not be subject to SQL command preprocessing. Naturally, you can continue to use the C `#include` directive to include other header files.

Note

The include file name is case-sensitive, even though the rest of the `EXEC SQL INCLUDE` command follows the normal SQL case-sensitivity rules.

35.9.2. The define and undef Directives

Similar to the directive `#define` that is known from C, embedded SQL has a similar concept:

```
EXEC SQL DEFINE name;  
EXEC SQL DEFINE name value;
```

So you can define a name:

```
EXEC SQL DEFINE HAVE_FEATURE;
```

And you can also define constants:

```
EXEC SQL DEFINE MYNUMBER 12;  
EXEC SQL DEFINE MYSTRING 'abc';
```

Use `undef` to remove a previous definition:

```
EXEC SQL UNDEF MYNUMBER;
```

Of course you can continue to use the C versions `#define` and `#undef` in your embedded SQL program. The difference is where your defined values get evaluated. If you use `EXEC SQL DEFINE` then the `ecpg` preprocessor evaluates the defines and substitutes the values. For example if you write:

```
EXEC SQL DEFINE MYNUMBER 12;  
...  
EXEC SQL UPDATE Tbl SET col = MYNUMBER;
```

then `ecpg` will already do the substitution and your C compiler will never see any name or identifier `MYNUMBER`. Note that you cannot use `#define` for a constant that you are going to use in an embedded SQL query because in this case the embedded SQL precompiler is not able to see this declaration.

35.9.3. ifdef, ifndef, else, elif, and endif Directives

You can use the following directives to compile code sections conditionally:

```
EXEC SQL ifdef name;
```

Checks a *name* and processes subsequent lines if *name* has been created with `EXEC SQL define name`.

```
EXEC SQL ifndef name;
```

Checks a *name* and processes subsequent lines if *name* has *not* been created with `EXEC SQL define name`.

```
EXEC SQL else;
```

Starts processing an alternative section to a section introduced by either `EXEC SQL ifdef name` or `EXEC SQL ifndef name`.

```
EXEC SQL elif name;
```

Checks *name* and starts an alternative section if *name* has been created with `EXEC SQL define name`.

```
EXEC SQL endif;
```

Ends an alternative section.

Example:

```
EXEC SQL ifndef TZVAR;
EXEC SQL SET TIMEZONE TO 'GMT';
EXEC SQL elif TZNAME;
EXEC SQL SET TIMEZONE TO TZNAME;
EXEC SQL else;
EXEC SQL SET TIMEZONE TO TZVAR;
EXEC SQL endif;
```

35.10. Processing Embedded SQL Programs

Now that you have an idea how to form embedded SQL C programs, you probably want to know how to compile them. Before compiling you run the file through the embedded SQL C preprocessor, which converts the SQL statements you used to special function calls. After compiling, you must link with a special library that contains the needed functions. These functions fetch information from the arguments, perform the SQL command using the libpq interface, and put the result in the arguments specified for output.

The preprocessor program is called `ecpg` and is included in a normal PostgreSQL installation. Embedded SQL programs are typically named with an extension `.pgc`. If you have a program file called `prog1.pgc`, you can preprocess it by simply calling:

```
ecpg prog1.pgc
```

This will create a file called `prog1.c`. If your input files do not follow the suggested naming pattern, you can specify the output file explicitly using the `-o` option.

The preprocessed file can be compiled normally, for example:

```
cc -c prog1.c
```

The generated C source files include header files from the PostgreSQL installation, so if you installed PostgreSQL in a location that is not searched by default, you have to add an option such as `-I/usr/local/pgsql/include` to the compilation command line.

To link an embedded SQL program, you need to include the `libecpg` library, like so:

```
cc -o myprog prog1.o prog2.o ... -lecpg
```

Again, you might have to add an option like `-L/usr/local/pgsql/lib` to that command line.

You can use `pg_config` or `pkg-config` with package name `libecpg` to get the paths for your installation.

If you manage the build process of a larger project using `make`, it might be convenient to include the following implicit rule to your makefiles:

```
ECPG = ecpg

%.c: %.pgc
    $(ECPG) $<
```

The complete syntax of the `ecpg` command is detailed in `ecpg`.

The `ecpg` library is thread-safe by default. However, you might need to use some threading command-line options to compile your client code.

35.11. Library Functions

The `libecpg` library primarily contains “hidden” functions that are used to implement the functionality expressed by the embedded SQL commands. But there are some functions that can usefully be called directly. Note that this makes your code unportable.

- `ECPGdebug(int on, FILE *stream)` turns on debug logging if called with the first argument non-zero. Debug logging is done on `stream`. The log contains all SQL statements with all the input variables inserted, and the results from the PostgreSQL server. This can be very useful when searching for errors in your SQL statements.

Note

On Windows, if the `ecpg` libraries and an application are compiled with different flags, this function call will crash the application because the internal representation of the `FILE` pointers differ. Specifically, `multithreaded/single-threaded`, `release/debug`, and `static/dynamic` flags should be the same for the library and all applications using that library.

- `ECPGget_PGconn(const char *connection_name)` returns the library database connection handle identified by the given name. If `connection_name` is set to `NULL`, the current connection handle is returned. If no connection handle can be identified, the function returns `NULL`. The returned connection handle can be used to call any other functions from `libpq`, if necessary.

Note

It is a bad idea to manipulate database connection handles made from `ecpg` directly with `libpq` routines.

- `ECPGtransactionStatus(const char *connection_name)` returns the current transaction status of the given connection identified by `connection_name`. See Section 33.2 and `libpq`'s `PQtransactionStatus()` for details about the returned status codes.
- `ECPGstatus(int lineno, const char* connection_name)` returns true if you are connected to a database and false if not. `connection_name` can be `NULL` if a single connection is being used.

35.12. Large Objects

Large objects are not directly supported by ECPG, but ECPG application can manipulate large objects through the libpq large object functions, obtaining the necessary PGconn object by calling the ECPGget_PGconn() function. (However, use of the ECPGget_PGconn() function and touching PGconn objects directly should be done very carefully and ideally not mixed with other ECPG database access calls.)

For more details about the ECPGget_PGconn(), see Section 35.11. For information about the large object function interface, see Chapter 34.

Large object functions have to be called in a transaction block, so when autocommit is off, BEGIN commands have to be issued explicitly.

Example 35.2 shows an example program that illustrates how to create, write, and read a large object in an ECPG application.

Example 35.2. ECPG Program Accessing Large Objects

```
#include <stdio.h>
#include <stdlib.h>
#include <libpq-fe.h>
#include <libpq/libpq-fs.h>

EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
    PGconn      *conn;
    Oid          loid;
    int          fd;
    char         buf[256];
    int          buflen = 256;
    char         buf2[256];
    int          rc;

    memset(buf, 1, buflen);

    EXEC SQL CONNECT TO testdb AS con1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

    conn = ECPGget_PGconn("con1");
    printf("conn = %p\n", conn);

    /* create */
    loid = lo_create(conn, 0);
    if (loid < 0)
        printf("lo_create() failed: %s", PQerrorMessage(conn));

    printf("loid = %d\n", loid);

    /* write test */
    fd = lo_open(conn, loid, INV_READ|INV_WRITE);
    if (fd < 0)
        printf("lo_open() failed: %s", PQerrorMessage(conn));
```

```
printf("fd = %d\n", fd);

rc = lo_write(conn, fd, buf, buflen);
if (rc < 0)
    printf("lo_write() failed\n");

rc = lo_close(conn, fd);
if (rc < 0)
    printf("lo_close() failed: %s", PQerrorMessage(conn));

/* read test */
fd = lo_open(conn, loid, INV_READ);
if (fd < 0)
    printf("lo_open() failed: %s", PQerrorMessage(conn));

printf("fd = %d\n", fd);

rc = lo_read(conn, fd, buf2, buflen);
if (rc < 0)
    printf("lo_read() failed\n");

rc = lo_close(conn, fd);
if (rc < 0)
    printf("lo_close() failed: %s", PQerrorMessage(conn));

/* check */
rc = memcmp(buf, buf2, buflen);
printf("memcmp() = %d\n", rc);

/* cleanup */
rc = lo_unlink(conn, loid);
if (rc < 0)
    printf("lo_unlink() failed: %s", PQerrorMessage(conn));

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
return 0;
}
```

35.13. C++ Applications

ECPG has some limited support for C++ applications. This section describes some caveats.

The `ecpg` preprocessor takes an input file written in C (or something like C) and embedded SQL commands, converts the embedded SQL commands into C language chunks, and finally generates a `.c` file. The header file declarations of the library functions used by the C language chunks that `ecpg` generates are wrapped in `extern "C" { ... }` blocks when used under C++, so they should work seamlessly in C++.

In general, however, the `ecpg` preprocessor only understands C; it does not handle the special syntax and reserved words of the C++ language. So, some embedded SQL code written in C++ application code that uses complicated features specific to C++ might fail to be preprocessed correctly or might not work as expected.

A safe way to use the embedded SQL code in a C++ application is hiding the ECPG calls in a C module, which the C++ application code calls into to access the database, and linking that together with the rest of the C++ code. See Section 35.13.2 about that.

35.13.1. Scope for Host Variables

The `ecpg` preprocessor understands the scope of variables in C. In the C language, this is rather simple because the scopes of variables is based on their code blocks. In C++, however, the class member variables are referenced in a different code block from the declared position, so the `ecpg` preprocessor will not understand the scope of the class member variables.

For example, in the following case, the `ecpg` preprocessor cannot find any declaration for the variable `dbname` in the `test` method, so an error will occur.

```
class TestCpp
{
    EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
    EXEC SQL END DECLARE SECTION;

public:
    TestCpp();
    void test();
    ~TestCpp();
};

TestCpp::TestCpp()
{
    EXEC SQL CONNECT TO testdb1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
}

void Test::test()
{
    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current_database = %s\n", dbname);
}

TestCpp::~TestCpp()
{
    EXEC SQL DISCONNECT ALL;
}
```

This code will result in an error like this:

```
ecpg test_cpp.pgc
```

```
test_cpp.pgc:28: ERROR: variable "dbname" is not declared
```

To avoid this scope issue, the `test` method could be modified to use a local variable as intermediate storage. But this approach is only a poor workaround, because it uglifies the code and reduces performance.

```
void TestCpp::test()
{
    EXEC SQL BEGIN DECLARE SECTION;
    char tmp[1024];
    EXEC SQL END DECLARE SECTION;

    EXEC SQL SELECT current_database() INTO :tmp;
```

```

    strcpy(dbname, tmp, sizeof(tmp));

    printf("current_database = %s\n", dbname);
}

```

35.13.2. C++ Application Development with External C Module

If you understand these technical limitations of the `ecpg` preprocessor in C++, you might come to the conclusion that linking C objects and C++ objects at the link stage to enable C++ applications to use ECPG features could be better than writing some embedded SQL commands in C++ code directly. This section describes a way to separate some embedded SQL commands from C++ application code with a simple example. In this example, the application is implemented in C++, while C and ECPG is used to connect to the PostgreSQL server.

Three kinds of files have to be created: a C file (`*.pgc`), a header file, and a C++ file:

`test_mod.pgc`

A sub-routine module to execute SQL commands embedded in C. It is going to be converted into `test_mod.c` by the preprocessor.

```

#include "test_mod.h"
#include <stdio.h>

void
db_connect()
{
    EXEC SQL CONNECT TO testdb1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
}

void
db_test()
{
    EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
    EXEC SQL END DECLARE SECTION;

    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current_database = %s\n", dbname);
}

void
db_disconnect()
{
    EXEC SQL DISCONNECT ALL;
}

```

`test_mod.h`

A header file with declarations of the functions in the C module (`test_mod.pgc`). It is included by `test_cpp.cpp`. This file has to have an `extern "C"` block around the declarations, because it will be linked from the C++ module.

```

#ifdef __cplusplus

```

```
extern "C" {
#endif

void db_connect();
void db_test();
void db_disconnect();

#ifdef __cplusplus
}
#endif
```

test_cpp.cpp

The main code for the application, including the main routine, and in this example a C++ class.

```
#include "test_mod.h"

class TestCpp
{
public:
    TestCpp();
    void test();
    ~TestCpp();
};

TestCpp::TestCpp()
{
    db_connect();
}

void
TestCpp::test()
{
    db_test();
}

TestCpp::~TestCpp()
{
    db_disconnect();
}

int
main(void)
{
    TestCpp *t = new TestCpp();

    t->test();
    return 0;
}
```

To build the application, proceed as follows. Convert `test_mod.pgc` into `test_mod.c` by running `ecpg`, and generate `test_mod.o` by compiling `test_mod.c` with the C compiler:

```
ecpg -o test_mod.c test_mod.pgc
cc -c test_mod.c -o test_mod.o
```

Next, generate `test_cpp.o` by compiling `test_cpp.cpp` with the C++ compiler:

```
c++ -c test_cpp.cpp -o test_cpp.o
```

Finally, link these object files, `test_cpp.o` and `test_mod.o`, into one executable, using the C++ compiler driver:

```
c++ test_cpp.o test_mod.o -lecpG -o test_cpp
```

35.14. Embedded SQL Commands

This section describes all SQL commands that are specific to embedded SQL. Also refer to the SQL commands listed in *SQL Commands*, which can also be used in embedded SQL, unless stated otherwise.

ALLOCATE DESCRIPTOR

ALLOCATE DESCRIPTOR — allocate an SQL descriptor area

Synopsis

```
ALLOCATE DESCRIPTOR name
```

Description

ALLOCATE DESCRIPTOR allocates a new named SQL descriptor area, which can be used to exchange data between the PostgreSQL server and the host program.

Descriptor areas should be freed after use using the DEALLOCATE DESCRIPTOR command.

Parameters

name

A name of SQL descriptor, case sensitive. This can be an SQL identifier or a host variable.

Examples

```
EXEC SQL ALLOCATE DESCRIPTOR mydesc;
```

Compatibility

ALLOCATE DESCRIPTOR is specified in the SQL standard.

See Also

DEALLOCATE DESCRIPTOR, GET DESCRIPTOR, SET DESCRIPTOR

CONNECT

CONNECT — establish a database connection

Synopsis

```
CONNECT TO connection_target [ AS connection_name ]
  [ USER connection_user ]
CONNECT TO DEFAULT
CONNECT connection_user
DATABASE connection_target
```

Description

The CONNECT command establishes a connection between the client and the PostgreSQL server.

Parameters

connection_target

connection_target specifies the target server of the connection on one of several forms.

[*database_name*] [@*host*] [:*port*]

Connect over TCP/IP

unix:postgresql://*host* [:*port*] / [*database_name*] [?*connection_option*]

Connect over Unix-domain sockets

tcp:postgresql://*host* [:*port*] / [*database_name*] [?*connection_option*]

Connect over TCP/IP

SQL string constant

containing a value in one of the above forms

host variable

host variable of type `char []` or `VARCHAR []` containing a value in one of the above forms

connection_name

An optional identifier for the connection, so that it can be referred to in other commands. This can be an SQL identifier or a host variable.

connection_user

The user name for the database connection.

This parameter can also specify user name and password, using one the forms `user_name/password`, `user_name IDENTIFIED BY password`, or `user_name USING password`.

User name and password can be SQL identifiers, string constants, or host variables.

DEFAULT

Use all default connection parameters, as defined by libpq.

Examples

Here are several variants for specifying connection parameters:

```
EXEC SQL CONNECT TO "connectdb" AS main;
EXEC SQL CONNECT TO "connectdb" AS second;
EXEC SQL CONNECT TO "unix:postgresql://200.46.204.71/connectdb" AS
  main USER connectuser;
EXEC SQL CONNECT TO "unix:postgresql://localhost/connectdb" AS main
  USER connectuser;
EXEC SQL CONNECT TO 'connectdb' AS main;
EXEC SQL CONNECT TO 'unix:postgresql://localhost/connectdb' AS main
  USER :user;
EXEC SQL CONNECT TO :db AS :id;
EXEC SQL CONNECT TO :db USER connectuser USING :pw;
EXEC SQL CONNECT TO @localhost AS main USER connectdb;
EXEC SQL CONNECT TO REGRESSDB1 as main;
EXEC SQL CONNECT TO AS main USER connectdb;
EXEC SQL CONNECT TO connectdb AS :id;
EXEC SQL CONNECT TO connectdb AS main USER connectuser/connectdb;
EXEC SQL CONNECT TO connectdb AS main;
EXEC SQL CONNECT TO connectdb@localhost AS main;
EXEC SQL CONNECT TO tcp:postgresql://localhost/ USER connectdb;
EXEC SQL CONNECT TO tcp:postgresql://localhost/connectdb USER
  connectuser IDENTIFIED BY connectpw;
EXEC SQL CONNECT TO tcp:postgresql://localhost:20/connectdb USER
  connectuser IDENTIFIED BY connectpw;
EXEC SQL CONNECT TO unix:postgresql://localhost/ AS main USER
  connectdb;
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb AS main
  USER connectuser;
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb USER
  connectuser IDENTIFIED BY "connectpw";
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb USER
  connectuser USING "connectpw";
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb?
  connect_timeout=14 USER connectuser;
```

Here is an example program that illustrates the use of host variables to specify connection parameters:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
  char *dbname      = "testdb";      /* database name */
  char *user        = "testuser";    /* connection user name */
  char *connection  = "tcp:postgresql://localhost:5432/testdb";
                                      /* connection string */
  char ver[256];      /* buffer to store the version
  string */
EXEC SQL END DECLARE SECTION;

  ECPGdebug(1, stderr);
```

```
    EXEC SQL CONNECT TO :dbname USER :user;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL SELECT version() INTO :ver;
    EXEC SQL DISCONNECT;

    printf("version: %s\n", ver);

    EXEC SQL CONNECT TO :connection USER :user;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL SELECT version() INTO :ver;
    EXEC SQL DISCONNECT;

    printf("version: %s\n", ver);

    return 0;
}
```

Compatibility

CONNECT is specified in the SQL standard, but the format of the connection parameters is implementation-specific.

See Also

DISCONNECT, SET CONNECTION

DEALLOCATE DESCRIPTOR

DEALLOCATE DESCRIPTOR — deallocate an SQL descriptor area

Synopsis

```
DEALLOCATE DESCRIPTOR name
```

Description

DEALLOCATE DESCRIPTOR deallocates a named SQL descriptor area.

Parameters

name

The name of the descriptor which is going to be deallocated. It is case sensitive. This can be an SQL identifier or a host variable.

Examples

```
EXEC SQL DEALLOCATE DESCRIPTOR mydesc;
```

Compatibility

DEALLOCATE DESCRIPTOR is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR, SET DESCRIPTOR

DECLARE

DECLARE — define a cursor

Synopsis

```
DECLARE cursor_name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]  
  CURSOR [ { WITH | WITHOUT } HOLD ] FOR prepared_name  
DECLARE cursor_name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]  
  CURSOR [ { WITH | WITHOUT } HOLD ] FOR query
```

Description

DECLARE declares a cursor for iterating over the result set of a prepared statement. This command has slightly different semantics from the direct SQL command DECLARE: Whereas the latter executes a query and prepares the result set for retrieval, this embedded SQL command merely declares a name as a “loop variable” for iterating over the result set of a query; the actual execution happens when the cursor is opened with the OPEN command.

Parameters

cursor_name

A cursor name, case sensitive. This can be an SQL identifier or a host variable.

prepared_name

The name of a prepared query, either as an SQL identifier or a host variable.

query

A SELECT or VALUES command which will provide the rows to be returned by the cursor.

For the meaning of the cursor options, see DECLARE.

Examples

Examples declaring a cursor for a query:

```
EXEC SQL DECLARE C CURSOR FOR SELECT * FROM My_Table;  
EXEC SQL DECLARE C CURSOR FOR SELECT Item1 FROM T;  
EXEC SQL DECLARE cur1 CURSOR FOR SELECT version();
```

An example declaring a cursor for a prepared statement:

```
EXEC SQL PREPARE stmt1 AS SELECT version();  
EXEC SQL DECLARE cur1 CURSOR FOR stmt1;
```

Compatibility

DECLARE is specified in the SQL standard.

See Also

OPEN, CLOSE, DECLARE

DESCRIBE

DESCRIBE — obtain information about a prepared statement or result set

Synopsis

```
DESCRIBE [ OUTPUT ] prepared_name USING [ SQL ]  
    DESCRIPTOR descriptor_name  
DESCRIBE [ OUTPUT ] prepared_name INTO [ SQL ]  
    DESCRIPTOR descriptor_name  
DESCRIBE [ OUTPUT ] prepared_name INTO slda_name
```

Description

DESCRIBE retrieves metadata information about the result columns contained in a prepared statement, without actually fetching a row.

Parameters

prepared_name

The name of a prepared statement. This can be an SQL identifier or a host variable.

descriptor_name

A descriptor name. It is case sensitive. It can be an SQL identifier or a host variable.

slda_name

The name of an SQLDA variable.

Examples

```
EXEC SQL ALLOCATE DESCRIPTOR mydesc;  
EXEC SQL PREPARE stmt1 FROM :sql_stmt;  
EXEC SQL DESCRIBE stmt1 INTO SQL DESCRIPTOR mydesc;  
EXEC SQL GET DESCRIPTOR mydesc VALUE 1 :charvar = NAME;  
EXEC SQL DEALLOCATE DESCRIPTOR mydesc;
```

Compatibility

DESCRIBE is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR

DISCONNECT

DISCONNECT — terminate a database connection

Synopsis

```
DISCONNECT connection_name
DISCONNECT [ CURRENT ]
DISCONNECT DEFAULT
DISCONNECT ALL
```

Description

DISCONNECT closes a connection (or all connections) to the database.

Parameters

connection_name

A database connection name established by the CONNECT command.

CURRENT

Close the “current” connection, which is either the most recently opened connection, or the connection set by the SET CONNECTION command. This is also the default if no argument is given to the DISCONNECT command.

DEFAULT

Close the default connection.

ALL

Close all open connections.

Examples

```
int
main(void)
{
    EXEC SQL CONNECT TO testdb AS DEFAULT USER testuser;
    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL CONNECT TO testdb AS con2 USER testuser;
    EXEC SQL CONNECT TO testdb AS con3 USER testuser;

    EXEC SQL DISCONNECT CURRENT; /* close con3          */
    EXEC SQL DISCONNECT DEFAULT; /* close DEFAULT  */
    EXEC SQL DISCONNECT ALL;     /* close con2 and con1 */

    return 0;
}
```

Compatibility

DISCONNECT is specified in the SQL standard.

See Also

CONNECT, SET CONNECTION

EXECUTE IMMEDIATE

EXECUTE IMMEDIATE — dynamically prepare and execute a statement

Synopsis

```
EXECUTE IMMEDIATE string
```

Description

EXECUTE IMMEDIATE immediately prepares and executes a dynamically specified SQL statement, without retrieving result rows.

Parameters

string

A literal C string or a host variable containing the SQL statement to be executed.

Examples

Here is an example that executes an INSERT statement using EXECUTE IMMEDIATE and a host variable named `command`:

```
printf(command, "INSERT INTO test (name, amount, letter) VALUES  
( 'db: 'r1''', 1, 'f')");  
EXEC SQL EXECUTE IMMEDIATE :command;
```

Compatibility

EXECUTE IMMEDIATE is specified in the SQL standard.

GET DESCRIPTOR

GET DESCRIPTOR — get information from an SQL descriptor area

Synopsis

```
GET DESCRIPTOR descriptor_name :cvariable = descriptor_header_item
[ , ... ]
GET DESCRIPTOR descriptor_name VALUE column_number :cvariable
= descriptor_item [ , ... ]
```

Description

GET DESCRIPTOR retrieves information about a query result set from an SQL descriptor area and stores it into host variables. A descriptor area is typically populated using FETCH or SELECT before using this command to transfer the information into host language variables.

This command has two forms: The first form retrieves descriptor “header” items, which apply to the result set in its entirety. One example is the row count. The second form, which requires the column number as additional parameter, retrieves information about a particular column. Examples are the column name and the actual column value.

Parameters

descriptor_name

A descriptor name.

descriptor_header_item

A token identifying which header information item to retrieve. Only COUNT, to get the number of columns in the result set, is currently supported.

column_number

The number of the column about which information is to be retrieved. The count starts at 1.

descriptor_item

A token identifying which item of information about a column to retrieve. See Section 35.7.1 for a list of supported items.

cvariable

A host variable that will receive the data retrieved from the descriptor area.

Examples

An example to retrieve the number of columns in a result set:

```
EXEC SQL GET DESCRIPTOR d :d_count = COUNT;
```

An example to retrieve a data length in the first column:

```
EXEC SQL GET DESCRIPTOR d VALUE 1 :d_returned_octet_length =
RETURNED_OCTET_LENGTH;
```

An example to retrieve the data body of the second column as a string:

```
EXEC SQL GET DESCRIPTOR d VALUE 2 :d_data = DATA;
```

Here is an example for a whole procedure of executing `SELECT current_database();` and showing the number of columns, the column data length, and the column data:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    int d_count;
    char d_data[1024];
    int d_returned_octet_length;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL ALLOCATE DESCRIPTOR d;

    /* Declare, open a cursor, and assign a descriptor to the
cursor */
    EXEC SQL DECLARE cur CURSOR FOR SELECT current_database();
    EXEC SQL OPEN cur;
    EXEC SQL FETCH NEXT FROM cur INTO SQL DESCRIPTOR d;

    /* Get a number of total columns */
    EXEC SQL GET DESCRIPTOR d :d_count = COUNT;
    printf("d_count                = %d\n", d_count);

    /* Get length of a returned column */
    EXEC SQL GET DESCRIPTOR d VALUE 1 :d_returned_octet_length =
RETURNED_OCTET_LENGTH;
    printf("d_returned_octet_length = %d\n",
d_returned_octet_length);

    /* Fetch the returned column as a string */
    EXEC SQL GET DESCRIPTOR d VALUE 1 :d_data = DATA;
    printf("d_data                  = %s\n", d_data);

    /* Closing */
    EXEC SQL CLOSE cur;
    EXEC SQL COMMIT;

    EXEC SQL DEALLOCATE DESCRIPTOR d;
    EXEC SQL DISCONNECT ALL;

    return 0;
}
```

When the example is executed, the result will look like this:

```
d_count                = 1
d_returned_octet_length = 6
d_data                  = testdb
```

Compatibility

GET DESCRIPTOR is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, SET DESCRIPTOR

OPEN

OPEN — open a dynamic cursor

Synopsis

```
OPEN cursor_name
OPEN cursor_name USING value [, ... ]
OPEN cursor_name USING SQL DESCRIPTOR descriptor_name
```

Description

OPEN opens a cursor and optionally binds actual values to the placeholders in the cursor's declaration. The cursor must previously have been declared with the DECLARE command. The execution of OPEN causes the query to start executing on the server.

Parameters

cursor_name

The name of the cursor to be opened. This can be an SQL identifier or a host variable.

value

A value to be bound to a placeholder in the cursor. This can be an SQL constant, a host variable, or a host variable with indicator.

descriptor_name

The name of a descriptor containing values to be bound to the placeholders in the cursor. This can be an SQL identifier or a host variable.

Examples

```
EXEC SQL OPEN a;
EXEC SQL OPEN d USING 1, 'test';
EXEC SQL OPEN c1 USING SQL DESCRIPTOR mydesc;
EXEC SQL OPEN :curname1;
```

Compatibility

OPEN is specified in the SQL standard.

See Also

DECLARE, CLOSE

PREPARE

PREPARE — prepare a statement for execution

Synopsis

```
PREPARE name FROM string
```

Description

PREPARE prepares a statement dynamically specified as a string for execution. This is different from the direct SQL statement PREPARE, which can also be used in embedded programs. The EXECUTE command is used to execute either kind of prepared statement.

Parameters

prepared_name

An identifier for the prepared query.

string

A literal C string or a host variable containing a preparable statement, one of the SELECT, INSERT, UPDATE, or DELETE.

Examples

```
char *stmt = "SELECT * FROM test1 WHERE a = ? AND b = ?";

EXEC SQL ALLOCATE DESCRIPTOR outdesc;
EXEC SQL PREPARE foo FROM :stmt;

EXEC SQL EXECUTE foo USING SQL DESCRIPTOR indesc INTO SQL
DESCRIPTOR outdesc;
```

Compatibility

PREPARE is specified in the SQL standard.

See Also

EXECUTE

SET AUTOCOMMIT

SET AUTOCOMMIT — set the autocommit behavior of the current session

Synopsis

```
SET AUTOCOMMIT { = | TO } { ON | OFF }
```

Description

SET AUTOCOMMIT sets the autocommit behavior of the current database session. By default, embedded SQL programs are *not* in autocommit mode, so COMMIT needs to be issued explicitly when desired. This command can change the session to autocommit mode, where each individual statement is committed implicitly.

Compatibility

SET AUTOCOMMIT is an extension of PostgreSQL ECPG.

SET CONNECTION

SET CONNECTION — select a database connection

Synopsis

```
SET CONNECTION [ TO | = ] connection_name
```

Description

SET CONNECTION sets the “current” database connection, which is the one that all commands use unless overridden.

Parameters

connection_name

A database connection name established by the CONNECT command.

DEFAULT

Set the connection to the default connection.

Examples

```
EXEC SQL SET CONNECTION TO con2;  
EXEC SQL SET CONNECTION = con1;
```

Compatibility

SET CONNECTION is specified in the SQL standard.

See Also

CONNECT, DISCONNECT

SET DESCRIPTOR

SET DESCRIPTOR — set information in an SQL descriptor area

Synopsis

```
SET DESCRIPTOR descriptor_name descriptor_header_item = value
[ , ... ]
SET DESCRIPTOR descriptor_name VALUE number descriptor_item = value
[ , ... ]
```

Description

SET DESCRIPTOR populates an SQL descriptor area with values. The descriptor area is then typically used to bind parameters in a prepared query execution.

This command has two forms: The first form applies to the descriptor “header”, which is independent of a particular datum. The second form assigns values to particular datums, identified by number.

Parameters

descriptor_name

A descriptor name.

descriptor_header_item

A token identifying which header information item to set. Only COUNT, to set the number of descriptor items, is currently supported.

number

The number of the descriptor item to set. The count starts at 1.

descriptor_item

A token identifying which item of information to set in the descriptor. See Section 35.7.1 for a list of supported items.

value

A value to store into the descriptor item. This can be an SQL constant or a host variable.

Examples

```
EXEC SQL SET DESCRIPTOR indesc COUNT = 1;
EXEC SQL SET DESCRIPTOR indesc VALUE 1 DATA = 2;
EXEC SQL SET DESCRIPTOR indesc VALUE 1 DATA = :val1;
EXEC SQL SET DESCRIPTOR indesc VALUE 2 INDICATOR = :val1, DATA =
'some string';
EXEC SQL SET DESCRIPTOR indesc VALUE 2 INDICATOR = :val2null, DATA
= :val2;
```

Compatibility

SET DESCRIPTOR is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR

TYPE

TYPE — define a new data type

Synopsis

```
TYPE type_name IS ctype
```

Description

The TYPE command defines a new C type. It is equivalent to putting a typedef into a declare section.

This command is only recognized when `ecpg` is run with the `-c` option.

Parameters

type_name

The name for the new type. It must be a valid C type name.

ctype

A C type specification.

Examples

```
EXEC SQL TYPE customer IS
  struct
  {
    varchar name[50];
    int     phone;
  };
```

```
EXEC SQL TYPE cust_ind IS
  struct ind
  {
    short  name_ind;
    short  phone_ind;
  };
```

```
EXEC SQL TYPE c IS char reference;
EXEC SQL TYPE ind IS union { int integer; short smallint; };
EXEC SQL TYPE intarray IS int[AMOUNT];
EXEC SQL TYPE str IS varchar[BUFFERSIZ];
EXEC SQL TYPE string IS char[11];
```

Here is an example program that uses EXEC SQL TYPE:

```
EXEC SQL WHENEVER SQLERROR SQLPRINT;

EXEC SQL TYPE tt IS
  struct
  {
    varchar v[256];
    int     i;
```

```
};

EXEC SQL TYPE tt_ind IS
  struct ind {
    short  v_ind;
    short  i_ind;
  };

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
  tt t;
  tt_ind t_ind;
EXEC SQL END DECLARE SECTION;

  EXEC SQL CONNECT TO testdb AS con1;
  EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;

  EXEC SQL SELECT current_database(), 256 INTO :t:t_ind LIMIT 1;

  printf("t.v = %s\n", t.v.arr);
  printf("t.i = %d\n", t.i);

  printf("t_ind.v_ind = %d\n", t_ind.v_ind);
  printf("t_ind.i_ind = %d\n", t_ind.i_ind);

  EXEC SQL DISCONNECT con1;

  return 0;
}
```

The output from this program looks like this:

```
t.v = testdb
t.i = 256
t_ind.v_ind = 0
t_ind.i_ind = 0
```

Compatibility

The TYPE command is a PostgreSQL extension.

VAR

VAR — define a variable

Synopsis

```
VAR varname IS ctype
```

Description

The VAR command assigns a new C data type to a host variable. The host variable must be previously declared in a declare section.

Parameters

varname

A C variable name.

ctype

A C type specification.

Examples

```
Exec sql begin declare section;  
short a;  
exec sql end declare section;  
EXEC SQL VAR a IS int;
```

Compatibility

The VAR command is a PostgreSQL extension.

WHENEVER

WHENEVER — specify the action to be taken when an SQL statement causes a specific class condition to be raised

Synopsis

```
WHENEVER { NOT FOUND | SQLERROR | SQLWARNING } action
```

Description

Define a behavior which is called on the special cases (Rows not found, SQL warnings or errors) in the result of SQL execution.

Parameters

See Section 35.8.1 for a description of the parameters.

Examples

```
EXEC SQL WHENEVER NOT FOUND CONTINUE;
EXEC SQL WHENEVER NOT FOUND DO BREAK;
EXEC SQL WHENEVER NOT FOUND DO CONTINUE;
EXEC SQL WHENEVER SQLWARNING SQLPRINT;
EXEC SQL WHENEVER SQLWARNING DO warn();
EXEC SQL WHENEVER SQLERROR sqlprint;
EXEC SQL WHENEVER SQLERROR CALL print2();
EXEC SQL WHENEVER SQLERROR DO handle_error("select");
EXEC SQL WHENEVER SQLERROR DO sqlnotice(NULL, NONO);
EXEC SQL WHENEVER SQLERROR DO sqlprint();
EXEC SQL WHENEVER SQLERROR GOTO error_label;
EXEC SQL WHENEVER SQLERROR STOP;
```

A typical application is the use of `WHENEVER NOT FOUND BREAK` to handle looping through result sets:

```
int
main(void)
{
    EXEC SQL CONNECT TO testdb AS con1;
    EXEC SQL SELECT pg_catalog.set_config('search_path', '',
false); EXEC SQL COMMIT;
    EXEC SQL ALLOCATE DESCRIPTOR d;
    EXEC SQL DECLARE cur CURSOR FOR SELECT current_database(),
'hoge', 256;
    EXEC SQL OPEN cur;

    /* when end of result set reached, break out of while loop */
    EXEC SQL WHENEVER NOT FOUND DO BREAK;

    while (1)
    {
        EXEC SQL FETCH NEXT FROM cur INTO SQL DESCRIPTOR d;
        ...
    }
}
```

```
EXEC SQL CLOSE cur;
EXEC SQL COMMIT;

EXEC SQL DEALLOCATE DESCRIPTOR d;
EXEC SQL DISCONNECT ALL;

return 0;
}
```

Compatibility

WHENEVER is specified in the SQL standard, but most of the actions are PostgreSQL extensions.

35.15. Informix Compatibility Mode

`ecpg` can be run in a so-called *Informix compatibility mode*. If this mode is active, it tries to behave as if it were the Informix precompiler for Informix E/SQL. Generally spoken this will allow you to use the dollar sign instead of the `EXEC SQL` primitive to introduce embedded SQL commands:

```
$int j = 3;
$CONNECT TO :dbname;
$CREATE TABLE test(i INT PRIMARY KEY, j INT);
$INSERT INTO test(i, j) VALUES (7, :j);
$COMMIT;
```

Note

There must not be any white space between the \$ and a following preprocessor directive, that is, `include`, `define`, `ifdef`, etc. Otherwise, the preprocessor will parse the token as a host variable.

There are two compatibility modes: `INFORMIX`, `INFORMIX_SE`

When linking programs that use this compatibility mode, remember to link against `libcompat` that is shipped with ECPG.

Besides the previously explained syntactic sugar, the Informix compatibility mode ports some functions for input, output and transformation of data as well as embedded SQL statements known from E/SQL to ECPG.

Informix compatibility mode is closely connected to the `pgtypeslib` library of ECPG. `pgtypeslib` maps SQL data types to data types within the C host program and most of the additional functions of the Informix compatibility mode allow you to operate on those C host program types. Note however that the extent of the compatibility is limited. It does not try to copy Informix behavior; it allows you to do more or less the same operations and gives you functions that have the same name and the same basic behavior but it is no drop-in replacement if you are using Informix at the moment. Moreover, some of the data types are different. For example, PostgreSQL's `datetime` and `interval` types do not know about ranges like for example `YEAR TO MINUTE` so you won't find support in ECPG for that either.

35.15.1. Additional Types

The Informix-special "string" pseudo-type for storing right-trimmed character string data is now supported in Informix-mode without using `typedef`. In fact, in Informix-mode, ECPG refuses to process source files that contain `typedef sometype string;`

```
EXEC SQL BEGIN DECLARE SECTION;
string userid; /* this variable will contain trimmed data */
EXEC SQL END DECLARE SECTION;
```

```
EXEC SQL FETCH MYCUR INTO :userid;
```

35.15.2. Additional/Missing Embedded SQL Statements

CLOSE DATABASE

This statement closes the current connection. In fact, this is a synonym for ECPG's DISCONNECT CURRENT:

```
$CLOSE DATABASE;           /* close the current connection
*/
EXEC SQL CLOSE DATABASE;
```

FREE cursor_name

Due to the differences how ECPG works compared to Informix's ESQL/C (i.e. which steps are purely grammar transformations and which steps rely on the underlying run-time library) there is no FREE cursor_name statement in ECPG. This is because in ECPG, DECLARE CURSOR doesn't translate to a function call into the run-time library that uses to the cursor name. This means that there's no run-time bookkeeping of SQL cursors in the ECPG run-time library, only in the PostgreSQL server.

FREE statement_name

FREE statement_name is a synonym for DEALLOCATE PREPARE statement_name.

35.15.3. Informix-compatible SQLDA Descriptor Areas

Informix-compatible mode supports a different structure than the one described in Section 35.7.2. See below:

```
struct sqlvar_compat
{
    short    sqltype;
    int      sqllen;
    char     *sqldata;
    short    *sqlind;
    char     *sqlname;
    char     *sqlformat;
    short    sqlitype;
    short    sqlilen;
    char     *sqlidata;
    int      sqlxid;
    char     *sqltypename;
    short    sqltypelen;
    short    sqlownerlen;
    short    sqlsourcetype;
    char     *sqlownername;
    int      sqlsourceid;
    char     *sqlilongdata;
```

```
    int    sqlflags;
    void   *sqlreserved;
};

struct sqlda_compat
{
    short  sqld;
    struct sqlvar_compat *sqlvar;
    char   desc_name[19];
    short  desc_occ;
    struct sqlda_compat *desc_next;
    void   *reserved;
};

typedef struct sqlvar_compat    sqlvar_t;
typedef struct sqlda_compat    sqlda_t;
```

The global properties are:

`sqld`

The number of fields in the SQLDA descriptor.

`sqlvar`

Pointer to the per-field properties.

`desc_name`

Unused, filled with zero-bytes.

`desc_occ`

Size of the allocated structure.

`desc_next`

Pointer to the next SQLDA structure if the result set contains more than one record.

`reserved`

Unused pointer, contains NULL. Kept for Informix-compatibility.

The per-field properties are below, they are stored in the `sqlvar` array:

`sqltype`

Type of the field. Constants are in `sqltypes.h`

`sqllen`

Length of the field data.

`sqldata`

Pointer to the field data. The pointer is of `char *` type, the data pointed by it is in a binary format. Example:

```
int intval;
```

```
switch (sqldata->sqlvar[i].sqltype)
```

```

    {
        case SQLINTEGER:
            intval = *(int *)sqldata->sqlvar[i].sqldata;
            break;
        ...
    }

```

`sqlind`

Pointer to the NULL indicator. If returned by DESCRIBE or FETCH then it's always a valid pointer. If used as input for EXECUTE ... USING `sqlda`; then NULL-pointer value means that the value for this field is non-NULL. Otherwise a valid pointer and `sqlitype` has to be properly set. Example:

```

if (*(int2 *)sqldata->sqlvar[i].sqlind != 0)
    printf("value is NULL\n");

```

`sqlname`

Name of the field. 0-terminated string.

`sqlformat`

Reserved in Informix, value of `PQfformat()` for the field.

`sqlitype`

Type of the NULL indicator data. It's always `SQLSMINT` when returning data from the server. When the `SQLDA` is used for a parameterized query, the data is treated according to the set type.

`sqlilen`

Length of the NULL indicator data.

`sqlxid`

Extended type of the field, result of `PQftype()`.

```

sqltypename
sqltypelen
sqlownerlen
sqlsourcetype
sqlownername
sqlsourceid
sqlflags
sqlreserved

```

Unused.

`sqlilongdata`

It equals to `sqldata` if `sqlilen` is larger than 32kB.

Example:

```
EXEC SQL INCLUDE sqlda.h;
```

```

    sqlda_t      *sqlda; /* This doesn't need to be under
embedded DECLARE SECTION */

```

```
EXEC SQL BEGIN DECLARE SECTION;
char *prep_stmt = "select * from table1";
int i;
EXEC SQL END DECLARE SECTION;

...

EXEC SQL PREPARE mystmt FROM :prep_stmt;

EXEC SQL DESCRIBE mystmt INTO sqlda;

printf("# of fields: %d\n", sqlda->sqld);
for (i = 0; i < sqlda->sqld; i++)
    printf("field %d: \"%s\"\n", sqlda->sqlvar[i]->sqlname);

EXEC SQL DECLARE mycursor CURSOR FOR mystmt;
EXEC SQL OPEN mycursor;
EXEC SQL WHENEVER NOT FOUND GOTO out;

while (1)
{
    EXEC SQL FETCH mycursor USING sqlda;
}

EXEC SQL CLOSE mycursor;

free(sqlda); /* The main structure is all to be free(),
              * sqlda and sqlda->sqlvar is in one allocated
area */
```

For more information, see the `sqlda.h` header and the `src/interfaces/ecpg/test/compat_informix/sqlda.pgc` regression test.

35.15.4. Additional Functions

decadd

Add two decimal type values.

```
int decadd(decimal *arg1, decimal *arg2, decimal *sum);
```

The function receives a pointer to the first operand of type decimal (`arg1`), a pointer to the second operand of type decimal (`arg2`) and a pointer to a value of type decimal that will contain the sum (`sum`). On success, the function returns 0. `ECPG_INFORMIX_NUM_OVERFLOW` is returned in case of overflow and `ECPG_INFORMIX_NUM_UNDERFLOW` in case of underflow. -1 is returned for other failures and `errno` is set to the respective `errno` number of the `pgtypeslib`.

deccmp

Compare two variables of type decimal.

```
int deccmp(decimal *arg1, decimal *arg2);
```

The function receives a pointer to the first decimal value (`arg1`), a pointer to the second decimal value (`arg2`) and returns an integer value that indicates which is the bigger value.

- 1, if the value that `arg1` points to is bigger than the value that `var2` points to

- -1, if the value that `arg1` points to is smaller than the value that `arg2` points to
- 0, if the value that `arg1` points to and the value that `arg2` points to are equal

`deccopy`

Copy a decimal value.

```
void deccopy(decimal *src, decimal *target);
```

The function receives a pointer to the decimal value that should be copied as the first argument (`src`) and a pointer to the target structure of type `decimal` (`target`) as the second argument.

`deccvasc`

Convert a value from its ASCII representation into a decimal type.

```
int deccvasc(char *cp, int len, decimal *np);
```

The function receives a pointer to string that contains the string representation of the number to be converted (`cp`) as well as its length `len`. `np` is a pointer to the decimal value that saves the result of the operation.

Valid formats are for example: `-2`, `.794`, `+3.44`, `592.49E07` or `-32.84e-4`.

The function returns 0 on success. If overflow or underflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` is returned. If the ASCII representation could not be parsed, `ECPG_INFORMIX_BAD_NUMERIC` is returned or `ECPG_INFORMIX_BAD_EXPONENT` if this problem occurred while parsing the exponent.

`deccvdbl`

Convert a value of type double to a value of type decimal.

```
int deccvdbl(double dbl, decimal *np);
```

The function receives the variable of type `double` that should be converted as its first argument (`dbl`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`deccvint`

Convert a value of type `int` to a value of type decimal.

```
int deccvint(int in, decimal *np);
```

The function receives the variable of type `int` that should be converted as its first argument (`in`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`deccvlong`

Convert a value of type `long` to a value of type decimal.

```
int deccvlong(long lng, decimal *np);
```

The function receives the variable of type long that should be converted as its first argument (`lng`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`decdiv`

Divide two variables of type decimal.

```
int decdiv(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1/n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the division fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively. If an attempt to divide by zero is observed, the function returns `ECPG_INFORMIX_DIVIDE_ZERO`.

`decmul`

Multiply two decimal values.

```
int decmul(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1*n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the multiplication fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively.

`decsub`

Subtract one decimal value from another.

```
int decsub(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1-n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the subtraction fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively.

`dectoasc`

Convert a variable of type decimal to its ASCII representation in a C char* string.

```
int dectoasc(decimal *np, char *cp, int len, int right)
```

The function receives a pointer to a variable of type decimal (`np`) that it converts to its textual representation. `cp` is the buffer that should hold the result of the operation. The parameter `right` specifies, how many digits right of the decimal point should be included in the output. The result will be rounded to this number of decimal digits. Setting `right` to -1 indicates that all available decimal digits should be included in the output. If the length of the output buffer, which is indicated by `len` is not sufficient to hold the textual representation including the trailing zero byte, only a single `*` character is stored in the result and -1 is returned.

The function returns either -1 if the buffer `cp` was too small or `ECPG_INFORMIX_OUT_OF_MEMORY` if memory was exhausted.

`dectodbl`

Convert a variable of type decimal to a double.

```
int dectodbl(decimal *np, double *dbl);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the double variable that should hold the result of the operation (`dbl`).

On success, 0 is returned and a negative value if the conversion failed.

`dectoint`

Convert a variable to type decimal to an integer.

```
int dectoint(decimal *np, int *ip);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the integer variable that should hold the result of the operation (`ip`).

On success, 0 is returned and a negative value if the conversion failed. If an overflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` is returned.

Note that the ECPG implementation differs from the Informix implementation. Informix limits an integer to the range from -32767 to 32767, while the limits in the ECPG implementation depend on the architecture (`-INT_MAX .. INT_MAX`).

`dectolong`

Convert a variable to type decimal to a long integer.

```
int dectolong(decimal *np, long *lng);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the long variable that should hold the result of the operation (`lng`).

On success, 0 is returned and a negative value if the conversion failed. If an overflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` is returned.

Note that the ECPG implementation differs from the Informix implementation. Informix limits a long integer to the range from -2,147,483,647 to 2,147,483,647, while the limits in the ECPG implementation depend on the architecture (`-LONG_MAX .. LONG_MAX`).

`rdatestr`

Converts a date to a C char* string.

```
int rdatestr(date d, char *str);
```

The function receives two arguments, the first one is the date to convert (*d*) and the second one is a pointer to the target string. The output format is always *yyyy-mm-dd*, so you need to allocate at least 11 bytes (including the zero-byte terminator) for the string.

The function returns 0 on success and a negative value in case of error.

Note that ECPG's implementation differs from the Informix implementation. In Informix the format can be influenced by setting environment variables. In ECPG however, you cannot change the output format.

`rstrdate`

Parse the textual representation of a date.

```
int rstrdate(char *str, date *d);
```

The function receives the textual representation of the date to convert (*str*) and a pointer to a variable of type `date` (*d*). This function does not allow you to specify a format mask. It uses the default format mask of Informix which is *mm/dd/yyyy*. Internally, this function is implemented by means of `rdefmtdate`. Therefore, `rstrdate` is not faster and if you have the choice you should opt for `rdefmtdate` which allows you to specify the format mask explicitly.

The function returns the same values as `rdefmtdate`.

`rtoday`

Get the current date.

```
void rtoday(date *d);
```

The function receives a pointer to a date variable (*d*) that it sets to the current date.

Internally this function uses the `PGTYPESdate_today` function.

`rjulmdy`

Extract the values for the day, the month and the year from a variable of type `date`.

```
int rjulmdy(date d, short mdy[3]);
```

The function receives the date *d* and a pointer to an array of 3 short integer values *mdy*. The variable name indicates the sequential order: *mdy*[0] will be set to contain the number of the month, *mdy*[1] will be set to the value of the day and *mdy*[2] will contain the year.

The function always returns 0 at the moment.

Internally the function uses the `PGTYPESdate_julmdy` function.

`rdefmtdate`

Use a format mask to convert a character string to a value of type `date`.

```
int rdefmtdate(date *d, char *fmt, char *str);
```

The function receives a pointer to the date value that should hold the result of the operation (*d*), the format mask to use for parsing the date (*fmt*) and the C `char*` string containing the textual

representation of the date (`str`). The textual representation is expected to match the format mask. However you do not need to have a 1:1 mapping of the string to the format mask. The function only analyzes the sequential order and looks for the literals `yy` or `yyyy` that indicate the position of the year, `mm` to indicate the position of the month and `dd` to indicate the position of the day.

The function returns the following values:

- 0 - The function terminated successfully.
- `ECPG_INFORMIX_ENOSHORTDATE` - The date does not contain delimiters between day, month and year. In this case the input string must be exactly 6 or 8 bytes long but isn't.
- `ECPG_INFORMIX_ENOTDMY` - The format string did not correctly indicate the sequential order of year, month and day.
- `ECPG_INFORMIX_BAD_DAY` - The input string does not contain a valid day.
- `ECPG_INFORMIX_BAD_MONTH` - The input string does not contain a valid month.
- `ECPG_INFORMIX_BAD_YEAR` - The input string does not contain a valid year.

Internally this function is implemented to use the `PGTYPESdate_defmt_asc` function. See the reference there for a table of example input.

`rfmtdate`

Convert a variable of type date to its textual representation using a format mask.

```
int rfmtdate(date d, char *fmt, char *str);
```

The function receives the date to convert (`d`), the format mask (`fmt`) and the string that will hold the textual representation of the date (`str`).

On success, 0 is returned and a negative value if an error occurred.

Internally this function uses the `PGTYPESdate_fmt_asc` function, see the reference there for examples.

`rmdyjul`

Create a date value from an array of 3 short integers that specify the day, the month and the year of the date.

```
int rmdyjul(short mdy[3], date *d);
```

The function receives the array of the 3 short integers (`mdy`) and a pointer to a variable of type date that should hold the result of the operation.

Currently the function returns always 0.

Internally the function is implemented to use the function `PGTYPESdate_mdyjul`.

`rdayofweek`

Return a number representing the day of the week for a date value.

```
int rdayofweek(date d);
```

The function receives the date variable `d` as its only argument and returns an integer that indicates the day of the week for this date.

- 0 - Sunday
- 1 - Monday
- 2 - Tuesday
- 3 - Wednesday
- 4 - Thursday
- 5 - Friday
- 6 - Saturday

Internally the function is implemented to use the function `PGTYPESdate_dayofweek`.

`dtcurrent`

Retrieve the current timestamp.

```
void dtcurrent(timestamp *ts);
```

The function retrieves the current timestamp and saves it into the timestamp variable that `ts` points to.

`dtcvasc`

Parses a timestamp from its textual representation into a timestamp variable.

```
int dtcvasc(char *str, timestamp *ts);
```

The function receives the string to parse (`str`) and a pointer to the timestamp variable that should hold the result of the operation (`ts`).

The function returns 0 on success and a negative value in case of error.

Internally this function uses the `PGTYPEStimestamp_from_asc` function. See the reference there for a table with example inputs.

`dtcvfmtasc`

Parses a timestamp from its textual representation using a format mask into a timestamp variable.

```
dtcvfmtasc(char *inbuf, char *fmtstr, timestamp *dtvalue)
```

The function receives the string to parse (`inbuf`), the format mask to use (`fmtstr`) and a pointer to the timestamp variable that should hold the result of the operation (`dtvalue`).

This function is implemented by means of the `PGTYPEStimestamp_defmt_asc` function. See the documentation there for a list of format specifiers that can be used.

The function returns 0 on success and a negative value in case of error.

`dtsub`

Subtract one timestamp from another and return a variable of type interval.

```
int dtsub(timestamp *ts1, timestamp *ts2, interval *iv);
```

The function will subtract the timestamp variable that `ts2` points to from the timestamp variable that `ts1` points to and will store the result in the interval variable that `iv` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

`dttoasc`

Convert a timestamp variable to a C `char*` string.

```
int dttoasc(timestamp *ts, char *output);
```

The function receives a pointer to the timestamp variable to convert (`ts`) and the string that should hold the result of the operation (`output`). It converts `ts` to its textual representation according to the SQL standard, which is be `YYYY-MM-DD HH:MM:SS`.

Upon success, the function returns 0 and a negative value if an error occurred.

`dttofmtasc`

Convert a timestamp variable to a C `char*` using a format mask.

```
int dttofmtasc(timestamp *ts, char *output, int str_len, char *fmtstr);
```

The function receives a pointer to the timestamp to convert as its first argument (`ts`), a pointer to the output buffer (`output`), the maximal length that has been allocated for the output buffer (`str_len`) and the format mask to use for the conversion (`fmtstr`).

Upon success, the function returns 0 and a negative value if an error occurred.

Internally, this function uses the `PGTYPEStimestamp_fmt_asc` function. See the reference there for information on what format mask specifiers can be used.

`intoasc`

Convert an interval variable to a C `char*` string.

```
int intoasc(interval *i, char *str);
```

The function receives a pointer to the interval variable to convert (`i`) and the string that should hold the result of the operation (`str`). It converts `i` to its textual representation according to the SQL standard, which is be `YYYY-MM-DD HH:MM:SS`.

Upon success, the function returns 0 and a negative value if an error occurred.

`rfmtlong`

Convert a long integer value to its textual representation using a format mask.

```
int rfmtlong(long lng_val, char *fmt, char *outbuf);
```

The function receives the long value `lng_val`, the format mask `fmt` and a pointer to the output buffer `outbuf`. It converts the long value according to the format mask to its textual representation.

The format mask can be composed of the following format specifying characters:

- * (asterisk) - if this position would be blank otherwise, fill it with an asterisk.

- & (ampersand) - if this position would be blank otherwise, fill it with a zero.
- # - turn leading zeroes into blanks.
- < - left-justify the number in the string.
- , (comma) - group numbers of four or more digits into groups of three digits separated by a comma.
- . (period) - this character separates the whole-number part of the number from the fractional part.
- - (minus) - the minus sign appears if the number is a negative value.
- + (plus) - the plus sign appears if the number is a positive value.
- (- this replaces the minus sign in front of the negative number. The minus sign will not appear.
-) - this character replaces the minus and is printed behind the negative value.
- \$ - the currency symbol.

`rupshift`

Convert a string to upper case.

```
void rupshift(char *str);
```

The function receives a pointer to the string and transforms every lower case character to upper case.

`byleng`

Return the number of characters in a string without counting trailing blanks.

```
int byleng(char *str, int len);
```

The function expects a fixed-length string as its first argument (`str`) and its length as its second argument (`len`). It returns the number of significant characters, that is the length of the string without trailing blanks.

`ldchar`

Copy a fixed-length string into a null-terminated string.

```
void ldchar(char *src, int len, char *dest);
```

The function receives the fixed-length string to copy (`src`), its length (`len`) and a pointer to the destination memory (`dest`). Note that you need to reserve at least `len+1` bytes for the string that `dest` points to. The function copies at most `len` bytes to the new location (less if the source string has trailing blanks) and adds the null-terminator.

`rgetmsg`

```
int rgetmsg(int msgnum, char *s, int maxsize);
```

This function exists but is not implemented at the moment!

rtpalign

```
int rtpalign(int offset, int type);
```

This function exists but is not implemented at the moment!

rtpmsize

```
int rtpmsize(int type, int len);
```

This function exists but is not implemented at the moment!

rtpwidth

```
int rtpwidth(int sqltype, int sqllen);
```

This function exists but is not implemented at the moment!

rsetnull

Set a variable to NULL.

```
int rsetnull(int t, char *ptr);
```

The function receives an integer that indicates the type of the variable and a pointer to the variable itself that is cast to a C char* pointer.

The following types exist:

- CCHARTYPE - For a variable of type char or char*
- CSHORTTYPE - For a variable of type short int
- CINTTYPE - For a variable of type int
- CBOOLTYPE - For a variable of type boolean
- CFLOATTYPE - For a variable of type float
- CLONGTYPE - For a variable of type long
- CDOUBLETYPE - For a variable of type double
- CDECIMALTYPE - For a variable of type decimal
- CDATETYPE - For a variable of type date
- CDTIMETYPE - For a variable of type timestamp

Here is an example of a call to this function:

```
$char c[] = "abc          ";
$short s = 17;
$int i = -74874;

rsetnull(CCHARTYPE, (char *) c);
rsetnull(CSHORTTYPE, (char *) &s);
rsetnull(CINTTYPE, (char *) &i);
```

`risnull`

Test if a variable is NULL.

```
int risnull(int t, char *ptr);
```

The function receives the type of the variable to test (`t`) as well a pointer to this variable (`ptr`). Note that the latter needs to be cast to a `char*`. See the function `rsetnull` for a list of possible variable types.

Here is an example of how to use this function:

```
$char c[] = "abc          ";
$short s = 17;
$int i = -74874;

risnull(CCHARTYPE, (char *) c);
risnull(CSHORTTYPE, (char *) &s);
risnull(CINTTYPE, (char *) &i);
```

35.15.5. Additional Constants

Note that all constants here describe errors and all of them are defined to represent negative values. In the descriptions of the different constants you can also find the value that the constants represent in the current implementation. However you should not rely on this number. You can however rely on the fact all of them are defined to represent negative values.

`ECPG_INFORMIX_NUM_OVERFLOW`

Functions return this value if an overflow occurred in a calculation. Internally it is defined as -1200 (the Informix definition).

`ECPG_INFORMIX_NUM_UNDERFLOW`

Functions return this value if an underflow occurred in a calculation. Internally it is defined as -1201 (the Informix definition).

`ECPG_INFORMIX_DIVIDE_ZERO`

Functions return this value if an attempt to divide by zero is observed. Internally it is defined as -1202 (the Informix definition).

`ECPG_INFORMIX_BAD_YEAR`

Functions return this value if a bad value for a year was found while parsing a date. Internally it is defined as -1204 (the Informix definition).

`ECPG_INFORMIX_BAD_MONTH`

Functions return this value if a bad value for a month was found while parsing a date. Internally it is defined as -1205 (the Informix definition).

`ECPG_INFORMIX_BAD_DAY`

Functions return this value if a bad value for a day was found while parsing a date. Internally it is defined as -1206 (the Informix definition).

ECPG_INFORMIX_ENOSHORTDATE

Functions return this value if a parsing routine needs a short date representation but did not get the date string in the right length. Internally it is defined as -1209 (the Informix definition).

ECPG_INFORMIX_DATE_CONVERT

Functions return this value if an error occurred during date formatting. Internally it is defined as -1210 (the Informix definition).

ECPG_INFORMIX_OUT_OF_MEMORY

Functions return this value if memory was exhausted during their operation. Internally it is defined as -1211 (the Informix definition).

ECPG_INFORMIX_ENOTDMY

Functions return this value if a parsing routine was supposed to get a format mask (like `mmddyy`) but not all fields were listed correctly. Internally it is defined as -1212 (the Informix definition).

ECPG_INFORMIX_BAD_NUMERIC

Functions return this value either if a parsing routine cannot parse the textual representation for a numeric value because it contains errors or if a routine cannot complete a calculation involving numeric variables because at least one of the numeric variables is invalid. Internally it is defined as -1213 (the Informix definition).

ECPG_INFORMIX_BAD_EXPONENT

Functions return this value if a parsing routine cannot parse an exponent. Internally it is defined as -1216 (the Informix definition).

ECPG_INFORMIX_BAD_DATE

Functions return this value if a parsing routine cannot parse a date. Internally it is defined as -1218 (the Informix definition).

ECPG_INFORMIX_EXTRA_CHARS

Functions return this value if a parsing routine is passed extra characters it cannot parse. Internally it is defined as -1264 (the Informix definition).

35.16. Internals

This section explains how ECPG works internally. This information can occasionally be useful to help users understand how to use ECPG.

The first four lines written by `ecpg` to the output are fixed lines. Two are comments and two are include lines necessary to interface to the library. Then the preprocessor reads through the file and writes output. Normally it just echoes everything to the output.

When it sees an `EXEC SQL` statement, it intervenes and changes it. The command starts with `EXEC SQL` and ends with `;`. Everything in between is treated as an `SQL` statement and parsed for variable substitution.

Variable substitution occurs when a symbol starts with a colon (`:`). The variable with that name is looked up among the variables that were previously declared within a `EXEC SQL DECLARE` section.

The most important function in the library is `ECPGdo`, which takes care of executing most commands. It takes a variable number of arguments. This can easily add up to 50 or so arguments, and we hope this will not be a problem on any platform.

The arguments are:

A line number

This is the line number of the original line; used in error messages only.

A string

This is the SQL command that is to be issued. It is modified by the input variables, i.e., the variables that were not known at compile time but are to be entered in the command. Where the variables should go the string contains ?.

Input variables

Every input variable causes ten arguments to be created. (See below.)

ECPGt_EOIT

An enum telling that there are no more input variables.

Output variables

Every output variable causes ten arguments to be created. (See below.) These variables are filled by the function.

ECPGt_EORT

An enum telling that there are no more variables.

For every variable that is part of the SQL command, the function gets ten arguments:

1. The type as a special symbol.
2. A pointer to the value or a pointer to the pointer.
3. The size of the variable if it is a char or varchar.
4. The number of elements in the array (for array fetches).
5. The offset to the next element in the array (for array fetches).
6. The type of the indicator variable as a special symbol.
7. A pointer to the indicator variable.
8. 0
9. The number of elements in the indicator array (for array fetches).
10. The offset to the next element in the indicator array (for array fetches).

Note that not all SQL commands are treated in this way. For instance, an open cursor statement like:

```
EXEC SQL OPEN cursor;
```

is not copied to the output. Instead, the cursor's DECLARE command is used at the position of the OPEN command because it indeed opens the cursor.

Here is a complete example describing the output of the preprocessor of a file `foo.pgc` (details might change with each particular version of the preprocessor):

```
EXEC SQL BEGIN DECLARE SECTION;
int index;
int result;
EXEC SQL END DECLARE SECTION;
...
EXEC SQL SELECT res INTO :result FROM mytable WHERE index = :index;
```

is translated into:

```
/* Processed by ecpg (2.6.0) */
/* These two include files are added by the preprocessor */
#include <ecpgtype.h>;
#include <ecpglib.h>;

/* exec sql begin declare section */

#line 1 "foo.pgc"

    int index;
    int result;
/* exec sql end declare section */
...
ECPGdo(__LINE__, NULL, "SELECT res FROM mytable WHERE index = ?
",
        ECPGt_int,&(index),1L,1L,sizeof(int),
        ECPGt_NO_INDICATOR, NULL , 0L, 0L, 0L, ECPGt_EOIT,
        ECPGt_int,&(result),1L,1L,sizeof(int),
        ECPGt_NO_INDICATOR, NULL , 0L, 0L, 0L, ECPGt_EORT);
#line 147 "foo.pgc"
```

(The indentation here is added for readability and not something the preprocessor does.)

Chapter 36. The Information Schema

The information schema consists of a set of views that contain information about the objects defined in the current database. The information schema is defined in the SQL standard and can therefore be expected to be portable and remain stable — unlike the system catalogs, which are specific to PostgreSQL and are modeled after implementation concerns. The information schema views do not, however, contain information about PostgreSQL-specific features; to inquire about those you need to query the system catalogs or other PostgreSQL-specific views.

Note

When querying the database for constraint information, it is possible for a standard-compliant query that expects to return one row to return several. This is because the SQL standard requires constraint names to be unique within a schema, but PostgreSQL does not enforce this restriction. PostgreSQL automatically-generated constraint names avoid duplicates in the same schema, but users can specify such duplicate names.

This problem can appear when querying information schema views such as `check_constraint_routine_usage`, `check_constraints`, `domain_constraints`, and `referential_constraints`. Some other views have similar issues but contain the table name to help distinguish duplicate rows, e.g., `constraint_column_usage`, `constraint_table_usage`, `table_constraints`.

36.1. The Schema

The information schema itself is a schema named `information_schema`. This schema automatically exists in all databases. The owner of this schema is the initial database user in the cluster, and that user naturally has all the privileges on this schema, including the ability to drop it (but the space savings achieved by that are minuscule).

By default, the information schema is not in the schema search path, so you need to access all objects in it through qualified names. Since the names of some of the objects in the information schema are generic names that might occur in user applications, you should be careful if you want to put the information schema in the path.

36.2. Data Types

The columns of the information schema views use special data types that are defined in the information schema. These are defined as simple domains over ordinary built-in types. You should not use these types for work outside the information schema, but your applications must be prepared for them if they select from the information schema.

These types are:

`cardinal_number`

A nonnegative integer.

`character_data`

A character string (without specific maximum length).

`sql_identifier`

A character string. This type is used for SQL identifiers, the type `character_data` is used for any other kind of text data.

`time_stamp`

A domain over the type `timestamp with time zone`

`yes_or_no`

A character string domain that contains either YES or NO. This is used to represent Boolean (true/false) data in the information schema. (The information schema was invented before the type `boolean` was added to the SQL standard, so this convention is necessary to keep the information schema backward compatible.)

Every column in the information schema has one of these five types.

36.3. `information_schema_catalog_name`

`information_schema_catalog_name` is a table that always contains one row and one column containing the name of the current database (current catalog, in SQL terminology).

Table 36.1. `information_schema_catalog_name` Columns

Name	Data Type	Description
<code>catalog_name</code>	<code>sql_identifier</code>	Name of the database that contains this information schema

36.4. `administrable_role_authorizations`

The view `administrable_role_authorizations` identifies all roles that the current user has the admin option for.

Table 36.2. `administrable_role_authorizations` Columns

Name	Data Type	Description
<code>grantee</code>	<code>sql_identifier</code>	Name of the role to which this role membership was granted (can be the current user, or a different role in case of nested role memberships)
<code>role_name</code>	<code>sql_identifier</code>	Name of a role
<code>is_grantable</code>	<code>yes_or_no</code>	Always YES

36.5. `applicable_roles`

The view `applicable_roles` identifies all roles whose privileges the current user can use. This means there is some chain of role grants from the current user to the role in question. The current user itself is also an applicable role. The set of applicable roles is generally used for permission checking.

Table 36.3. applicable_roles Columns

Name	Data Type	Description
grantee	sql_identifier	Name of the role to which this role membership was granted (can be the current user, or a different role in case of nested role memberships)
role_name	sql_identifier	Name of a role
is_grantable	yes_or_no	YES if the grantee has the admin option on the role, NO if not

36.6. attributes

The view `attributes` contains information about the attributes of composite data types defined in the database. (Note that the view does not give information about table columns, which are sometimes called attributes in PostgreSQL contexts.) Only those attributes are shown that the current user has access to (by way of being the owner of or having some privilege on the type).

Table 36.4. attributes Columns

Name	Data Type	Description
udt_catalog	sql_identifier	Name of the database containing the data type (always the current database)
udt_schema	sql_identifier	Name of the schema containing the data type
udt_name	sql_identifier	Name of the data type
attribute_name	sql_identifier	Name of the attribute
ordinal_position	cardinal_number	Ordinal position of the attribute within the data type (count starts at 1)
attribute_default	character_data	Default expression of the attribute
is_nullable	yes_or_no	YES if the attribute is possibly nullable, NO if it is known not nullable.
data_type	character_data	Data type of the attribute, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code>), else USER-DEFINED (in that case, the type is identified in <code>attribute_udt_name</code> and associated columns).
character_maximum_length	cardinal_number	If <code>data_type</code> identifies a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
character_octet_length	cardinal_number	If <code>data_type</code> identifies a character type, the maximum possible length in octets (bytes) of

Name	Data Type	Description
		a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Name of the database containing the collation of the attribute (always the current database), null if default or the data type of the attribute is not collatable
collation_schema	sql_identifier	Name of the schema containing the collation of the attribute, null if default or the data type of the attribute is not collatable
collation_name	sql_identifier	Name of the collation of the attribute, null if default or the data type of the attribute is not collatable
numeric_precision	cardinal_number	If data_type identifies a numeric type, this column contains the (declared or implicit) precision of the type for this attribute. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
numeric_precision_radix	cardinal_number	If data_type identifies a numeric type, this column indicates in which base the values in the columns numeric_precision and numeric_scale are expressed. The value is either 2 or 10. For all other data types, this column is null.
numeric_scale	cardinal_number	If data_type identifies an exact numeric type, this column contains the (declared or implicit) scale of the type for this attribute. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed

Name	Data Type	Description
		in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>datetime_precision</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this attribute, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
<code>interval_type</code>	<code>character_data</code>	If <code>data_type</code> identifies an interval type, this column contains the specification which fields the intervals include for this attribute, e.g., <code>YEAR TO MONTH</code> , <code>DAY TO SECOND</code> , etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
<code>interval_precision</code>	<code>cardinal_number</code>	Applies to a feature not available in PostgreSQL (see <code>datetime_precision</code> for the fractional seconds precision of interval type attributes)
<code>attribute_udt_catalog</code>	<code>sql_identifier</code>	Name of the database that the attribute data type is defined in (always the current database)
<code>attribute_udt_schema</code>	<code>sql_identifier</code>	Name of the schema that the attribute data type is defined in
<code>attribute_udt_name</code>	<code>sql_identifier</code>	Name of the attribute data type
<code>scope_catalog</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>scope_schema</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>scope_name</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>maximum_cardinality</code>	<code>cardinal_number</code>	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
<code>dtd_identifier</code>	<code>sql_identifier</code>	An identifier of the data type descriptor of the column, unique among the data type descriptors pertaining to the table. This is mainly useful for joining with other instances of such identifiers. (The specific format of the

Name	Data Type	Description
		identifier is not defined and not guaranteed to remain the same in future versions.)
<code>is_derived_reference_attribute</code>	<code>yes_or_no</code>	Applies to a feature not available in PostgreSQL

See also under Section 36.17, a similarly structured view, for further information on some of the columns.

36.7. `character_sets`

The view `character_sets` identifies the character sets available in the current database. Since PostgreSQL does not support multiple character sets within one database, this view only shows one, which is the database encoding.

Take note of how the following terms are used in the SQL standard:

character repertoire

An abstract collection of characters, for example UNICODE, UCS, or LATIN1. Not exposed as an SQL object, but visible in this view.

character encoding form

An encoding of some character repertoire. Most older character repertoires only use one encoding form, and so there are no separate names for them (e.g., LATIN1 is an encoding form applicable to the LATIN1 repertoire). But for example Unicode has the encoding forms UTF8, UTF16, etc. (not all supported by PostgreSQL). Encoding forms are not exposed as an SQL object, but are visible in this view.

character set

A named SQL object that identifies a character repertoire, a character encoding, and a default collation. A predefined character set would typically have the same name as an encoding form, but users could define other names. For example, the character set UTF8 would typically identify the character repertoire UCS, encoding form UTF8, and some default collation.

You can think of an “encoding” in PostgreSQL either as a character set or a character encoding form. They will have the same name, and there can only be one in one database.

Table 36.5. `character_sets` Columns

Name	Data Type	Description
<code>character_set_catalog</code>	<code>sql_identifier</code>	Character sets are currently not implemented as schema objects, so this column is null.
<code>character_set_schema</code>	<code>sql_identifier</code>	Character sets are currently not implemented as schema objects, so this column is null.
<code>character_set_name</code>	<code>sql_identifier</code>	Name of the character set, currently implemented as showing the name of the database encoding
<code>character_repertoire</code>	<code>sql_identifier</code>	Character repertoire, showing UCS if the encoding is UTF8, else just the encoding name

Name	Data Type	Description
form_of_use	sql_identifier	Character encoding form, same as the database encoding
default_collate_catalog	sql_identifier	Name of the database containing the default collation (always the current database, if any collation is identified)
default_collate_schema	sql_identifier	Name of the schema containing the default collation
default_collate_name	sql_identifier	Name of the default collation. The default collation is identified as the collation that matches the COLLATE and CTYPE settings of the current database. If there is no such collation, then this column and the associated schema and catalog columns are null.

36.8. check_constraint_routine_usage

The view `check_constraint_routine_usage` identifies routines (functions and procedures) that are used by a check constraint. Only those routines are shown that are owned by a currently enabled role.

Table 36.6. check_constraint_routine_usage Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema containing the constraint
constraint_name	sql_identifier	Name of the constraint
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The “specific name” of the function. See Section 36.41 for more information.

36.9. check_constraints

The view `check_constraints` contains all check constraints, either defined on a table or on a domain, that are owned by a currently enabled role. (The owner of the table or domain is the owner of the constraint.)

Table 36.7. check_constraints Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema containing the constraint
constraint_name	sql_identifier	Name of the constraint
check_clause	character_data	The check expression of the check constraint

36.10. collations

The view `collations` contains the collations available in the current database.

Table 36.8. collations Columns

Name	Data Type	Description
collation_catalog	sql_identifier	Name of the database containing the collation (always the current database)
collation_schema	sql_identifier	Name of the schema containing the collation
collation_name	sql_identifier	Name of the default collation
pad_attribute	character_data	Always NO PAD (The alternative PAD SPACE is not supported by PostgreSQL.)

36.11. collation_character_set_applicability

The view `collation_character_set_applicability` identifies which character set the available collations are applicable to. In PostgreSQL, there is only one character set per database (see explanation in Section 36.7), so this view does not provide much useful information.

Table 36.9. collation_character_set_applicability Columns

Name	Data Type	Description
collation_catalog	sql_identifier	Name of the database containing the collation (always the current database)
collation_schema	sql_identifier	Name of the schema containing the collation
collation_name	sql_identifier	Name of the default collation
character_set_catalog	sql_identifier	Character sets are currently not implemented as schema objects, so this column is null
character_set_schema	sql_identifier	Character sets are currently not implemented as schema objects, so this column is null

Name	Data Type	Description
character_set_name	sql_identifier	Name of the character set

36.12. column_column_usage

The view `column_column_usage` identifies all generated columns that depend on another base column in the same table. Only tables owned by a currently enabled role are included.

Table 36.10. column_column_usage Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database containing the table (always the current database)
table_schema	sql_identifier	Name of the schema containing the table
table_name	sql_identifier	Name of the table
column_name	sql_identifier	Name of the base column that a generated column depends on
dependent_column	sql_identifier	Name of the generated column

36.13. column_domain_usage

The view `column_domain_usage` identifies all columns (of a table or a view) that make use of some domain defined in the current database and owned by a currently enabled role.

Table 36.11. column_domain_usage Columns

Name	Data Type	Description
domain_catalog	sql_identifier	Name of the database containing the domain (always the current database)
domain_schema	sql_identifier	Name of the schema containing the domain
domain_name	sql_identifier	Name of the domain
table_catalog	sql_identifier	Name of the database containing the table (always the current database)
table_schema	sql_identifier	Name of the schema containing the table
table_name	sql_identifier	Name of the table
column_name	sql_identifier	Name of the column

36.14. column_options

The view `column_options` contains all the options defined for foreign table columns in the current database. Only those foreign table columns are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.12. column_options Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the foreign table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the foreign table
table_name	sql_identifier	Name of the foreign table
column_name	sql_identifier	Name of the column
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

36.15. column_privileges

The view `column_privileges` identifies all privileges granted on columns to a currently enabled role or by a currently enabled role. There is one row for each combination of column, grantor, and grantee.

If a privilege has been granted on an entire table, it will show up in this view as a grant for each column, but only for the privilege types where column granularity is possible: `SELECT`, `INSERT`, `UPDATE`, `REFERENCES`.

Table 36.13. column_privileges Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table that contains the column (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column
table_name	sql_identifier	Name of the table that contains the column
column_name	sql_identifier	Name of the column
privilege_type	character_data	Type of the privilege: <code>SELECT</code> , <code>INSERT</code> , <code>UPDATE</code> , or <code>REFERENCES</code>
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.16. column_udt_usage

The view `column_udt_usage` identifies all columns that use data types owned by a currently enabled role. Note that in PostgreSQL, built-in data types behave like user-defined types, so they are included here as well. See also Section 36.17 for details.

Table 36.14. column_udt_usage Columns

Name	Data Type	Description
udt_catalog	sql_identifier	Name of the database that the column data type (the underlying type of the domain, if applicable) is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the column data type (the underlying type of the domain, if applicable) is defined in
udt_name	sql_identifier	Name of the column data type (the underlying type of the domain, if applicable)
table_catalog	sql_identifier	Name of the database containing the table (always the current database)
table_schema	sql_identifier	Name of the schema containing the table
table_name	sql_identifier	Name of the table
column_name	sql_identifier	Name of the column

36.17. columns

The view `columns` contains information about all table columns (or view columns) in the database. System columns (`ctid`, etc.) are not included. Only those columns are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.15. columns Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database containing the table (always the current database)
table_schema	sql_identifier	Name of the schema containing the table
table_name	sql_identifier	Name of the table
column_name	sql_identifier	Name of the column
ordinal_position	cardinal_number	Ordinal position of the column within the table (count starts at 1)
column_default	character_data	Default expression of the column
is_nullable	yes_or_no	YES if the column is possibly nullable, NO if it is known not nullable. A not-null constraint is one way a column can be known not nullable, but there can be others.
data_type	character_data	Data type of the column, if it is a built-in type, or ARRAY if it is some array (in that case,

Name	Data Type	Description
		see the view <code>element_types</code>), else <code>USER-DEFINED</code> (in that case, the type is identified in <code>udt_name</code> and associated columns). If the column is based on a domain, this column refers to the type underlying the domain (and the domain is identified in <code>domain_name</code> and associated columns).
<code>character_maximum_length</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
<code>character_octet_length</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
<code>numeric_precision</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies a numeric type, this column contains the (declared or implicit) precision of the type for this column. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>numeric_precision_radix</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies a numeric type, this column indicates in which base the values in the columns <code>numeric_precision</code> and <code>numeric_scale</code> are expressed. The value is either 2 or 10. For all other data types, this column is null.
<code>numeric_scale</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies an exact numeric type, this column contains the (declared or implicit) scale of the type for this column. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in

Name	Data Type	Description
		the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
<code>datetime_precision</code>	<code>cardinal_number</code>	If <code>data_type</code> identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this column, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
<code>interval_type</code>	<code>character_data</code>	If <code>data_type</code> identifies an interval type, this column contains the specification which fields the intervals include for this column, e.g., <code>YEAR TO MONTH</code> , <code>DAY TO SECOND</code> , etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
<code>interval_precision</code>	<code>cardinal_number</code>	Applies to a feature not available in PostgreSQL (see <code>datetime_precision</code> for the fractional seconds precision of interval type columns)
<code>character_set_catalog</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>character_set_schema</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>character_set_name</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>collation_catalog</code>	<code>sql_identifier</code>	Name of the database containing the collation of the column (always the current database), null if default or the data type of the column is not collatable
<code>collation_schema</code>	<code>sql_identifier</code>	Name of the schema containing the collation of the column, null if default or the data type of the column is not collatable
<code>collation_name</code>	<code>sql_identifier</code>	Name of the collation of the column, null if default or the data type of the column is not collatable
<code>domain_catalog</code>	<code>sql_identifier</code>	If the column has a domain type, the name of the database that the domain is defined in (always the current database), else null.

Name	Data Type	Description
domain_schema	sql_identifier	If the column has a domain type, the name of the schema that the domain is defined in, else null.
domain_name	sql_identifier	If the column has a domain type, the name of the domain, else null.
udt_catalog	sql_identifier	Name of the database that the column data type (the underlying type of the domain, if applicable) is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the column data type (the underlying type of the domain, if applicable) is defined in
udt_name	sql_identifier	Name of the column data type (the underlying type of the domain, if applicable)
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the column, unique among the data type descriptors pertaining to the table. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
is_self_referencing	yes_or_no	Applies to a feature not available in PostgreSQL
is_identity	yes_or_no	If the column is an identity column, then YES, else NO.
identity_generation	character_data	If the column is an identity column, then ALWAYS or BY DEFAULT, reflecting the definition of the column.
identity_start	character_data	If the column is an identity column, then the start value of the internal sequence, else null.
identity_increment	character_data	If the column is an identity column, then the increment of the internal sequence, else null.

Name	Data Type	Description
identity_maximum	character_data	If the column is an identity column, then the maximum value of the internal sequence, else null.
identity_minimum	character_data	If the column is an identity column, then the minimum value of the internal sequence, else null.
identity_cycle	yes_or_no	If the column is an identity column, then YES if the internal sequence cycles or NO if it does not; otherwise null.
is_generated	character_data	If the column is a generated column, then ALWAYS, else NEVER.
generation_expression	character_data	If the column is a generated column, then the generation expression, else null.
is_updatable	yes_or_no	YES if the column is updatable, NO if not (Columns in base tables are always updatable, columns in views not necessarily)

Since data types can be defined in a variety of ways in SQL, and PostgreSQL contains additional ways to define data types, their representation in the information schema can be somewhat difficult. The column `data_type` is supposed to identify the underlying built-in type of the column. In PostgreSQL, this means that the type is defined in the system catalog schema `pg_catalog`. This column might be useful if the application can handle the well-known built-in types specially (for example, format the numeric types differently or use the data in the precision columns). The columns `udt_name`, `udt_schema`, and `udt_catalog` always identify the underlying data type of the column, even if the column is based on a domain. (Since PostgreSQL treats built-in types like user-defined types, built-in types appear here as well. This is an extension of the SQL standard.) These columns should be used if an application wants to process data differently according to the type, because in that case it wouldn't matter if the column is really based on a domain. If the column is based on a domain, the identity of the domain is stored in the columns `domain_name`, `domain_schema`, and `domain_catalog`. If you want to pair up columns with their associated data types and treat domains as separate types, you could write `coalesce(domain_name, udt_name)`, etc.

36.18. constraint_column_usage

The view `constraint_column_usage` identifies all columns in the current database that are used by some constraint. Only those columns are shown that are contained in a table owned by a currently enabled role. For a check constraint, this view identifies the columns that are used in the check expression. For a foreign key constraint, this view identifies the columns that the foreign key references. For a unique or primary key constraint, this view identifies the constrained columns.

Table 36.16. constraint_column_usage Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the table that contains the column that is used by some constraint (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the

Name	Data Type	Description
		column that is used by some constraint
table_name	sql_identifier	Name of the table that contains the column that is used by some constraint
column_name	sql_identifier	Name of the column that is used by some constraint
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint

36.19. constraint_table_usage

The view `constraint_table_usage` identifies all tables in the current database that are used by some constraint and are owned by a currently enabled role. (This is different from the view `table_constraints`, which identifies all table constraints along with the table they are defined on.) For a foreign key constraint, this view identifies the table that the foreign key references. For a unique or primary key constraint, this view simply identifies the table the constraint belongs to. Check constraints and not-null constraints are not included in this view.

Table 36.17. constraint_table_usage Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the table that is used by some constraint (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that is used by some constraint
table_name	sql_identifier	Name of the table that is used by some constraint
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint

36.20. data_type_privileges

The view `data_type_privileges` identifies all data type descriptors that the current user has access to, by way of being the owner of the described object or having some privilege for it. A data type descriptor is generated whenever a data type is used in the definition of a table column, a domain, or a function (as parameter or return type) and stores some information about how the data type is used in that instance (for example, the declared maximum length, if applicable). Each data type descriptor is assigned an arbitrary identifier that is unique among the data type descriptor identifiers assigned for

one object (table, domain, function). This view is probably not useful for applications, but it is used to define some other views in the information schema.

Table 36.18. data_type_privileges Columns

Name	Data Type	Description
object_catalog	sql_identifier	Name of the database that contains the described object (always the current database)
object_schema	sql_identifier	Name of the schema that contains the described object
object_name	sql_identifier	Name of the described object
object_type	character_data	The type of the described object: one of TABLE (the data type descriptor pertains to a column of that table), DOMAIN (the data type descriptors pertains to that domain), ROUTINE (the data type descriptor pertains to a parameter or the return data type of that function).
dtd_identifier	sql_identifier	The identifier of the data type descriptor, which is unique among the data type descriptors for that same object.

36.21. domain_constraints

The view `domain_constraints` contains all constraints belonging to domains defined in the current database. Only those domains are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.19. domain_constraints Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint
domain_catalog	sql_identifier	Name of the database that contains the domain (always the current database)
domain_schema	sql_identifier	Name of the schema that contains the domain
domain_name	sql_identifier	Name of the domain
is_deferrable	yes_or_no	YES if the constraint is deferrable, NO if not
initially_deferred	yes_or_no	YES if the constraint is deferrable and initially deferred, NO if not

36.22. domain_udt_usage

The view `domain_udt_usage` identifies all domains that are based on data types owned by a currently enabled role. Note that in PostgreSQL, built-in data types behave like user-defined types, so they are included here as well.

Table 36.20. domain_udt_usage Columns

Name	Data Type	Description
<code>udt_catalog</code>	<code>sql_identifier</code>	Name of the database that the domain data type is defined in (always the current database)
<code>udt_schema</code>	<code>sql_identifier</code>	Name of the schema that the domain data type is defined in
<code>udt_name</code>	<code>sql_identifier</code>	Name of the domain data type
<code>domain_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the domain (always the current database)
<code>domain_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the domain
<code>domain_name</code>	<code>sql_identifier</code>	Name of the domain

36.23. domains

The view `domains` contains all domains defined in the current database. Only those domains are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.21. domains Columns

Name	Data Type	Description
<code>domain_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the domain (always the current database)
<code>domain_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the domain
<code>domain_name</code>	<code>sql_identifier</code>	Name of the domain
<code>data_type</code>	<code>character_data</code>	Data type of the domain, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code>), else USER-DEFINED (in that case, the type is identified in <code>udt_name</code> and associated columns).
<code>character_maximum_length</code>	<code>cardinal_number</code>	If the domain has a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
<code>character_octet_length</code>	<code>cardinal_number</code>	If the domain has a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types.

Name	Data Type	Description
		The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Name of the database containing the collation of the domain (always the current database), null if default or the data type of the domain is not collatable
collation_schema	sql_identifier	Name of the schema containing the collation of the domain, null if default or the data type of the domain is not collatable
collation_name	sql_identifier	Name of the collation of the domain, null if default or the data type of the domain is not collatable
numeric_precision	cardinal_number	If the domain has a numeric type, this column contains the (declared or implicit) precision of the type for this domain. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> . For all other data types, this column is null.
numeric_precision_radix	cardinal_number	If the domain has a numeric type, this column indicates in which base the values in the columns <code>numeric_precision</code> and <code>numeric_scale</code> are expressed. The value is either 2 or 10. For all other data types, this column is null.
numeric_scale	cardinal_number	If the domain has an exact numeric type, this column contains the (declared or implicit) scale of the type for this domain. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_</code>

Name	Data Type	Description
		ic_precision_radix. For all other data types, this column is null.
datetime_precision	cardinal_number	If data_type identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this domain, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
interval_type	character_data	If data_type identifies an interval type, this column contains the specification which fields the intervals include for this domain, e.g., YEAR TO MONTH, DAY TO SECOND, etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL (see datetime_precision for the fractional seconds precision of interval type domains)
domain_default	character_data	Default expression of the domain
udt_catalog	sql_identifier	Name of the database that the domain data type is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the domain data type is defined in
udt_name	sql_identifier	Name of the domain data type
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the domain, unique among the data type descriptors pertaining to the domain (which is trivial, because a domain only contains one data type descriptor). This is mainly useful

Name	Data Type	Description
		for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)

36.24. element_types

The view `element_types` contains the data type descriptors of the elements of arrays. When a table column, composite-type attribute, domain, function parameter, or function return value is defined to be of an array type, the respective information schema view only contains `ARRAY` in the column `data_type`. To obtain information on the element type of the array, you can join the respective view with this view. For example, to show the columns of a table with data types and array element types, if applicable, you could do:

```
SELECT c.column_name, c.data_type, e.data_type AS element_type
FROM information_schema.columns c LEFT JOIN
    information_schema.element_types e
    ON ((c.table_catalog, c.table_schema, c.table_name, 'TABLE',
        c.dtd_identifier)
        = (e.object_catalog, e.object_schema, e.object_name,
        e.object_type, e.collection_type_identifier))
WHERE c.table_schema = '...' AND c.table_name = '...'
ORDER BY c.ordinal_position;
```

This view only includes objects that the current user has access to, by way of being the owner or having some privilege.

Table 36.22. element_types Columns

Name	Data Type	Description
<code>object_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the object that uses the array being described (always the current database)
<code>object_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the object that uses the array being described
<code>object_name</code>	<code>sql_identifier</code>	Name of the object that uses the array being described
<code>object_type</code>	<code>character_data</code>	The type of the object that uses the array being described: one of <code>TABLE</code> (the array is used by a column of that table), <code>USER-DEFINED TYPE</code> (the array is used by an attribute of that composite type), <code>DOMAIN</code> (the array is used by that domain), <code>ROUTINE</code> (the array is used by a parameter or the return data type of that function).
<code>collection_type_identifier</code>	<code>sql_identifier</code>	The identifier of the data type descriptor of the array being de-

Name	Data Type	Description
		scribed. Use this to join with the <code>dtd_identifier</code> columns of other information schema views.
<code>data_type</code>	<code>character_data</code>	Data type of the array elements, if it is a built-in type, else <code>USER-DEFINED</code> (in that case, the type is identified in <code>udt_name</code> and associated columns).
<code>character_maximum_length</code>	<code>cardinal_number</code>	Always null, since this information is not applied to array element data types in PostgreSQL
<code>character_octet_length</code>	<code>cardinal_number</code>	Always null, since this information is not applied to array element data types in PostgreSQL
<code>character_set_catalog</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>character_set_schema</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>character_set_name</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>collation_catalog</code>	<code>sql_identifier</code>	Name of the database containing the collation of the element type (always the current database), null if default or the data type of the element is not collatable
<code>collation_schema</code>	<code>sql_identifier</code>	Name of the schema containing the collation of the element type, null if default or the data type of the element is not collatable
<code>collation_name</code>	<code>sql_identifier</code>	Name of the collation of the element type, null if default or the data type of the element is not collatable
<code>numeric_precision</code>	<code>cardinal_number</code>	Always null, since this information is not applied to array element data types in PostgreSQL
<code>numeric_precision_radix</code>	<code>cardinal_number</code>	Always null, since this information is not applied to array element data types in PostgreSQL
<code>numeric_scale</code>	<code>cardinal_number</code>	Always null, since this information is not applied to array element data types in PostgreSQL
<code>datetime_precision</code>	<code>cardinal_number</code>	Always null, since this information is not applied to array element data types in PostgreSQL
<code>interval_type</code>	<code>character_data</code>	Always null, since this information is not applied to array element data types in PostgreSQL

Name	Data Type	Description
interval_precision	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
domain_default	character_data	Not yet implemented
udt_catalog	sql_identifier	Name of the database that the data type of the elements is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the data type of the elements is defined in
udt_name	sql_identifier	Name of the data type of the elements
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the element. This is currently not useful.

36.25. enabled_roles

The view `enabled_roles` identifies the currently “enabled roles”. The enabled roles are recursively defined as the current user together with all roles that have been granted to the enabled roles with automatic inheritance. In other words, these are all roles that the current user has direct or indirect, automatically inheriting membership in.

For permission checking, the set of “applicable roles” is applied, which can be broader than the set of enabled roles. So generally, it is better to use the view `applicable_roles` instead of this one; See Section 36.5 for details on `applicable_roles` view.

Table 36.23. enabled_roles Columns

Name	Data Type	Description
role_name	sql_identifier	Name of a role

36.26. foreign_data_wrapper_options

The view `foreign_data_wrapper_options` contains all the options defined for foreign-data wrappers in the current database. Only those foreign-data wrappers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.24. foreign_data_wrapper_options Columns

Name	Data Type	Description
foreign_data_wrapper_catalog	sql_identifier	Name of the database that the foreign-data wrapper is defined in (always the current database)

Name	Data Type	Description
foreign_data_wrap- per_name	sql_identifier	Name of the foreign-data wrap- per
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

36.27. foreign_data_wrappers

The view `foreign_data_wrappers` contains all foreign-data wrappers defined in the current database. Only those foreign-data wrappers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.25. foreign_data_wrappers Columns

Name	Data Type	Description
foreign_data_wrap- per_catalog	sql_identifier	Name of the database that con- tains the foreign-data wrapper (always the current database)
foreign_data_wrap- per_name	sql_identifier	Name of the foreign-data wrap- per
authorization_identi- fier	sql_identifier	Name of the owner of the foreign server
library_name	character_data	File name of the library that implementing this foreign-data wrapper
foreign_data_wrap- per_language	character_data	Language used to implement this foreign-data wrapper

36.28. foreign_server_options

The view `foreign_server_options` contains all the options defined for foreign servers in the current database. Only those foreign servers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.26. foreign_server_options Columns

Name	Data Type	Description
foreign_server_cata- log	sql_identifier	Name of the database that the foreign server is defined in (al- ways the current database)
foreign_server_name	sql_identifier	Name of the foreign server
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

36.29. foreign_servers

The view `foreign_servers` contains all foreign servers defined in the current database. Only those foreign servers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.27. foreign_servers Columns

Name	Data Type	Description
foreign_server_catalog	sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server
foreign_data_wrapper_catalog	sql_identifier	Name of the database that contains the foreign-data wrapper used by the foreign server (always the current database)
foreign_data_wrapper_name	sql_identifier	Name of the foreign-data wrapper used by the foreign server
foreign_server_type	character_data	Foreign server type information, if specified upon creation
foreign_server_version	character_data	Foreign server version information, if specified upon creation
authorization_identifier	sql_identifier	Name of the owner of the foreign server

36.30. foreign_table_options

The view `foreign_table_options` contains all the options defined for foreign tables in the current database. Only those foreign tables are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.28. foreign_table_options Columns

Name	Data Type	Description
foreign_table_catalog	sql_identifier	Name of the database that contains the foreign table (always the current database)
foreign_table_schema	sql_identifier	Name of the schema that contains the foreign table
foreign_table_name	sql_identifier	Name of the foreign table
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

36.31. foreign_tables

The view `foreign_tables` contains all foreign tables defined in the current database. Only those foreign tables are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.29. foreign_tables Columns

Name	Data Type	Description
foreign_table_catalog	sql_identifier	Name of the database that the foreign table is defined in (always the current database)
foreign_table_schema	sql_identifier	Name of the schema that contains the foreign table

Name	Data Type	Description
foreign_table_name	sql_identifier	Name of the foreign table
foreign_server_catalog	sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server

36.32. key_column_usage

The view `key_column_usage` identifies all columns in the current database that are restricted by some unique, primary key, or foreign key constraint. Check constraints are not included in this view. Only those columns are shown that the current user has access to, by way of being the owner or having some privilege.

Table 36.30. key_column_usage Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint
table_catalog	sql_identifier	Name of the database that contains the table that contains the column that is restricted by this constraint (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column that is restricted by this constraint
table_name	sql_identifier	Name of the table that contains the column that is restricted by this constraint
column_name	sql_identifier	Name of the column that is restricted by this constraint
ordinal_position	cardinal_number	Ordinal position of the column within the constraint key (count starts at 1)
position_in_unique_constraint	cardinal_number	For a foreign-key constraint, ordinal position of the referenced column within its unique constraint (count starts at 1); otherwise null

36.33. parameters

The view `parameters` contains information about the parameters (arguments) of all functions in the current database. Only those functions are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.31. parameters Columns

Name	Data Type	Description
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The “specific name” of the function. See Section 36.41 for more information.
ordinal_position	cardinal_number	Ordinal position of the parameter in the argument list of the function (count starts at 1)
parameter_mode	character_data	IN for input parameter, OUT for output parameter, and INOUT for input/output parameter.
is_result	yes_or_no	Applies to a feature not available in PostgreSQL
as_locator	yes_or_no	Applies to a feature not available in PostgreSQL
parameter_name	sql_identifier	Name of the parameter, or null if the parameter has no name
data_type	character_data	Data type of the parameter, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in udt_name and associated columns).
character_maximum_length	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
character_octet_length	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Always null, since this information is not applied to parameter data types in PostgreSQL
collation_schema	sql_identifier	Always null, since this information is not applied to parameter data types in PostgreSQL

Name	Data Type	Description
collation_name	sql_identifier	Always null, since this information is not applied to parameter data types in PostgreSQL
numeric_precision	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
numeric_precision_radix	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
numeric_scale	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
datetime_precision	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
interval_type	character_data	Always null, since this information is not applied to parameter data types in PostgreSQL
interval_precision	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
udt_catalog	sql_identifier	Name of the database that the data type of the parameter is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the data type of the parameter is defined in
udt_name	sql_identifier	Name of the data type of the parameter
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the parameter, unique among the data type descriptors pertaining to the function. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)

Name	Data Type	Description
parameter_default	character_data	The default expression of the parameter, or null if none or if the function is not owned by a currently enabled role.

36.34. referential_constraints

The view `referential_constraints` contains all referential (foreign key) constraints in the current database. Only those constraints are shown for which the current user has write access to the referencing table (by way of being the owner or having some privilege other than `SELECT`).

Table 36.32. referential_constraints Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema containing the constraint
constraint_name	sql_identifier	Name of the constraint
unique_constraint_catalog	sql_identifier	Name of the database that contains the unique or primary key constraint that the foreign key constraint references (always the current database)
unique_constraint_schema	sql_identifier	Name of the schema that contains the unique or primary key constraint that the foreign key constraint references
unique_constraint_name	sql_identifier	Name of the unique or primary key constraint that the foreign key constraint references
match_option	character_data	Match option of the foreign key constraint: <code>FULL</code> , <code>PARTIAL</code> , or <code>NONE</code> .
update_rule	character_data	Update rule of the foreign key constraint: <code>CASCADE</code> , <code>SET NULL</code> , <code>SET DEFAULT</code> , <code>RESTRICT</code> , or <code>NO ACTION</code> .
delete_rule	character_data	Delete rule of the foreign key constraint: <code>CASCADE</code> , <code>SET NULL</code> , <code>SET DEFAULT</code> , <code>RESTRICT</code> , or <code>NO ACTION</code> .

36.35. role_column_grants

The view `role_column_grants` identifies all privileges granted on columns where the grantor or grantee is a currently enabled role. Further information can be found under `column_privileges`. The only effective difference between this view and `column_privileges` is that this view omits columns that have been made accessible to the current user by way of a grant to `PUBLIC`.

Table 36.33. role_column_grants Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table that contains the column (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column
table_name	sql_identifier	Name of the table that contains the column
column_name	sql_identifier	Name of the column
privilege_type	character_data	Type of the privilege: SELECT, INSERT, UPDATE, or REFERENCES
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.36. role_routine_grants

The view `role_routine_grants` identifies all privileges granted on functions where the grantor or grantee is a currently enabled role. Further information can be found under `routine_privileges`. The only effective difference between this view and `routine_privileges` is that this view omits functions that have been made accessible to the current user by way of a grant to PUBLIC.

Table 36.34. role_routine_grants Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The “specific name” of the function. See Section 36.41 for more information.
routine_catalog	sql_identifier	Name of the database containing the function (always the current database)
routine_schema	sql_identifier	Name of the schema containing the function

Name	Data Type	Description
routine_name	sql_identifier	Name of the function (might be duplicated in case of overloading)
privilege_type	character_data	Always EXECUTE (the only privilege type for functions)
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.37. role_table_grants

The view `role_table_grants` identifies all privileges granted on tables or views where the grantor or grantee is a currently enabled role. Further information can be found under `table_privileges`. The only effective difference between this view and `table_privileges` is that this view omits tables that have been made accessible to the current user by way of a grant to PUBLIC.

Table 36.35. role_table_grants Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table
table_name	sql_identifier	Name of the table
privilege_type	character_data	Type of the privilege: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, or TRIGGER
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not
with_hierarchy	yes_or_no	In the SQL standard, WITH HIERARCHY OPTION is a separate (sub-)privilege allowing certain operations on table inheritance hierarchies. In PostgreSQL, this is included in the SELECT privilege, so this column shows YES if the privilege is SELECT, else NO.

36.38. role_udt_grants

The view `role_udt_grants` is intended to identify USAGE privileges granted on user-defined types where the grantor or grantee is a currently enabled role. Further information can be found under `udt_privileges`. The only effective difference between this view and `udt_privileges` is that this view omits objects that have been made accessible to the current user by way of a grant to

PUBLIC. Since data types do not have real privileges in PostgreSQL, but only an implicit grant to PUBLIC, this view is empty.

Table 36.36. role_udt_grants Columns

Name	Data Type	Description
grantor	sql_identifier	The name of the role that granted the privilege
grantee	sql_identifier	The name of the role that the privilege was granted to
udt_catalog	sql_identifier	Name of the database containing the type (always the current database)
udt_schema	sql_identifier	Name of the schema containing the type
udt_name	sql_identifier	Name of the type
privilege_type	character_data	Always TYPE USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.39. role_usage_grants

The view `role_usage_grants` identifies USAGE privileges granted on various kinds of objects where the grantor or grantee is a currently enabled role. Further information can be found under `usage_privileges`. The only effective difference between this view and `usage_privileges` is that this view omits objects that have been made accessible to the current user by way of a grant to PUBLIC.

Table 36.37. role_usage_grants Columns

Name	Data Type	Description
grantor	sql_identifier	The name of the role that granted the privilege
grantee	sql_identifier	The name of the role that the privilege was granted to
object_catalog	sql_identifier	Name of the database containing the object (always the current database)
object_schema	sql_identifier	Name of the schema containing the object, if applicable, else an empty string
object_name	sql_identifier	Name of the object
object_type	character_data	COLLATION or DOMAIN or FOREIGN DATA WRAPPER or FOREIGN SERVER or SEQUENCE
privilege_type	character_data	Always USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.40. routine_privileges

The view `routine_privileges` identifies all privileges granted on functions to a currently enabled role or by a currently enabled role. There is one row for each combination of function, grantor, and grantee.

Table 36.38. routine_privileges Columns

Name	Data Type	Description
<code>grantor</code>	<code>sql_identifier</code>	Name of the role that granted the privilege
<code>grantee</code>	<code>sql_identifier</code>	Name of the role that the privilege was granted to
<code>specific_catalog</code>	<code>sql_identifier</code>	Name of the database containing the function (always the current database)
<code>specific_schema</code>	<code>sql_identifier</code>	Name of the schema containing the function
<code>specific_name</code>	<code>sql_identifier</code>	The “specific name” of the function. See Section 36.41 for more information.
<code>routine_catalog</code>	<code>sql_identifier</code>	Name of the database containing the function (always the current database)
<code>routine_schema</code>	<code>sql_identifier</code>	Name of the schema containing the function
<code>routine_name</code>	<code>sql_identifier</code>	Name of the function (might be duplicated in case of overloading)
<code>privilege_type</code>	<code>character_data</code>	Always EXECUTE (the only privilege type for functions)
<code>is_grantable</code>	<code>yes_or_no</code>	YES if the privilege is grantable, NO if not

36.41. routines

The view `routines` contains all functions and procedures in the current database. Only those functions and procedures are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.39. routines Columns

Name	Data Type	Description
<code>specific_catalog</code>	<code>sql_identifier</code>	Name of the database containing the function (always the current database)
<code>specific_schema</code>	<code>sql_identifier</code>	Name of the schema containing the function
<code>specific_name</code>	<code>sql_identifier</code>	The “specific name” of the function. This is a name that uniquely identifies the function in the schema, even if the real name of

Name	Data Type	Description
		the function is overloaded. The format of the specific name is not defined, it should only be used to compare it to other instances of specific routine names.
routine_catalog	sql_identifier	Name of the database containing the function (always the current database)
routine_schema	sql_identifier	Name of the schema containing the function
routine_name	sql_identifier	Name of the function (might be duplicated in case of overloading)
routine_type	character_data	FUNCTION for a function, PROCEDURE for a procedure
module_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
module_schema	sql_identifier	Applies to a feature not available in PostgreSQL
module_name	sql_identifier	Applies to a feature not available in PostgreSQL
udt_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
udt_schema	sql_identifier	Applies to a feature not available in PostgreSQL
udt_name	sql_identifier	Applies to a feature not available in PostgreSQL
data_type	character_data	Return data type of the function, if it is a built-in type, or ARRAY if it is some array (in that case, see the view <code>element_types</code>), else <code>USER-DEFINED</code> (in that case, the type is identified in <code>type_udt_name</code> and associated columns). Null for a procedure.
character_maximum_length	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
character_octet_length	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
collation_catalog	sql_identifier	Always null, since this information is not applied to return data types in PostgreSQL
collation_schema	sql_identifier	Always null, since this information is not applied to return data types in PostgreSQL
collation_name	sql_identifier	Always null, since this information is not applied to return data types in PostgreSQL
numeric_precision	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
numeric_precision_radix	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
numeric_scale	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
datetime_precision	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
interval_type	character_data	Always null, since this information is not applied to return data types in PostgreSQL
interval_precision	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
type_udt_catalog	sql_identifier	Name of the database that the return data type of the function is defined in (always the current database). Null for a procedure.
type_udt_schema	sql_identifier	Name of the schema that the return data type of the function is defined in. Null for a procedure.
type_udt_name	sql_identifier	Name of the return data type of the function. Null for a procedure.
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the return data type of this function, unique among the data type descriptors pertaining

Name	Data Type	Description
		to the function. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
routine_body	character_data	If the function is an SQL function, then SQL, else EXTERNAL.
routine_definition	character_data	The source text of the function (null if the function is not owned by a currently enabled role). (According to the SQL standard, this column is only applicable if routine_body is SQL, but in PostgreSQL it will contain whatever source text was specified when the function was created.)
external_name	character_data	If this function is a C function, then the external name (link symbol) of the function; else null. (This works out to be the same value that is shown in routine_definition.)
external_language	character_data	The language the function is written in
parameter_style	character_data	Always GENERAL (The SQL standard defines other parameter styles, which are not available in PostgreSQL.)
is_deterministic	yes_or_no	If the function is declared immutable (called deterministic in the SQL standard), then YES, else NO. (You cannot query the other volatility levels available in PostgreSQL through the information schema.)
sql_data_access	character_data	Always MODIFIES, meaning that the function possibly modifies SQL data. This information is not useful for PostgreSQL.
is_null_call	yes_or_no	If the function automatically returns null if any of its arguments are null, then YES, else NO. Null for a procedure.
sql_path	character_data	Applies to a feature not available in PostgreSQL
schema_level_routine	yes_or_no	Always YES (The opposite would be a method of a user-defined type, which is a feature not available in PostgreSQL.)

Name	Data Type	Description
max_dynamic_result_sets	cardinal_number	Applies to a feature not available in PostgreSQL
is_user_defined_cast	yes_or_no	Applies to a feature not available in PostgreSQL
is_implicitly_invocable	yes_or_no	Applies to a feature not available in PostgreSQL
security_type	character_data	If the function runs with the privileges of the current user, then INVOKER, if the function runs with the privileges of the user who defined it, then DEFINER.
to_sql_specific_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
to_sql_specific_schema	sql_identifier	Applies to a feature not available in PostgreSQL
to_sql_specific_name	sql_identifier	Applies to a feature not available in PostgreSQL
as_locator	yes_or_no	Applies to a feature not available in PostgreSQL
created	time_stamp	Applies to a feature not available in PostgreSQL
last_altered	time_stamp	Applies to a feature not available in PostgreSQL
new_savepoint_level	yes_or_no	Applies to a feature not available in PostgreSQL
is_udt_dependent	yes_or_no	Currently always NO. The alternative YES applies to a feature not available in PostgreSQL.
result_cast_from_data_type	character_data	Applies to a feature not available in PostgreSQL
result_cast_as_locator	yes_or_no	Applies to a feature not available in PostgreSQL
result_cast_char_max_length	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_char_octet_length	character_data	Applies to a feature not available in PostgreSQL
result_cast_char_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_char_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_char_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_collation_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_collation_schema	sql_identifier	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
result_cast_collation_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_numeric_precision	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_numeric_precision_radix	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_numeric_scale	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_datetime_precision	character_data	Applies to a feature not available in PostgreSQL
result_cast_interval_type	character_data	Applies to a feature not available in PostgreSQL
result_cast_interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_type_udt_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_type_udt_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_type_udt_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_maximum_cardinality	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_dtd_identifier	sql_identifier	Applies to a feature not available in PostgreSQL

36.42. schemata

The view `schemata` contains all schemas in the current database that the current user has access to (by way of being the owner or having some privilege).

Table 36.40. schemata Columns

Name	Data Type	Description
catalog_name	sql_identifier	Name of the database that the schema is contained in (always the current database)
schema_name	sql_identifier	Name of the schema
schema_owner	sql_identifier	Name of the owner of the schema
default_character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
default_character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
default_character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
sql_path	character_data	Applies to a feature not available in PostgreSQL

36.43. sequences

The view `sequences` contains all sequences defined in the current database. Only those sequences are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.41. sequences Columns

Name	Data Type	Description
sequence_catalog	sql_identifier	Name of the database that contains the sequence (always the current database)
sequence_schema	sql_identifier	Name of the schema that contains the sequence
sequence_name	sql_identifier	Name of the sequence
data_type	character_data	The data type of the sequence.
numeric_precision	cardinal_number	This column contains the (declared or implicit) precision of the sequence data type (see above). The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> .
numeric_precision_radix	cardinal_number	This column indicates in which base the values in the columns <code>numeric_precision</code> and <code>numeric_scale</code> are expressed. The value is either 2 or 10.
numeric_scale	cardinal_number	This column contains the (declared or implicit) scale of the sequence data type (see above). The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column <code>numeric_precision_radix</code> .
start_value	character_data	The start value of the sequence
minimum_value	character_data	The minimum value of the sequence

Name	Data Type	Description
maximum_value	character_data	The maximum value of the sequence
increment	character_data	The increment of the sequence
cycle_option	yes_or_no	YES if the sequence cycles, else NO

Note that in accordance with the SQL standard, the start, minimum, maximum, and increment values are returned as character strings.

36.44. sql_features

The table `sql_features` contains information about which formal features defined in the SQL standard are supported by PostgreSQL. This is the same information that is presented in Appendix D. There you can also find some additional background information.

Table 36.42. sql_features Columns

Name	Data Type	Description
feature_id	character_data	Identifier string of the feature
feature_name	character_data	Descriptive name of the feature
sub_feature_id	character_data	Identifier string of the subfeature, or a zero-length string if not a subfeature
sub_feature_name	character_data	Descriptive name of the subfeature, or a zero-length string if not a subfeature
is_supported	yes_or_no	YES if the feature is fully supported by the current version of PostgreSQL, NO if not
is_verified_by	character_data	Always null, since the PostgreSQL development group does not perform formal testing of feature conformance
comments	character_data	Possibly a comment about the supported status of the feature

36.45. sql_implementation_info

The table `sql_implementation_info` contains information about various aspects that are left implementation-defined by the SQL standard. This information is primarily intended for use in the context of the ODBC interface; users of other interfaces will probably find this information to be of little use. For this reason, the individual implementation information items are not described here; you will find them in the description of the ODBC interface.

Table 36.43. sql_implementation_info Columns

Name	Data Type	Description
implementation_info_id	character_data	Identifier string of the implementation information item
implementation_info_name	character_data	Descriptive name of the implementation information item

Name	Data Type	Description
integer_value	cardinal_number	Value of the implementation information item, or null if the value is contained in the column character_value
character_value	character_data	Value of the implementation information item, or null if the value is contained in the column integer_value
comments	character_data	Possibly a comment pertaining to the implementation information item

36.46. sql_languages

The table `sql_languages` contains one row for each SQL language binding that is supported by PostgreSQL. PostgreSQL supports direct SQL and embedded SQL in C; that is all you will learn from this table.

This table was removed from the SQL standard in SQL:2008, so there are no entries referring to standards later than SQL:2003.

Table 36.44. sql_languages Columns

Name	Data Type	Description
sql_language_source	character_data	The name of the source of the language definition; always ISO 9075, that is, the SQL standard
sql_language_year	character_data	The year the standard referenced in <code>sql_language_source</code> was approved.
sql_language_conformance	character_data	The standard conformance level for the language binding. For ISO 9075:2003 this is always CORE.
sql_language_integrity	character_data	Always null (This value is relevant to an earlier version of the SQL standard.)
sql_language_implementation	character_data	Always null
sql_language_binding_style	character_data	The language binding style, either DIRECT or EMBEDDED
sql_language_programming_language	character_data	The programming language, if the binding style is EMBEDDED, else null. PostgreSQL only supports the language C.

36.47. sql_packages

The table `sql_packages` contains information about which feature packages defined in the SQL standard are supported by PostgreSQL. Refer to Appendix D for background information on feature packages.

Table 36.45. sql_packages Columns

Name	Data Type	Description
feature_id	character_data	Identifier string of the package
feature_name	character_data	Descriptive name of the package
is_supported	yes_or_no	YES if the package is fully supported by the current version of PostgreSQL, NO if not
is_verified_by	character_data	Always null, since the PostgreSQL development group does not perform formal testing of feature conformance
comments	character_data	Possibly a comment about the supported status of the package

36.48. sql_parts

The table `sql_parts` contains information about which of the several parts of the SQL standard are supported by PostgreSQL.

Table 36.46. sql_parts Columns

Name	Data Type	Description
feature_id	character_data	An identifier string containing the number of the part
feature_name	character_data	Descriptive name of the part
is_supported	yes_or_no	YES if the part is fully supported by the current version of PostgreSQL, NO if not
is_verified_by	character_data	Always null, since the PostgreSQL development group does not perform formal testing of feature conformance
comments	character_data	Possibly a comment about the supported status of the part

36.49. sql_sizing

The table `sql_sizing` contains information about various size limits and maximum values in PostgreSQL. This information is primarily intended for use in the context of the ODBC interface; users of other interfaces will probably find this information to be of little use. For this reason, the individual sizing items are not described here; you will find them in the description of the ODBC interface.

Table 36.47. sql_sizing Columns

Name	Data Type	Description
sizing_id	cardinal_number	Identifier of the sizing item
sizing_name	character_data	Descriptive name of the sizing item
supported_value	cardinal_number	Value of the sizing item, or 0 if the size is unlimited or cannot be

Name	Data Type	Description
		determined, or null if the features for which the sizing item is applicable are not supported
comments	character_data	Possibly a comment pertaining to the sizing item

36.50. sql_sizing_profiles

The table `sql_sizing_profiles` contains information about the `sql_sizing` values that are required by various profiles of the SQL standard. PostgreSQL does not track any SQL profiles, so this table is empty.

Table 36.48. sql_sizing_profiles Columns

Name	Data Type	Description
sizing_id	cardinal_number	Identifier of the sizing item
sizing_name	character_data	Descriptive name of the sizing item
profile_id	character_data	Identifier string of a profile
required_value	cardinal_number	The value required by the SQL profile for the sizing item, or 0 if the profile places no limit on the sizing item, or null if the profile does not require any of the features for which the sizing item is applicable
comments	character_data	Possibly a comment pertaining to the sizing item within the profile

36.51. table_constraints

The view `table_constraints` contains all constraints belonging to tables that the current user owns or has some privilege other than `SELECT` on.

Table 36.49. table_constraints Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint
table_catalog	sql_identifier	Name of the database that contains the table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table
table_name	sql_identifier	Name of the table

Name	Data Type	Description
constraint_type	character_data	Type of the constraint: CHECK, FOREIGN KEY, PRIMARY KEY, or UNIQUE
is_deferrable	yes_or_no	YES if the constraint is deferrable, NO if not
initially_deferred	yes_or_no	YES if the constraint is deferrable and initially deferred, NO if not
enforced	yes_or_no	Applies to a feature not available in PostgreSQL (currently always YES)

36.52. table_privileges

The view `table_privileges` identifies all privileges granted on tables or views to a currently enabled role or by a currently enabled role. There is one row for each combination of table, grantor, and grantee.

Table 36.50. table_privileges Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table
table_name	sql_identifier	Name of the table
privilege_type	character_data	Type of the privilege: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, or TRIGGER
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not
with_hierarchy	yes_or_no	In the SQL standard, WITH HIERARCHY OPTION is a separate (sub-)privilege allowing certain operations on table inheritance hierarchies. In PostgreSQL, this is included in the SELECT privilege, so this column shows YES if the privilege is SELECT, else NO.

36.53. tables

The view `tables` contains all tables and views defined in the current database. Only those tables and views are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.51. tables Columns

Name	Data Type	Description
<code>table_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the table (always the current database)
<code>table_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the table
<code>table_name</code>	<code>sql_identifier</code>	Name of the table
<code>table_type</code>	<code>character_data</code>	Type of the table: <code>BASE TABLE</code> for a persistent base table (the normal table type), <code>VIEW</code> for a view, <code>FOREIGN</code> for a foreign table, or <code>LOCAL TEMPORARY</code> for a temporary table
<code>self_referencing_column_name</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>reference_generation</code>	<code>character_data</code>	Applies to a feature not available in PostgreSQL
<code>user_defined_type_catalog</code>	<code>sql_identifier</code>	If the table is a typed table, the name of the database that contains the underlying data type (always the current database), else null.
<code>user_defined_type_schema</code>	<code>sql_identifier</code>	If the table is a typed table, the name of the schema that contains the underlying data type, else null.
<code>user_defined_type_name</code>	<code>sql_identifier</code>	If the table is a typed table, the name of the underlying data type, else null.
<code>is_insertable_into</code>	<code>yes_or_no</code>	YES if the table is insertable into, NO if not (Base tables are always insertable into, views not necessarily.)
<code>is_typed</code>	<code>yes_or_no</code>	YES if the table is a typed table, NO if not
<code>commit_action</code>	<code>character_data</code>	Not yet implemented

36.54. transforms

The view `transforms` contains information about the transforms defined in the current database. More precisely, it contains a row for each function contained in a transform (the “from SQL” or “to SQL” function).

Table 36.52. transforms Columns

Name	Data Type	Description
udt_catalog	sql_identifier	Name of the database that contains the type the transform is for (always the current database)
udt_schema	sql_identifier	Name of the schema that contains the type the transform is for
udt_name	sql_identifier	Name of the type the transform is for
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The “specific name” of the function. See Section 36.41 for more information.
group_name	sql_identifier	The SQL standard allows defining transforms in “groups”, and selecting a group at run time. PostgreSQL does not support this. Instead, transforms are specific to a language. As a compromise, this field contains the language the transform is for.
transform_type	character_data	FROM SQL or TO SQL

36.55. triggered_update_columns

For triggers in the current database that specify a column list (like `UPDATE OF column1, column2`), the view `triggered_update_columns` identifies these columns. Triggers that do not specify a column list are not included in this view. Only those columns are shown that the current user owns or has some privilege other than `SELECT` on.

Table 36.53. triggered_update_columns Columns

Name	Data Type	Description
trigger_catalog	sql_identifier	Name of the database that contains the trigger (always the current database)
trigger_schema	sql_identifier	Name of the schema that contains the trigger
trigger_name	sql_identifier	Name of the trigger
event_object_catalog	sql_identifier	Name of the database that contains the table that the trigger is defined on (always the current database)
event_object_schema	sql_identifier	Name of the schema that contains the table that the trigger is defined on

Name	Data Type	Description
event_object_table	sql_identifier	Name of the table that the trigger is defined on
event_object_column	sql_identifier	Name of the column that the trigger is defined on

36.56. triggers

The view `triggers` contains all triggers defined in the current database on tables and views that the current user owns or has some privilege other than `SELECT` on.

Table 36.54. triggers Columns

Name	Data Type	Description
trigger_catalog	sql_identifier	Name of the database that contains the trigger (always the current database)
trigger_schema	sql_identifier	Name of the schema that contains the trigger
trigger_name	sql_identifier	Name of the trigger
event_manipulation	character_data	Event that fires the trigger (INSERT, UPDATE, or DELETE)
event_object_catalog	sql_identifier	Name of the database that contains the table that the trigger is defined on (always the current database)
event_object_schema	sql_identifier	Name of the schema that contains the table that the trigger is defined on
event_object_table	sql_identifier	Name of the table that the trigger is defined on
action_order	cardinal_number	Firing order among triggers on the same table having the same event_manipulation, action_timing, and action_orientation. In PostgreSQL, triggers are fired in name order, so this column reflects that.
action_condition	character_data	WHEN condition of the trigger, null if none (also null if the table is not owned by a currently enabled role)
action_statement	character_data	Statement that is executed by the trigger (currently always EXECUTE FUNCTION <i>function(...)</i>)
action_orientation	character_data	Identifies whether the trigger fires once for each processed row or once for each statement (ROW or STATEMENT)

Name	Data Type	Description
action_timing	character_data	Time at which the trigger fires (BEFORE, AFTER, or INSTEAD OF)
action_reference_old_table	sql_identifier	Name of the “old” transition table, or null if none
action_reference_new_table	sql_identifier	Name of the “new” transition table, or null if none
action_reference_old_row	sql_identifier	Applies to a feature not available in PostgreSQL
action_reference_new_row	sql_identifier	Applies to a feature not available in PostgreSQL
created	time_stamp	Applies to a feature not available in PostgreSQL

Triggers in PostgreSQL have two incompatibilities with the SQL standard that affect the representation in the information schema. First, trigger names are local to each table in PostgreSQL, rather than being independent schema objects. Therefore there can be duplicate trigger names defined in one schema, so long as they belong to different tables. (`trigger_catalog` and `trigger_schema` are really the values pertaining to the table that the trigger is defined on.) Second, triggers can be defined to fire on multiple events in PostgreSQL (e.g., `ON INSERT OR UPDATE`), whereas the SQL standard only allows one. If a trigger is defined to fire on multiple events, it is represented as multiple rows in the information schema, one for each type of event. As a consequence of these two issues, the primary key of the view `triggers` is really (`trigger_catalog`, `trigger_schema`, `event_object_table`, `trigger_name`, `event_manipulation`) instead of (`trigger_catalog`, `trigger_schema`, `trigger_name`), which is what the SQL standard specifies. Nonetheless, if you define your triggers in a manner that conforms with the SQL standard (trigger names unique in the schema and only one event type per trigger), this will not affect you.

Note

Prior to PostgreSQL 9.1, this view's columns `action_timing`, `action_reference_old_table`, `action_reference_new_table`, `action_reference_old_row`, and `action_reference_new_row` were named `condition_timing`, `condition_reference_old_table`, `condition_reference_new_table`, `condition_reference_old_row`, and `condition_reference_new_row` respectively. That was how they were named in the SQL:1999 standard. The new naming conforms to SQL:2003 and later.

36.57. `udt_privileges`

The view `udt_privileges` identifies `USAGE` privileges granted on user-defined types to a currently enabled role or by a currently enabled role. There is one row for each combination of type, grantor, and grantee. This view shows only composite types (see under Section 36.59 for why); see Section 36.58 for domain privileges.

Table 36.55. `udt_privileges` Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to

Name	Data Type	Description
udt_catalog	sql_identifier	Name of the database containing the type (always the current database)
udt_schema	sql_identifier	Name of the schema containing the type
udt_name	sql_identifier	Name of the type
privilege_type	character_data	Always TYPE USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.58. usage_privileges

The view `usage_privileges` identifies USAGE privileges granted on various kinds of objects to a currently enabled role or by a currently enabled role. In PostgreSQL, this currently applies to collations, domains, foreign-data wrappers, foreign servers, and sequences. There is one row for each combination of object, grantor, and grantee.

Since collations do not have real privileges in PostgreSQL, this view shows implicit non-grantable USAGE privileges granted by the owner to PUBLIC for all collations. The other object types, however, show real privileges.

In PostgreSQL, sequences also support SELECT and UPDATE privileges in addition to the USAGE privilege. These are nonstandard and therefore not visible in the information schema.

Table 36.56. usage_privileges Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
object_catalog	sql_identifier	Name of the database containing the object (always the current database)
object_schema	sql_identifier	Name of the schema containing the object, if applicable, else an empty string
object_name	sql_identifier	Name of the object
object_type	character_data	COLLATION or DOMAIN or FOREIGN DATA WRAPPER or FOREIGN SERVER or SEQUENCE
privilege_type	character_data	Always USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

36.59. user_defined_types

The view `user_defined_types` currently contains all composite types defined in the current database. Only those types are shown that the current user has access to (by way of being the owner or having some privilege).

SQL knows about two kinds of user-defined types: structured types (also known as composite types in PostgreSQL) and distinct types (not implemented in PostgreSQL). To be future-proof, use the column `user_defined_type_category` to differentiate between these. Other user-defined types such as base types and enums, which are PostgreSQL extensions, are not shown here. For domains, see Section 36.23 instead.

Table 36.57. `user_defined_types` Columns

Name	Data Type	Description
<code>user_defined_type_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the type (always the current database)
<code>user_defined_type_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the type
<code>user_defined_type_name</code>	<code>sql_identifier</code>	Name of the type
<code>user_defined_type_category</code>	<code>character_data</code>	Currently always <code>STRUCTURED</code>
<code>is_instantiable</code>	<code>yes_or_no</code>	Applies to a feature not available in PostgreSQL
<code>is_final</code>	<code>yes_or_no</code>	Applies to a feature not available in PostgreSQL
<code>ordering_form</code>	<code>character_data</code>	Applies to a feature not available in PostgreSQL
<code>ordering_category</code>	<code>character_data</code>	Applies to a feature not available in PostgreSQL
<code>ordering_routine_catalog</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>ordering_routine_schema</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>ordering_routine_name</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>reference_type</code>	<code>character_data</code>	Applies to a feature not available in PostgreSQL
<code>data_type</code>	<code>character_data</code>	Applies to a feature not available in PostgreSQL
<code>character_maximum_length</code>	<code>cardinal_number</code>	Applies to a feature not available in PostgreSQL
<code>character_octet_length</code>	<code>cardinal_number</code>	Applies to a feature not available in PostgreSQL
<code>character_set_catalog</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>character_set_schema</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>character_set_name</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>collation_catalog</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL
<code>collation_schema</code>	<code>sql_identifier</code>	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
collation_name	sql_identifier	Applies to a feature not available in PostgreSQL
numeric_precision	cardinal_number	Applies to a feature not available in PostgreSQL
numeric_precision_radix	cardinal_number	Applies to a feature not available in PostgreSQL
numeric_scale	cardinal_number	Applies to a feature not available in PostgreSQL
datetime_precision	cardinal_number	Applies to a feature not available in PostgreSQL
interval_type	character_data	Applies to a feature not available in PostgreSQL
interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL
source_dtd_identifier	sql_identifier	Applies to a feature not available in PostgreSQL
ref_dtd_identifier	sql_identifier	Applies to a feature not available in PostgreSQL

36.60. user_mapping_options

The view `user_mapping_options` contains all the options defined for user mappings in the current database. Only those user mappings are shown where the current user has access to the corresponding foreign server (by way of being the owner or having some privilege).

Table 36.58. user_mapping_options Columns

Name	Data Type	Description
authorization_identifier	sql_identifier	Name of the user being mapped, or PUBLIC if the mapping is public
foreign_server_catalog	sql_identifier	Name of the database that the foreign server used by this mapping is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server used by this mapping
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option. This column will show as null unless the current user is the user being mapped, or the mapping is for PUBLIC and the current user is the server owner, or the current user is a superuser. The intent is to protect password information stored as user mapping option.

36.61. user_mappings

The view `user_mappings` contains all user mappings defined in the current database. Only those user mappings are shown where the current user has access to the corresponding foreign server (by way of being the owner or having some privilege).

Table 36.59. user_mappings Columns

Name	Data Type	Description
<code>authorization_identifier</code>	<code>sql_identifier</code>	Name of the user being mapped, or <code>PUBLIC</code> if the mapping is public
<code>foreign_server_catalog</code>	<code>sql_identifier</code>	Name of the database that the foreign server used by this mapping is defined in (always the current database)
<code>foreign_server_name</code>	<code>sql_identifier</code>	Name of the foreign server used by this mapping

36.62. view_column_usage

The view `view_column_usage` identifies all columns that are used in the query expression of a view (the `SELECT` statement that defines the view). A column is only included if the table that contains the column is owned by a currently enabled role.

Note

Columns of system tables are not included. This should be fixed sometime.

Table 36.60. view_column_usage Columns

Name	Data Type	Description
<code>view_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the view (always the current database)
<code>view_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the view
<code>view_name</code>	<code>sql_identifier</code>	Name of the view
<code>table_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the table that contains the column that is used by the view (always the current database)
<code>table_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the table that contains the column that is used by the view
<code>table_name</code>	<code>sql_identifier</code>	Name of the table that contains the column that is used by the view
<code>column_name</code>	<code>sql_identifier</code>	Name of the column that is used by the view

36.63. view_routine_usage

The view `view_routine_usage` identifies all routines (functions and procedures) that are used in the query expression of a view (the `SELECT` statement that defines the view). A routine is only included if that routine is owned by a currently enabled role.

Table 36.61. view_routine_usage Columns

Name	Data Type	Description
<code>table_catalog</code>	<code>sql_identifier</code>	Name of the database containing the view (always the current database)
<code>table_schema</code>	<code>sql_identifier</code>	Name of the schema containing the view
<code>table_name</code>	<code>sql_identifier</code>	Name of the view
<code>specific_catalog</code>	<code>sql_identifier</code>	Name of the database containing the function (always the current database)
<code>specific_schema</code>	<code>sql_identifier</code>	Name of the schema containing the function
<code>specific_name</code>	<code>sql_identifier</code>	The “specific name” of the function. See Section 36.41 for more information.

36.64. view_table_usage

The view `view_table_usage` identifies all tables that are used in the query expression of a view (the `SELECT` statement that defines the view). A table is only included if that table is owned by a currently enabled role.

Note

System tables are not included. This should be fixed sometime.

Table 36.62. view_table_usage Columns

Name	Data Type	Description
<code>view_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the view (always the current database)
<code>view_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the view
<code>view_name</code>	<code>sql_identifier</code>	Name of the view
<code>table_catalog</code>	<code>sql_identifier</code>	Name of the database that contains the table that is used by the view (always the current database)
<code>table_schema</code>	<code>sql_identifier</code>	Name of the schema that contains the table that is used by the view

Name	Data Type	Description
table_name	sql_identifier	Name of the table that is used by the view

36.65. views

The view `views` contains all views defined in the current database. Only those views are shown that the current user has access to (by way of being the owner or having some privilege).

Table 36.63. views Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the view (always the current database)
table_schema	sql_identifier	Name of the schema that contains the view
table_name	sql_identifier	Name of the view
view_definition	character_data	Query expression defining the view (null if the view is not owned by a currently enabled role)
check_option	character_data	CASCADED or LOCAL if the view has a CHECK OPTION defined on it, NONE if not
is_updatable	yes_or_no	YES if the view is updatable (allows UPDATE and DELETE), NO if not
is_insertable_into	yes_or_no	YES if the view is insertable into (allows INSERT), NO if not
is_trigger_updatable	yes_or_no	YES if the view has an INSTEAD OF UPDATE trigger defined on it, NO if not
is_trigger_deletable	yes_or_no	YES if the view has an INSTEAD OF DELETE trigger defined on it, NO if not
is_trigger_insertable_into	yes_or_no	YES if the view has an INSTEAD OF INSERT trigger defined on it, NO if not

Part V. Server Programming

This part is about extending the server functionality with user-defined functions, data types, triggers, etc. These are advanced topics which should probably be approached only after all the other user documentation about PostgreSQL has been understood. Later chapters in this part describe the server-side programming languages available in the PostgreSQL distribution as well as general issues concerning server-side programming languages. It is essential to read at least the earlier sections of Chapter 37 (covering functions) before diving into the material about server-side programming languages.

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Chapter 37. Extending SQL

In the sections that follow, we will discuss how you can extend the PostgreSQL SQL query language by adding:

- functions (starting in Section 37.3)
- aggregates (starting in Section 37.12)
- data types (starting in Section 37.13)
- operators (starting in Section 37.14)
- operator classes for indexes (starting in Section 37.16)
- packages of related objects (starting in Section 37.17)

37.1. How Extensibility Works

PostgreSQL is extensible because its operation is catalog-driven. If you are familiar with standard relational database systems, you know that they store information about databases, tables, columns, etc., in what are commonly known as system catalogs. (Some systems call this the data dictionary.) The catalogs appear to the user as tables like any other, but the DBMS stores its internal bookkeeping in them. One key difference between PostgreSQL and standard relational database systems is that PostgreSQL stores much more information in its catalogs: not only information about tables and columns, but also information about data types, functions, access methods, and so on. These tables can be modified by the user, and since PostgreSQL bases its operation on these tables, this means that PostgreSQL can be extended by users. By comparison, conventional database systems can only be extended by changing hardcoded procedures in the source code or by loading modules specially written by the DBMS vendor.

The PostgreSQL server can moreover incorporate user-written code into itself through dynamic loading. That is, the user can specify an object code file (e.g., a shared library) that implements a new type or function, and PostgreSQL will load it as required. Code written in SQL is even more trivial to add to the server. This ability to modify its operation “on the fly” makes PostgreSQL uniquely suited for rapid prototyping of new applications and storage structures.

37.2. The PostgreSQL Type System

PostgreSQL data types can be divided into base types, container types, domains, and pseudo-types.

37.2.1. Base Types

Base types are those, like `integer`, that are implemented below the level of the SQL language (typically in a low-level language such as C). They generally correspond to what are often known as abstract data types. PostgreSQL can only operate on such types through functions provided by the user and only understands the behavior of such types to the extent that the user describes them. The built-in base types are described in Chapter 8.

Enumerated (`enum`) types can be considered as a subcategory of base types. The main difference is that they can be created using just SQL commands, without any low-level programming. Refer to Section 8.7 for more information.

37.2.2. Container Types

PostgreSQL has three kinds of “container” types, which are types that contain multiple values of other types. These are arrays, composites, and ranges.

Arrays can hold multiple values that are all of the same type. An array type is automatically created for each base type, composite type, range type, and domain type. But there are no arrays of arrays. So

far as the type system is concerned, multi-dimensional arrays are the same as one-dimensional arrays. Refer to Section 8.15 for more information.

Composite types, or row types, are created whenever the user creates a table. It is also possible to use `CREATE TYPE` to define a “stand-alone” composite type with no associated table. A composite type is simply a list of types with associated field names. A value of a composite type is a row or record of field values. Refer to Section 8.16 for more information.

A range type can hold two values of the same type, which are the lower and upper bounds of the range. Range types are user-created, although a few built-in ones exist. Refer to Section 8.17 for more information.

37.2.3. Domains

A domain is based on a particular underlying type and for many purposes is interchangeable with its underlying type. However, a domain can have constraints that restrict its valid values to a subset of what the underlying type would allow. Domains are created using the SQL command `CREATE DOMAIN`. Refer to Section 8.18 for more information.

37.2.4. Pseudo-Types

There are a few “pseudo-types” for special purposes. Pseudo-types cannot appear as columns of tables or components of container types, but they can be used to declare the argument and result types of functions. This provides a mechanism within the type system to identify special classes of functions. Table 8.27 lists the existing pseudo-types.

37.2.5. Polymorphic Types

Five pseudo-types of special interest are `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`, which are collectively called *polymorphic types*. Any function declared using these types is said to be a *polymorphic function*. A polymorphic function can operate on many different data types, with the specific data type(s) being determined by the data types actually passed to it in a particular call.

Polymorphic arguments and results are tied to each other and are resolved to a specific data type when a query calling a polymorphic function is parsed. Each position (either argument or return value) declared as `anyelement` is allowed to have any specific actual data type, but in any given call they must all be the *same* actual type. Each position declared as `anyarray` can have any array data type, but similarly they must all be the same type. And similarly, positions declared as `anyrange` must all be the same range type. Furthermore, if there are positions declared `anyarray` and others declared `anyelement`, the actual array type in the `anyarray` positions must be an array whose elements are the same type appearing in the `anyelement` positions. Similarly, if there are positions declared `anyrange` and others declared `anyelement`, the actual range type in the `anyrange` positions must be a range whose subtype is the same type appearing in the `anyelement` positions. `anynonarray` is treated exactly the same as `anyelement`, but adds the additional constraint that the actual type must not be an array type. `anyenum` is treated exactly the same as `anyelement`, but adds the additional constraint that the actual type must be an enum type.

Thus, when more than one argument position is declared with a polymorphic type, the net effect is that only certain combinations of actual argument types are allowed. For example, a function declared as `equal(anyelement, anyelement)` will take any two input values, so long as they are of the same data type.

When the return value of a function is declared as a polymorphic type, there must be at least one argument position that is also polymorphic, and the actual data type supplied as the argument determines the actual result type for that call. For example, if there were not already an array subscripting mechanism, one could define a function that implements subscripting as `subscript(anyarray,`

`integer`) returns `anyelement`. This declaration constrains the actual first argument to be an array type, and allows the parser to infer the correct result type from the actual first argument's type. Another example is that a function declared as `f(anyarray) returns anyenum` will only accept arrays of enum types.

Note that `anynonarray` and `anyenum` do not represent separate type variables; they are the same type as `anyelement`, just with an additional constraint. For example, declaring a function as `f(anyelement, anyenum)` is equivalent to declaring it as `f(anyenum, anyenum)`: both actual arguments have to be the same enum type.

A variadic function (one taking a variable number of arguments, as in Section 37.5.5) can be polymorphic: this is accomplished by declaring its last parameter as `VARIADIC anyarray`. For purposes of argument matching and determining the actual result type, such a function behaves the same as if you had written the appropriate number of `anynonarray` parameters.

37.3. User-Defined Functions

PostgreSQL provides four kinds of functions:

- query language functions (functions written in SQL) (Section 37.5)
- procedural language functions (functions written in, for example, PL/pgSQL or PL/Tcl) (Section 37.8)
- internal functions (Section 37.9)
- C-language functions (Section 37.10)

Every kind of function can take base types, composite types, or combinations of these as arguments (parameters). In addition, every kind of function can return a base type or a composite type. Functions can also be defined to return sets of base or composite values.

Many kinds of functions can take or return certain pseudo-types (such as polymorphic types), but the available facilities vary. Consult the description of each kind of function for more details.

It's easiest to define SQL functions, so we'll start by discussing those. Most of the concepts presented for SQL functions will carry over to the other types of functions.

Throughout this chapter, it can be useful to look at the reference page of the `CREATE FUNCTION` command to understand the examples better. Some examples from this chapter can be found in `funcs.sql` and `funcs.c` in the `src/tutorial` directory in the PostgreSQL source distribution.

37.4. User-Defined Procedures

A procedure is a database object similar to a function. The difference is that a procedure does not return a value, so there is no return type declaration. While a function is called as part of a query or DML command, a procedure is called explicitly using the `CALL` statement.

The explanations on how to define user-defined functions in the rest of this chapter apply to procedures as well, except that the `CREATE PROCEDURE` command is used instead, there is no return type, and some other features such as strictness don't apply.

Collectively, functions and procedures are also known as *routines*. There are commands such as `ALTER ROUTINE` and `DROP ROUTINE` that can operate on functions and procedures without having to know which kind it is. Note, however, that there is no `CREATE ROUTINE` command.

37.5. Query Language (SQL) Functions

SQL functions execute an arbitrary list of SQL statements, returning the result of the last query in the list. In the simple (non-set) case, the first row of the last query's result will be returned. (Bear in mind that “the first row” of a multirow result is not well-defined unless you use `ORDER BY`.) If the last query happens to return no rows at all, the null value will be returned.

Alternatively, an SQL function can be declared to return a set (that is, multiple rows) by specifying the function's return type as `SETOF sometype`, or equivalently by declaring it as `RETURNS TABLE(columns)`. In this case all rows of the last query's result are returned. Further details appear below.

The body of an SQL function must be a list of SQL statements separated by semicolons. A semicolon after the last statement is optional. Unless the function is declared to return `void`, the last statement must be a `SELECT`, or an `INSERT`, `UPDATE`, or `DELETE` that has a `RETURNING` clause.

Any collection of commands in the SQL language can be packaged together and defined as a function. Besides `SELECT` queries, the commands can include data modification queries (`INSERT`, `UPDATE`, and `DELETE`), as well as other SQL commands. (You cannot use transaction control commands, e.g. `COMMIT`, `SAVEPOINT`, and some utility commands, e.g. `VACUUM`, in SQL functions.) However, the final command must be a `SELECT` or have a `RETURNING` clause that returns whatever is specified as the function's return type. Alternatively, if you want to define a SQL function that performs actions but has no useful value to return, you can define it as returning `void`. For example, this function removes rows with negative salaries from the `emp` table:

```
CREATE FUNCTION clean_emp() RETURNS void AS '
    DELETE FROM emp
        WHERE salary < 0;
' LANGUAGE SQL;

SELECT clean_emp();

clean_emp
-----

(1 row)
```

Note

The entire body of a SQL function is parsed before any of it is executed. While a SQL function can contain commands that alter the system catalogs (e.g., `CREATE TABLE`), the effects of such commands will not be visible during parse analysis of later commands in the function. Thus, for example, `CREATE TABLE foo (...); INSERT INTO foo VALUES (...);` will not work as desired if packaged up into a single SQL function, since `foo` won't exist yet when the `INSERT` command is parsed. It's recommended to use PL/pgSQL instead of a SQL function in this type of situation.

The syntax of the `CREATE FUNCTION` command requires the function body to be written as a string constant. It is usually most convenient to use dollar quoting (see Section 4.1.2.4) for the string constant. If you choose to use regular single-quoted string constant syntax, you must double single quote marks (`'`) and backslashes (`\`) (assuming escape string syntax) in the body of the function (see Section 4.1.2.1).

37.5.1. Arguments for SQL Functions

Arguments of a SQL function can be referenced in the function body using either names or numbers. Examples of both methods appear below.

To use a name, declare the function argument as having a name, and then just write that name in the function body. If the argument name is the same as any column name in the current SQL command within the function, the column name will take precedence. To override this, qualify the argument name with the name of the function itself, that is *function_name.argument_name*. (If this would conflict with a qualified column name, again the column name wins. You can avoid the ambiguity by choosing a different alias for the table within the SQL command.)

In the older numeric approach, arguments are referenced using the syntax *\$n*: *\$1* refers to the first input argument, *\$2* to the second, and so on. This will work whether or not the particular argument was declared with a name.

If an argument is of a composite type, then the dot notation, e.g., *argname.fieldname* or *\$1.fieldname*, can be used to access attributes of the argument. Again, you might need to qualify the argument's name with the function name to make the form with an argument name unambiguous.

SQL function arguments can only be used as data values, not as identifiers. Thus for example this is reasonable:

```
INSERT INTO mytable VALUES ($1);
```

but this will not work:

```
INSERT INTO $1 VALUES (42);
```

Note

The ability to use names to reference SQL function arguments was added in PostgreSQL 9.2. Functions to be used in older servers must use the *\$n* notation.

37.5.2. SQL Functions on Base Types

The simplest possible SQL function has no arguments and simply returns a base type, such as integer:

```
CREATE FUNCTION one() RETURNS integer AS $$
    SELECT 1 AS result;
$$ LANGUAGE SQL;
```

```
-- Alternative syntax for string literal:
CREATE FUNCTION one() RETURNS integer AS '
    SELECT 1 AS result;
' LANGUAGE SQL;
```

```
SELECT one();
```

```
one
-----
1
```

Notice that we defined a column alias within the function body for the result of the function (with the name *result*), but this column alias is not visible outside the function. Hence, the result is labeled *one* instead of *result*.

It is almost as easy to define SQL functions that take base types as arguments:

```
CREATE FUNCTION add_em(x integer, y integer) RETURNS integer AS $$
    SELECT x + y;
$$ LANGUAGE SQL;
```

```
SELECT add_em(1, 2) AS answer;
```

```
answer
-----
      3
```

Alternatively, we could dispense with names for the arguments and use numbers:

```
CREATE FUNCTION add_em(integer, integer) RETURNS integer AS $$
    SELECT $1 + $2;
$$ LANGUAGE SQL;
```

```
SELECT add_em(1, 2) AS answer;
```

```
answer
-----
      3
```

Here is a more useful function, which might be used to debit a bank account:

```
CREATE FUNCTION tf1 (accountno integer, debit numeric) RETURNS
numeric AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tf1.accountno;
    SELECT 1;
$$ LANGUAGE SQL;
```

A user could execute this function to debit account 17 by \$100.00 as follows:

```
SELECT tf1(17, 100.0);
```

In this example, we chose the name `accountno` for the first argument, but this is the same as the name of a column in the `bank` table. Within the `UPDATE` command, `accountno` refers to the column `bank.accountno`, so `tf1.accountno` must be used to refer to the argument. We could of course avoid this by using a different name for the argument.

In practice one would probably like a more useful result from the function than a constant 1, so a more likely definition is:

```
CREATE FUNCTION tf1 (accountno integer, debit numeric) RETURNS
numeric AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tf1.accountno;
    SELECT balance FROM bank WHERE accountno = tf1.accountno;
$$ LANGUAGE SQL;
```

which adjusts the balance and returns the new balance. The same thing could be done in one command using `RETURNING`:

```
CREATE FUNCTION tfl (accountno integer, debit numeric) RETURNS
numeric AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tfl.accountno
    RETURNING balance;
$$ LANGUAGE SQL;
```

A SQL function must return exactly its declared result type. This may require inserting an explicit cast. For example, suppose we wanted the previous `add_em` function to return type `float8` instead. This won't work:

```
CREATE FUNCTION add_em(integer, integer) RETURNS float8 AS $$
    SELECT $1 + $2;
$$ LANGUAGE SQL;
```

even though in other contexts PostgreSQL would be willing to insert an implicit cast to convert integer to `float8`. We need to write it as

```
CREATE FUNCTION add_em(integer, integer) RETURNS float8 AS $$
    SELECT ($1 + $2)::float8;
$$ LANGUAGE SQL;
```

37.5.3. SQL Functions on Composite Types

When writing functions with arguments of composite types, we must not only specify which argument we want but also the desired attribute (field) of that argument. For example, suppose that `emp` is a table containing employee data, and therefore also the name of the composite type of each row of the table. Here is a function `double_salary` that computes what someone's salary would be if it were doubled:

```
CREATE TABLE emp (
    name      text,
    salary    numeric,
    age       integer,
    cubicle   point
);

INSERT INTO emp VALUES ('Bill', 4200, 45, '(2,1)');

CREATE FUNCTION double_salary(emp) RETURNS numeric AS $$
    SELECT $1.salary * 2 AS salary;
$$ LANGUAGE SQL;
```

```
SELECT name, double_salary(emp.*) AS dream
FROM emp
WHERE emp.cubicle ~= point '(2,1)';
```

```
name | dream
-----+-----
Bill | 8400
```

Notice the use of the syntax `$1.salary` to select one field of the argument row value. Also notice how the calling `SELECT` command uses `table_name.*` to select the entire current row of a table as a composite value. The table row can alternatively be referenced using just the table name, like this:

```
SELECT name, double_salary(emp) AS dream
       FROM emp
       WHERE emp.cubicle ~= point '(2,1)';
```

but this usage is deprecated since it's easy to get confused. (See Section 8.16.5 for details about these two notations for the composite value of a table row.)

Sometimes it is handy to construct a composite argument value on-the-fly. This can be done with the ROW construct. For example, we could adjust the data being passed to the function:

```
SELECT name, double_salary(ROW(name, salary*1.1, age, cubicle)) AS
       dream
       FROM emp;
```

It is also possible to build a function that returns a composite type. This is an example of a function that returns a single emp row:

```
CREATE FUNCTION new_emp() RETURNS emp AS $$
       SELECT text 'None' AS name,
              1000.0 AS salary,
              25 AS age,
              point '(2,2)' AS cubicle;
$$ LANGUAGE SQL;
```

In this example we have specified each of the attributes with a constant value, but any computation could have been substituted for these constants.

Note two important things about defining the function:

- The select list order in the query must be exactly the same as that in which the columns appear in the table associated with the composite type. (Naming the columns, as we did above, is irrelevant to the system.)
- We must ensure each expression's type matches the corresponding column of the composite type, inserting a cast if necessary. Otherwise we'll get errors like this:

```
ERROR: function declared to return emp returns varchar instead
of text at column 1
```

As with the base-type case, the function will not insert any casts automatically.

A different way to define the same function is:

```
CREATE FUNCTION new_emp() RETURNS emp AS $$
       SELECT ROW('None', 1000.0, 25, '(2,2)')::emp;
$$ LANGUAGE SQL;
```

Here we wrote a SELECT that returns just a single column of the correct composite type. This isn't really better in this situation, but it is a handy alternative in some cases — for example, if we need to compute the result by calling another function that returns the desired composite value. Another example is that if we are trying to write a function that returns a domain over composite, rather than a plain composite type, it is always necessary to write it as returning a single column, since there is no other way to produce a value that is exactly of the domain type.

We could call this function directly either by using it in a value expression:

```
SELECT new_emp();

      new_emp
-----
(None,1000.0,25,"(2,2)")
```

or by calling it as a table function:

```
SELECT * FROM new_emp();

 name | salary | age | cubicle
-----+-----+----+-----
None  | 1000.0 |  25 | (2,2)
```

The second way is described more fully in Section 37.5.7.

When you use a function that returns a composite type, you might want only one field (attribute) from its result. You can do that with syntax like this:

```
SELECT (new_emp()).name;

 name
-----
None
```

The extra parentheses are needed to keep the parser from getting confused. If you try to do it without them, you get something like this:

```
SELECT new_emp().name;
ERROR:  syntax error at or near "."
LINE 1: SELECT new_emp().name;
                ^
```

Another option is to use functional notation for extracting an attribute:

```
SELECT name(new_emp());

 name
-----
None
```

As explained in Section 8.16.5, the field notation and functional notation are equivalent.

Another way to use a function returning a composite type is to pass the result to another function that accepts the correct row type as input:

```
CREATE FUNCTION getname(emp) RETURNS text AS $$
    SELECT $1.name;
$$ LANGUAGE SQL;

SELECT getname(new_emp());
```

```

getname
-----
None
(1 row)

```

37.5.4. SQL Functions with Output Parameters

An alternative way of describing a function's results is to define it with *output parameters*, as in this example:

```

CREATE FUNCTION add_em (IN x int, IN y int, OUT sum int)
AS 'SELECT x + y'
LANGUAGE SQL;

SELECT add_em(3,7);
 add_em
-----
      10
(1 row)

```

This is not essentially different from the version of `add_em` shown in Section 37.5.2. The real value of output parameters is that they provide a convenient way of defining functions that return several columns. For example,

```

CREATE FUNCTION sum_n_product (x int, y int, OUT sum int, OUT
 product int)
AS 'SELECT x + y, x * y'
LANGUAGE SQL;

SELECT * FROM sum_n_product(11,42);
 sum | product
-----+-----
   53 |    462
(1 row)

```

What has essentially happened here is that we have created an anonymous composite type for the result of the function. The above example has the same end result as

```

CREATE TYPE sum_prod AS (sum int, product int);

CREATE FUNCTION sum_n_product (int, int) RETURNS sum_prod
AS 'SELECT $1 + $2, $1 * $2'
LANGUAGE SQL;

```

but not having to bother with the separate composite type definition is often handy. Notice that the names attached to the output parameters are not just decoration, but determine the column names of the anonymous composite type. (If you omit a name for an output parameter, the system will choose a name on its own.)

Notice that output parameters are not included in the calling argument list when invoking such a function from SQL. This is because PostgreSQL considers only the input parameters to define the function's calling signature. That means also that only the input parameters matter when referencing the function for purposes such as dropping it. We could drop the above function with either of

```
DROP FUNCTION sum_n_product (x int, y int, OUT sum int, OUT product
int);
DROP FUNCTION sum_n_product (int, int);
```

Parameters can be marked as IN (the default), OUT, INOUT, or VARIADIC. An INOUT parameter serves as both an input parameter (part of the calling argument list) and an output parameter (part of the result record type). VARIADIC parameters are input parameters, but are treated specially as described next.

37.5.5. SQL Functions with Variable Numbers of Arguments

SQL functions can be declared to accept variable numbers of arguments, so long as all the “optional” arguments are of the same data type. The optional arguments will be passed to the function as an array. The function is declared by marking the last parameter as VARIADIC; this parameter must be declared as being of an array type. For example:

```
CREATE FUNCTION mleast(VARIADIC arr numeric[]) RETURNS numeric AS $
$
    SELECT min($1[i]) FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;

SELECT mleast(10, -1, 5, 4.4);
 mleast
-----
      -1
(1 row)
```

Effectively, all the actual arguments at or beyond the VARIADIC position are gathered up into a one-dimensional array, as if you had written

```
SELECT mleast(ARRAY[10, -1, 5, 4.4]);    -- doesn't work
```

You can't actually write that, though — or at least, it will not match this function definition. A parameter marked VARIADIC matches one or more occurrences of its element type, not of its own type.

Sometimes it is useful to be able to pass an already-constructed array to a variadic function; this is particularly handy when one variadic function wants to pass on its array parameter to another one. Also, this is the only secure way to call a variadic function found in a schema that permits untrusted users to create objects; see Section 10.3. You can do this by specifying VARIADIC in the call:

```
SELECT mleast(VARIADIC ARRAY[10, -1, 5, 4.4]);
```

This prevents expansion of the function's variadic parameter into its element type, thereby allowing the array argument value to match normally. VARIADIC can only be attached to the last actual argument of a function call.

Specifying VARIADIC in the call is also the only way to pass an empty array to a variadic function, for example:

```
SELECT mleast(VARIADIC ARRAY[]::numeric[]);
```

Simply writing `SELECT mleast()` does not work because a variadic parameter must match at least one actual argument. (You could define a second function also named `mleast`, with no parameters, if you wanted to allow such calls.)

The array element parameters generated from a variadic parameter are treated as not having any names of their own. This means it is not possible to call a variadic function using named arguments (Section 4.3), except when you specify VARIADIC. For example, this will work:

```
SELECT mleast(VARIADIC arr => ARRAY[10, -1, 5, 4.4]);
```

but not these:

```
SELECT mleast(arr => 10);
SELECT mleast(arr => ARRAY[10, -1, 5, 4.4]);
```

37.5.6. SQL Functions with Default Values for Arguments

Functions can be declared with default values for some or all input arguments. The default values are inserted whenever the function is called with insufficiently many actual arguments. Since arguments can only be omitted from the end of the actual argument list, all parameters after a parameter with a default value have to have default values as well. (Although the use of named argument notation could allow this restriction to be relaxed, it's still enforced so that positional argument notation works sensibly.) Whether or not you use it, this capability creates a need for precautions when calling functions in databases where some users mistrust other users; see Section 10.3.

For example:

```
CREATE FUNCTION foo(a int, b int DEFAULT 2, c int DEFAULT 3)
RETURNS int
LANGUAGE SQL
AS $$
    SELECT $1 + $2 + $3;
$$;
```

```
SELECT foo(10, 20, 30);
foo
-----
 60
(1 row)
```

```
SELECT foo(10, 20);
foo
-----
 33
(1 row)
```

```
SELECT foo(10);
foo
-----
 15
(1 row)
```

```
SELECT foo(); -- fails since there is no default for the first
argument
ERROR: function foo() does not exist
```

The = sign can also be used in place of the key word DEFAULT.

37.5.7. SQL Functions as Table Sources

All SQL functions can be used in the FROM clause of a query, but it is particularly useful for functions returning composite types. If the function is defined to return a base type, the table function produces a one-column table. If the function is defined to return a composite type, the table function produces a column for each attribute of the composite type.

Here is an example:

```
CREATE TABLE foo (fooid int, foosubid int, fooname text);
INSERT INTO foo VALUES (1, 1, 'Joe');
INSERT INTO foo VALUES (1, 2, 'Ed');
INSERT INTO foo VALUES (2, 1, 'Mary');
```

```
CREATE FUNCTION getfoo(int) RETURNS foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;
```

```
SELECT *, upper(fooname) FROM getfoo(1) AS t1;
```

```
 fooid | foosubid | fooname | upper
-----+-----+-----+-----
      1 |         1 | Joe     | JOE
(1 row)
```

As the example shows, we can work with the columns of the function's result just the same as if they were columns of a regular table.

Note that we only got one row out of the function. This is because we did not use SETOF. That is described in the next section.

37.5.8. SQL Functions Returning Sets

When an SQL function is declared as returning SETOF *sometype*, the function's final query is executed to completion, and each row it outputs is returned as an element of the result set.

This feature is normally used when calling the function in the FROM clause. In this case each row returned by the function becomes a row of the table seen by the query. For example, assume that table foo has the same contents as above, and we say:

```
CREATE FUNCTION getfoo(int) RETURNS SETOF foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;
```

```
SELECT * FROM getfoo(1) AS t1;
```

Then we would get:

```
 fooid | foosubid | fooname
-----+-----+-----
      1 |         1 | Joe
      1 |         2 | Ed
(2 rows)
```

It is also possible to return multiple rows with the columns defined by output parameters, like this:

```

CREATE TABLE tab (y int, z int);
INSERT INTO tab VALUES (1, 2), (3, 4), (5, 6), (7, 8);

CREATE FUNCTION sum_n_product_with_tab (x int, OUT sum int, OUT
  product int)
RETURNS SETOF record
AS $$
  SELECT $1 + tab.y, $1 * tab.y FROM tab;
$$ LANGUAGE SQL;

SELECT * FROM sum_n_product_with_tab(10);
  sum | product
-----+-----
   11 |      10
   13 |      30
   15 |      50
   17 |      70
(4 rows)

```

The key point here is that you must write `RETURNS SETOF record` to indicate that the function returns multiple rows instead of just one. If there is only one output parameter, write that parameter's type instead of `record`.

It is frequently useful to construct a query's result by invoking a set-returning function multiple times, with the parameters for each invocation coming from successive rows of a table or subquery. The preferred way to do this is to use the `LATERAL` key word, which is described in Section 7.2.1.5. Here is an example using a set-returning function to enumerate elements of a tree structure:

```

SELECT * FROM nodes;
  name      | parent
-----+-----
  Top       |
  Child1    | Top
  Child2    | Top
  Child3    | Top
  SubChild1 | Child1
  SubChild2 | Child1
(6 rows)

CREATE FUNCTION listchildren(text) RETURNS SETOF text AS $$
  SELECT name FROM nodes WHERE parent = $1
$$ LANGUAGE SQL STABLE;

SELECT * FROM listchildren('Top');
  listchildren
-----
  Child1
  Child2
  Child3
(3 rows)

SELECT name, child FROM nodes, LATERAL listchildren(name) AS child;
  name      | child
-----+-----
  Top       | Child1
  Top       | Child2
  Top       | Child3

```

```
Child1 | SubChild1
Child1 | SubChild2
(5 rows)
```

This example does not do anything that we couldn't have done with a simple join, but in more complex calculations the option to put some of the work into a function can be quite convenient.

Functions returning sets can also be called in the select list of a query. For each row that the query generates by itself, the set-returning function is invoked, and an output row is generated for each element of the function's result set. The previous example could also be done with queries like these:

```
SELECT listchildren('Top');
 listchildren
-----
Child1
Child2
Child3
(3 rows)
```

```
SELECT name, listchildren(name) FROM nodes;
 name | listchildren
-----+-----
Top   | Child1
Top   | Child2
Top   | Child3
Child1 | SubChild1
Child1 | SubChild2
(5 rows)
```

In the last SELECT, notice that no output row appears for Child2, Child3, etc. This happens because `listchildren` returns an empty set for those arguments, so no result rows are generated. This is the same behavior as we got from an inner join to the function result when using the LATERAL syntax.

PostgreSQL's behavior for a set-returning function in a query's select list is almost exactly the same as if the set-returning function had been written in a LATERAL FROM-clause item instead. For example,

```
SELECT x, generate_series(1,5) AS g FROM tab;
```

is almost equivalent to

```
SELECT x, g FROM tab, LATERAL generate_series(1,5) AS g;
```

It would be exactly the same, except that in this specific example, the planner could choose to put `g` on the outside of the nested-loop join, since `g` has no actual lateral dependency on `tab`. That would result in a different output row order. Set-returning functions in the select list are always evaluated as though they are on the inside of a nested-loop join with the rest of the FROM clause, so that the function(s) are run to completion before the next row from the FROM clause is considered.

If there is more than one set-returning function in the query's select list, the behavior is similar to what you get from putting the functions into a single LATERAL ROWS FROM(. . .) FROM-clause item. For each row from the underlying query, there is an output row using the first result from each function, then an output row using the second result, and so on. If some of the set-returning functions produce fewer outputs than others, null values are substituted for the missing data, so that the total number of rows emitted for one underlying row is the same as for the set-returning function that produced the most outputs. Thus the set-returning functions run “in lockstep” until they are all exhausted, and then execution continues with the next underlying row.

Set-returning functions can be nested in a select list, although that is not allowed in FROM-clause items. In such cases, each level of nesting is treated separately, as though it were a separate LATERAL ROWS FROM(. . .) item. For example, in

```
SELECT srf1(srf2(x), srf3(y)), srf4(srf5(z)) FROM tab;
```

the set-returning functions `srf2`, `srf3`, and `srf5` would be run in lockstep for each row of `tab`, and then `srf1` and `srf4` would be applied in lockstep to each row produced by the lower functions.

Set-returning functions cannot be used within conditional-evaluation constructs, such as CASE or COALESCE. For example, consider

```
SELECT x, CASE WHEN x > 0 THEN generate_series(1, 5) ELSE 0 END
FROM tab;
```

It might seem that this should produce five repetitions of input rows that have `x > 0`, and a single repetition of those that do not; but actually, because `generate_series(1, 5)` would be run in an implicit LATERAL FROM item before the CASE expression is ever evaluated, it would produce five repetitions of every input row. To reduce confusion, such cases produce a parse-time error instead.

Note

If a function's last command is INSERT, UPDATE, or DELETE with RETURNING, that command will always be executed to completion, even if the function is not declared with SETOF or the calling query does not fetch all the result rows. Any extra rows produced by the RETURNING clause are silently dropped, but the commanded table modifications still happen (and are all completed before returning from the function).

Note

Before PostgreSQL 10, putting more than one set-returning function in the same select list did not behave very sensibly unless they always produced equal numbers of rows. Otherwise, what you got was a number of output rows equal to the least common multiple of the numbers of rows produced by the set-returning functions. Also, nested set-returning functions did not work as described above; instead, a set-returning function could have at most one set-returning argument, and each nest of set-returning functions was run independently. Also, conditional execution (set-returning functions inside CASE etc) was previously allowed, complicating things even more. Use of the LATERAL syntax is recommended when writing queries that need to work in older PostgreSQL versions, because that will give consistent results across different versions. If you have a query that is relying on conditional execution of a set-returning function, you may be able to fix it by moving the conditional test into a custom set-returning function. For example,

```
SELECT x, CASE WHEN y > 0 THEN generate_series(1, z)
ELSE 5 END FROM tab;
```

could become

```
CREATE FUNCTION case_generate_series(cond bool, start
int, fin int, els int)
RETURNS SETOF int AS $$
```

```
BEGIN
  IF cond THEN
    RETURN QUERY SELECT generate_series(start, fin);
  ELSE
    RETURN QUERY SELECT els;
  END IF;
END$$ LANGUAGE plpgsql;

SELECT x, case_generate_series(y > 0, 1, z, 5) FROM tab;
```

This formulation will work the same in all versions of PostgreSQL.

37.5.9. SQL Functions Returning TABLE

There is another way to declare a function as returning a set, which is to use the syntax `RETURNS TABLE(columns)`. This is equivalent to using one or more `OUT` parameters plus marking the function as returning `SETOF record` (or `SETOF` a single output parameter's type, as appropriate). This notation is specified in recent versions of the SQL standard, and thus may be more portable than using `SETOF`.

For example, the preceding sum-and-product example could also be done this way:

```
CREATE FUNCTION sum_n_product_with_tab (x int)
RETURNS TABLE(sum int, product int) AS $$
  SELECT $1 + tab.y, $1 * tab.y FROM tab;
$$ LANGUAGE SQL;
```

It is not allowed to use explicit `OUT` or `INOUT` parameters with the `RETURNS TABLE` notation — you must put all the output columns in the `TABLE` list.

37.5.10. Polymorphic SQL Functions

SQL functions can be declared to accept and return the polymorphic types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`. See Section 37.2.5 for a more detailed explanation of polymorphic functions. Here is a polymorphic function `make_array` that builds up an array from two arbitrary data type elements:

```
CREATE FUNCTION make_array(anyelement, anyelement) RETURNS anyarray
AS $$
  SELECT ARRAY[$1, $2];
$$ LANGUAGE SQL;
```

```
SELECT make_array(1, 2) AS intarray, make_array('a'::text, 'b') AS
  textarray;
 intarray | textarray
-----+-----
 {1,2}   | {a,b}
(1 row)
```

Notice the use of the typecast `'a'::text` to specify that the argument is of type `text`. This is required if the argument is just a string literal, since otherwise it would be treated as type `unknown`, and array of `unknown` is not a valid type. Without the typecast, you will get errors like this:

ERROR: could not determine polymorphic type because input has type "unknown"

It is permitted to have polymorphic arguments with a fixed return type, but the converse is not. For example:

```
CREATE FUNCTION is_greater(anyelement, anyelement) RETURNS boolean
AS $$
    SELECT $1 > $2;
$$ LANGUAGE SQL;
```

```
SELECT is_greater(1, 2);
 is_greater
-----
         f
(1 row)
```

```
CREATE FUNCTION invalid_func() RETURNS anyelement AS $$
    SELECT 1;
$$ LANGUAGE SQL;
```

ERROR: cannot determine result data type
 DETAIL: A function returning a polymorphic type must have at least one polymorphic argument.

Polymorphism can be used with functions that have output arguments. For example:

```
CREATE FUNCTION dup (f1 anyelement, OUT f2 anyelement, OUT f3
anyarray)
AS 'select $1, array[$1,$1]' LANGUAGE SQL;
```

```
SELECT * FROM dup(22);
 f2 |   f3
-----+-----
 22 | {22,22}
(1 row)
```

Polymorphism can also be used with variadic functions. For example:

```
CREATE FUNCTION anyleast (VARIADIC anyarray) RETURNS anyelement AS
$$
    SELECT min($1[i]) FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;
```

```
SELECT anyleast(10, -1, 5, 4);
 anyleast
-----
        -1
(1 row)
```

```
SELECT anyleast('abc'::text, 'def');
 anyleast
-----
      abc
(1 row)
```

```
CREATE FUNCTION concat_values(text, VARIADIC anyarray) RETURNS text
AS $$
    SELECT array_to_string($2, $1);
$$ LANGUAGE SQL;

SELECT concat_values('|', 1, 4, 2);
concat_values
-----
1|4|2
(1 row)
```

37.5.11. SQL Functions with Collations

When a SQL function has one or more parameters of collatable data types, a collation is identified for each function call depending on the collations assigned to the actual arguments, as described in Section 23.2. If a collation is successfully identified (i.e., there are no conflicts of implicit collations among the arguments) then all the collatable parameters are treated as having that collation implicitly. This will affect the behavior of collation-sensitive operations within the function. For example, using the `anyleast` function described above, the result of

```
SELECT anyleast('abc'::text, 'ABC');
```

will depend on the database's default collation. In C locale the result will be ABC, but in many other locales it will be abc. The collation to use can be forced by adding a `COLLATE` clause to any of the arguments, for example

```
SELECT anyleast('abc'::text, 'ABC' COLLATE "C");
```

Alternatively, if you wish a function to operate with a particular collation regardless of what it is called with, insert `COLLATE` clauses as needed in the function definition. This version of `anyleast` would always use `en_US` locale to compare strings:

```
CREATE FUNCTION anyleast (VARIADIC anyarray) RETURNS anyelement AS
$$
    SELECT min($1[i] COLLATE "en_US") FROM generate_subscripts($1,
1) g(i);
$$ LANGUAGE SQL;
```

But note that this will throw an error if applied to a non-collatable data type.

If no common collation can be identified among the actual arguments, then a SQL function treats its parameters as having their data types' default collation (which is usually the database's default collation, but could be different for parameters of domain types).

The behavior of collatable parameters can be thought of as a limited form of polymorphism, applicable only to textual data types.

37.6. Function Overloading

More than one function can be defined with the same SQL name, so long as the arguments they take are different. In other words, function names can be *overloaded*. Whether or not you use it, this capability entails security precautions when calling functions in databases where some users mistrust other users; see Section 10.3. When a query is executed, the server will determine which function to call from the data types and the number of the provided arguments. Overloading can also be used to simulate functions with a variable number of arguments, up to a finite maximum number.

When creating a family of overloaded functions, one should be careful not to create ambiguities. For instance, given the functions:

```
CREATE FUNCTION test(int, real) RETURNS ...
CREATE FUNCTION test(smallint, double precision) RETURNS ...
```

it is not immediately clear which function would be called with some trivial input like `test(1, 1.5)`. The currently implemented resolution rules are described in Chapter 10, but it is unwise to design a system that subtly relies on this behavior.

A function that takes a single argument of a composite type should generally not have the same name as any attribute (field) of that type. Recall that `attribute(table)` is considered equivalent to `table.attribute`. In the case that there is an ambiguity between a function on a composite type and an attribute of the composite type, the attribute will always be used. It is possible to override that choice by schema-qualifying the function name (that is, `schema.func(table)`) but it's better to avoid the problem by not choosing conflicting names.

Another possible conflict is between variadic and non-variadic functions. For instance, it is possible to create both `foo(numeric)` and `foo(VARIADIC numeric[])`. In this case it is unclear which one should be matched to a call providing a single numeric argument, such as `foo(10.1)`. The rule is that the function appearing earlier in the search path is used, or if the two functions are in the same schema, the non-variadic one is preferred.

When overloading C-language functions, there is an additional constraint: The C name of each function in the family of overloaded functions must be different from the C names of all other functions, either internal or dynamically loaded. If this rule is violated, the behavior is not portable. You might get a run-time linker error, or one of the functions will get called (usually the internal one). The alternative form of the AS clause for the SQL `CREATE FUNCTION` command decouples the SQL function name from the function name in the C source code. For instance:

```
CREATE FUNCTION test(int) RETURNS int
  AS 'filename', 'test_larg'
  LANGUAGE C;
CREATE FUNCTION test(int, int) RETURNS int
  AS 'filename', 'test_2arg'
  LANGUAGE C;
```

The names of the C functions here reflect one of many possible conventions.

37.7. Function Volatility Categories

Every function has a *volatility* classification, with the possibilities being `VOLATILE`, `STABLE`, or `IMMUTABLE`. `VOLATILE` is the default if the `CREATE FUNCTION` command does not specify a category. The volatility category is a promise to the optimizer about the behavior of the function:

- A `VOLATILE` function can do anything, including modifying the database. It can return different results on successive calls with the same arguments. The optimizer makes no assumptions about the behavior of such functions. A query using a volatile function will re-evaluate the function at every row where its value is needed.
- A `STABLE` function cannot modify the database and is guaranteed to return the same results given the same arguments for all rows within a single statement. This category allows the optimizer to optimize multiple calls of the function to a single call. In particular, it is safe to use an expression containing such a function in an index scan condition. (Since an index scan will evaluate the comparison value only once, not once at each row, it is not valid to use a `VOLATILE` function in an index scan condition.)

- An `IMMUTABLE` function cannot modify the database and is guaranteed to return the same results given the same arguments forever. This category allows the optimizer to pre-evaluate the function when a query calls it with constant arguments. For example, a query like `SELECT ... WHERE x = 2 + 2` can be simplified on sight to `SELECT ... WHERE x = 4`, because the function underlying the integer addition operator is marked `IMMUTABLE`.

For best optimization results, you should label your functions with the strictest volatility category that is valid for them.

Any function with side-effects *must* be labeled `VOLATILE`, so that calls to it cannot be optimized away. Even a function with no side-effects needs to be labeled `VOLATILE` if its value can change within a single query; some examples are `random()`, `currval()`, `timeofday()`.

Another important example is that the `current_timestamp` family of functions qualify as `STABLE`, since their values do not change within a transaction.

There is relatively little difference between `STABLE` and `IMMUTABLE` categories when considering simple interactive queries that are planned and immediately executed: it doesn't matter a lot whether a function is executed once during planning or once during query execution startup. But there is a big difference if the plan is saved and reused later. Labeling a function `IMMUTABLE` when it really isn't might allow it to be prematurely folded to a constant during planning, resulting in a stale value being re-used during subsequent uses of the plan. This is a hazard when using prepared statements or when using function languages that cache plans (such as PL/pgSQL).

For functions written in SQL or in any of the standard procedural languages, there is a second important property determined by the volatility category, namely the visibility of any data changes that have been made by the SQL command that is calling the function. A `VOLATILE` function will see such changes, a `STABLE` or `IMMUTABLE` function will not. This behavior is implemented using the snapshotting behavior of MVCC (see Chapter 13): `STABLE` and `IMMUTABLE` functions use a snapshot established as of the start of the calling query, whereas `VOLATILE` functions obtain a fresh snapshot at the start of each query they execute.

Note

Functions written in C can manage snapshots however they want, but it's usually a good idea to make C functions work this way too.

Because of this snapshotting behavior, a function containing only `SELECT` commands can safely be marked `STABLE`, even if it selects from tables that might be undergoing modifications by concurrent queries. PostgreSQL will execute all commands of a `STABLE` function using the snapshot established for the calling query, and so it will see a fixed view of the database throughout that query.

The same snapshotting behavior is used for `SELECT` commands within `IMMUTABLE` functions. It is generally unwise to select from database tables within an `IMMUTABLE` function at all, since the immutability will be broken if the table contents ever change. However, PostgreSQL does not enforce that you do not do that.

A common error is to label a function `IMMUTABLE` when its results depend on a configuration parameter. For example, a function that manipulates timestamps might well have results that depend on the `TimeZone` setting. For safety, such functions should be labeled `STABLE` instead.

Note

PostgreSQL requires that `STABLE` and `IMMUTABLE` functions contain no SQL commands other than `SELECT` to prevent data modification. (This is not a completely bulletproof test, since such functions could still call `VOLATILE` functions that modify the database. If you do that, you will find that the `STABLE` or `IMMUTABLE` function does

not notice the database changes applied by the called function, since they are hidden from its snapshot.)

37.8. Procedural Language Functions

PostgreSQL allows user-defined functions to be written in other languages besides SQL and C. These other languages are generically called *procedural languages* (PLs). Procedural languages aren't built into the PostgreSQL server; they are offered by loadable modules. See Chapter 41 and following chapters for more information.

37.9. Internal Functions

Internal functions are functions written in C that have been statically linked into the PostgreSQL server. The “body” of the function definition specifies the C-language name of the function, which need not be the same as the name being declared for SQL use. (For reasons of backward compatibility, an empty body is accepted as meaning that the C-language function name is the same as the SQL name.)

Normally, all internal functions present in the server are declared during the initialization of the database cluster (see Section 18.2), but a user could use `CREATE FUNCTION` to create additional alias names for an internal function. Internal functions are declared in `CREATE FUNCTION` with language name `internal`. For instance, to create an alias for the `sqrt` function:

```
CREATE FUNCTION square_root(double precision) RETURNS double
precision
AS 'dsqrt'
LANGUAGE internal
STRICT;
```

(Most internal functions expect to be declared “strict”).

Note

Not all “predefined” functions are “internal” in the above sense. Some predefined functions are written in SQL.

37.10. C-Language Functions

User-defined functions can be written in C (or a language that can be made compatible with C, such as C++). Such functions are compiled into dynamically loadable objects (also called shared libraries) and are loaded by the server on demand. The dynamic loading feature is what distinguishes “C language” functions from “internal” functions — the actual coding conventions are essentially the same for both. (Hence, the standard internal function library is a rich source of coding examples for user-defined C functions.)

Currently only one calling convention is used for C functions (“version 1”). Support for that calling convention is indicated by writing a `PG_FUNCTION_INFO_V1 ()` macro call for the function, as illustrated below.

37.10.1. Dynamic Loading

The first time a user-defined function in a particular loadable object file is called in a session, the dynamic loader loads that object file into memory so that the function can be called. The `CREATE`

FUNCTION for a user-defined C function must therefore specify two pieces of information for the function: the name of the loadable object file, and the C name (link symbol) of the specific function to call within that object file. If the C name is not explicitly specified then it is assumed to be the same as the SQL function name.

The following algorithm is used to locate the shared object file based on the name given in the CREATE FUNCTION command:

1. If the name is an absolute path, the given file is loaded.
2. If the name starts with the string `$libdir`, that part is replaced by the PostgreSQL package library directory name, which is determined at build time.
3. If the name does not contain a directory part, the file is searched for in the path specified by the configuration variable `dynamic_library_path`.
4. Otherwise (the file was not found in the path, or it contains a non-absolute directory part), the dynamic loader will try to take the name as given, which will most likely fail. (It is unreliable to depend on the current working directory.)

If this sequence does not work, the platform-specific shared library file name extension (often `.so`) is appended to the given name and this sequence is tried again. If that fails as well, the load will fail.

It is recommended to locate shared libraries either relative to `$libdir` or through the dynamic library path. This simplifies version upgrades if the new installation is at a different location. The actual directory that `$libdir` stands for can be found out with the command `pg_config --pkglibdir`.

The user ID the PostgreSQL server runs as must be able to traverse the path to the file you intend to load. Making the file or a higher-level directory not readable and/or not executable by the postgres user is a common mistake.

In any case, the file name that is given in the CREATE FUNCTION command is recorded literally in the system catalogs, so if the file needs to be loaded again the same procedure is applied.

Note

PostgreSQL will not compile a C function automatically. The object file must be compiled before it is referenced in a CREATE FUNCTION command. See Section 37.10.5 for additional information.

To ensure that a dynamically loaded object file is not loaded into an incompatible server, PostgreSQL checks that the file contains a “magic block” with the appropriate contents. This allows the server to detect obvious incompatibilities, such as code compiled for a different major version of PostgreSQL. To include a magic block, write this in one (and only one) of the module source files, after having included the header `fmgr.h`:

```
PG_MODULE_MAGIC;
```

After it is used for the first time, a dynamically loaded object file is retained in memory. Future calls in the same session to the function(s) in that file will only incur the small overhead of a symbol table lookup. If you need to force a reload of an object file, for example after recompiling it, begin a fresh session.

Optionally, a dynamically loaded file can contain initialization and finalization functions. If the file includes a function named `_PG_init`, that function will be called immediately after loading the file. The function receives no parameters and should return void. If the file includes a function named

`_PG_fini`, that function will be called immediately before unloading the file. Likewise, the function receives no parameters and should return void. Note that `_PG_fini` will only be called during an unload of the file, not during process termination. (Presently, unloads are disabled and will never occur, but this may change in the future.)

37.10.2. Base Types in C-Language Functions

To know how to write C-language functions, you need to know how PostgreSQL internally represents base data types and how they can be passed to and from functions. Internally, PostgreSQL regards a base type as a “blob of memory”. The user-defined functions that you define over a type in turn define the way that PostgreSQL can operate on it. That is, PostgreSQL will only store and retrieve the data from disk and use your user-defined functions to input, process, and output the data.

Base types can have one of three internal formats:

- pass by value, fixed-length
- pass by reference, fixed-length
- pass by reference, variable-length

By-value types can only be 1, 2, or 4 bytes in length (also 8 bytes, if `sizeof(Datum)` is 8 on your machine). You should be careful to define your types such that they will be the same size (in bytes) on all architectures. For example, the `long` type is dangerous because it is 4 bytes on some machines and 8 bytes on others, whereas `int` type is 4 bytes on most Unix machines. A reasonable implementation of the `int4` type on Unix machines might be:

```
/* 4-byte integer, passed by value */
typedef int int4;
```

(The actual PostgreSQL C code calls this type `int32`, because it is a convention in C that `intXX` means *XX bits*. Note therefore also that the C type `int8` is 1 byte in size. The SQL type `int8` is called `int64` in C. See also Table 37.1.)

On the other hand, fixed-length types of any size can be passed by-reference. For example, here is a sample implementation of a PostgreSQL type:

```
/* 16-byte structure, passed by reference */
typedef struct
{
    double x, y;
} Point;
```

Only pointers to such types can be used when passing them in and out of PostgreSQL functions. To return a value of such a type, allocate the right amount of memory with `palloc`, fill in the allocated memory, and return a pointer to it. (Also, if you just want to return the same value as one of your input arguments that's of the same data type, you can skip the extra `palloc` and just return the pointer to the input value.)

Finally, all variable-length types must also be passed by reference. All variable-length types must begin with an opaque length field of exactly 4 bytes, which will be set by `SET_VARSIZE`; never set this field directly! All data to be stored within that type must be located in the memory immediately following that length field. The length field contains the total length of the structure, that is, it includes the size of the length field itself.

Another important point is to avoid leaving any uninitialized bits within data type values; for example, take care to zero out any alignment padding bytes that might be present in structs. Without this,

logically-equivalent constants of your data type might be seen as unequal by the planner, leading to inefficient (though not incorrect) plans.

Warning

Never modify the contents of a pass-by-reference input value. If you do so you are likely to corrupt on-disk data, since the pointer you are given might point directly into a disk buffer. The sole exception to this rule is explained in Section 37.12.

As an example, we can define the type `text` as follows:

```
typedef struct {
    int32 length;
    char data[FLEXIBLE_ARRAY_MEMBER];
} text;
```

The `[FLEXIBLE_ARRAY_MEMBER]` notation means that the actual length of the data part is not specified by this declaration.

When manipulating variable-length types, we must be careful to allocate the correct amount of memory and set the length field correctly. For example, if we wanted to store 40 bytes in a `text` structure, we might use a code fragment like this:

```
#include "postgres.h"
...
char buffer[40]; /* our source data */
...
text *destination = (text *) palloc(VARHDRSZ + 40);
SET_VARSIZE(destination, VARHDRSZ + 40);
memcpy(destination->data, buffer, 40);
...

```

`VARHDRSZ` is the same as `sizeof(int32)`, but it's considered good style to use the macro `VARHDRSZ` to refer to the size of the overhead for a variable-length type. Also, the length field *must* be set using the `SET_VARSIZE` macro, not by simple assignment.

Table 37.1 specifies which C type corresponds to which SQL type when writing a C-language function that uses a built-in type of PostgreSQL. The “Defined In” column gives the header file that needs to be included to get the type definition. (The actual definition might be in a different file that is included by the listed file. It is recommended that users stick to the defined interface.) Note that you should always include `postgres.h` first in any source file, because it declares a number of things that you will need anyway.

Table 37.1. Equivalent C Types for Built-in SQL Types

SQL Type	C Type	Defined In
boolean	bool	postgres.h (maybe compiler built-in)
box	BOX*	utils/geo_decls.h
bytea	bytea*	postgres.h
"char"	char	(compiler built-in)

SQL Type	C Type	Defined In
character	BpChar*	postgres.h
cid	CommandId	postgres.h
date	DateADT	utils/date.h
smallint (int2)	int16	postgres.h
int2vector	int2vector*	postgres.h
integer (int4)	int32	postgres.h
real (float4)	float4*	postgres.h
double precision (float8)	float8*	postgres.h
interval	Interval*	datatype/timestamp.h
lseg	LSEG*	utils/geo_decls.h
name	Name	postgres.h
oid	Oid	postgres.h
oidvector	oidvector*	postgres.h
path	PATH*	utils/geo_decls.h
point	POINT*	utils/geo_decls.h
regproc	regproc	postgres.h
text	text*	postgres.h
tid	ItemPointer	storage/itemptr.h
time	TimeADT	utils/date.h
time with time zone	TimeTzADT	utils/date.h
timestamp	Timestamp*	datatype/timestamp.h
varchar	VarChar*	postgres.h
xid	TransactionId	postgres.h

Now that we've gone over all of the possible structures for base types, we can show some examples of real functions.

37.10.3. Version 1 Calling Conventions

The version-1 calling convention relies on macros to suppress most of the complexity of passing arguments and results. The C declaration of a version-1 function is always:

```
Datum funcname(PG_FUNCTION_ARGS)
```

In addition, the macro call:

```
PG_FUNCTION_INFO_V1(funcname);
```

must appear in the same source file. (Conventionally, it's written just before the function itself.) This macro call is not needed for internal-language functions, since PostgreSQL assumes that all internal functions use the version-1 convention. It is, however, required for dynamically-loaded functions.

In a version-1 function, each actual argument is fetched using a `PG_GETARG_xxx()` macro that corresponds to the argument's data type. In non-strict functions there needs to be a previous check about argument null-ness using `PG_ARGNULL_xxx()`. The result is returned using a `PG_RETURN_xxx()` macro for the return type. `PG_GETARG_xxx()` takes as its argument the number of the function

argument to fetch, where the count starts at 0. `PG_RETURN_xxx()` takes as its argument the actual value to return.

Here are some examples using the version-1 calling convention:

```
#include "postgres.h"
#include <string.h>
#include "fmgr.h"
#include "utils/geo_decls.h"

PG_MODULE_MAGIC;

/* by value */

PG_FUNCTION_INFO_V1(add_one);

Datum
add_one(PG_FUNCTION_ARGS)
{
    int32    arg = PG_GETARG_INT32(0);

    PG_RETURN_INT32(arg + 1);
}

/* by reference, fixed length */

PG_FUNCTION_INFO_V1(add_one_float8);

Datum
add_one_float8(PG_FUNCTION_ARGS)
{
    /* The macros for FLOAT8 hide its pass-by-reference nature. */
    float8   arg = PG_GETARG_FLOAT8(0);

    PG_RETURN_FLOAT8(arg + 1.0);
}

PG_FUNCTION_INFO_V1(makepoint);

Datum
makepoint(PG_FUNCTION_ARGS)
{
    /* Here, the pass-by-reference nature of Point is not hidden.
    */
    Point    *pointx = PG_GETARG_POINT_P(0);
    Point    *pointy = PG_GETARG_POINT_P(1);
    Point    *new_point = (Point *) palloc(sizeof(Point));

    new_point->x = pointx->x;
    new_point->y = pointy->y;

    PG_RETURN_POINT_P(new_point);
}

/* by reference, variable length */

PG_FUNCTION_INFO_V1(copytext);
```

```

Datum
copytext(PG_FUNCTION_ARGS)
{
    text      *t = PG_GETARG_TEXT_PP(0);

    /*
     * VARSIZE_ANY_EXHDR is the size of the struct in bytes, minus
     the
     * VARHDRSZ or VARHDRSZ_SHORT of its header. Construct the
     copy with a
     * full-length header.
     */
    text      *new_t = (text *) palloc(VARSIZE_ANY_EXHDR(t) +
VARHDRSZ);
    SET_VARSIZE(new_t, VARSIZE_ANY_EXHDR(t) + VARHDRSZ);

    /*
     * VARDATA is a pointer to the data region of the new struct.
     The source
     * could be a short datum, so retrieve its data through
     VARDATA_ANY.
     */
    memcpy((void *) VARDATA(new_t), /* destination */
           (void *) VARDATA_ANY(t), /* source */
           VARSIZE_ANY_EXHDR(t)); /* how many bytes */
    PG_RETURN_TEXT_P(new_t);
}

PG_FUNCTION_INFO_V1(concat_text);

```

```

Datum
concat_text(PG_FUNCTION_ARGS)
{
    text  *arg1 = PG_GETARG_TEXT_PP(0);
    text  *arg2 = PG_GETARG_TEXT_PP(1);
    int32 arg1_size = VARSIZE_ANY_EXHDR(arg1);
    int32 arg2_size = VARSIZE_ANY_EXHDR(arg2);
    int32 new_text_size = arg1_size + arg2_size + VARHDRSZ;
    text *new_text = (text *) palloc(new_text_size);

    SET_VARSIZE(new_text, new_text_size);
    memcpy(VARDATA(new_text), VARDATA_ANY(arg1), arg1_size);
    memcpy(VARDATA(new_text) + arg1_size, VARDATA_ANY(arg2),
arg2_size);
    PG_RETURN_TEXT_P(new_text);
}

```

Supposing that the above code has been prepared in file `funcs.c` and compiled into a shared object, we could define the functions to PostgreSQL with commands like this:

```

CREATE FUNCTION add_one(integer) RETURNS integer
    AS 'DIRECTORY/funcs', 'add_one'
    LANGUAGE C STRICT;

-- note overloading of SQL function name "add_one"

```

```

CREATE FUNCTION add_one(double precision) RETURNS double precision
    AS 'DIRECTORY/funcs', 'add_one_float8'
    LANGUAGE C STRICT;

CREATE FUNCTION makepoint(point, point) RETURNS point
    AS 'DIRECTORY/funcs', 'makepoint'
    LANGUAGE C STRICT;

CREATE FUNCTION copytext(text) RETURNS text
    AS 'DIRECTORY/funcs', 'copytext'
    LANGUAGE C STRICT;

CREATE FUNCTION concat_text(text, text) RETURNS text
    AS 'DIRECTORY/funcs', 'concat_text'
    LANGUAGE C STRICT;

```

Here, *DIRECTORY* stands for the directory of the shared library file (for instance the PostgreSQL tutorial directory, which contains the code for the examples used in this section). (Better style would be to use just 'funcs' in the AS clause, after having added *DIRECTORY* to the search path. In any case, we can omit the system-specific extension for a shared library, commonly .so.)

Notice that we have specified the functions as “strict”, meaning that the system should automatically assume a null result if any input value is null. By doing this, we avoid having to check for null inputs in the function code. Without this, we'd have to check for null values explicitly, using `PG_ARGISNULL()`.

At first glance, the version-1 coding conventions might appear to be just pointless obscurantism, over using plain C calling conventions. They do however allow to deal with NULLable arguments/return values, and “toasted” (compressed or out-of-line) values.

The macro `PG_ARGISNULL(n)` allows a function to test whether each input is null. (Of course, doing this is only necessary in functions not declared “strict”.) As with the `PG_GETARG_xxx()` macros, the input arguments are counted beginning at zero. Note that one should refrain from executing `PG_GETARG_xxx()` until one has verified that the argument isn't null. To return a null result, execute `PG_RETURN_NULL()`; this works in both strict and nonstrict functions.

Other options provided by the version-1 interface are two variants of the `PG_GETARG_xxx()` macros. The first of these, `PG_GETARG_xxx_COPY()`, guarantees to return a copy of the specified argument that is safe for writing into. (The normal macros will sometimes return a pointer to a value that is physically stored in a table, which must not be written to. Using the `PG_GETARG_xxx_COPY()` macros guarantees a writable result.) The second variant consists of the `PG_GETARG_xxx_SLICE()` macros which take three arguments. The first is the number of the function argument (as above). The second and third are the offset and length of the segment to be returned. Offsets are counted from zero, and a negative length requests that the remainder of the value be returned. These macros provide more efficient access to parts of large values in the case where they have storage type “external”. (The storage type of a column can be specified using `ALTER TABLE tablename ALTER COLUMN colname SET STORAGE storagetype.storagetype` is one of plain, external, extended, or main.)

Finally, the version-1 function call conventions make it possible to return set results (Section 37.10.8) and implement trigger functions (Chapter 38) and procedural-language call handlers (Chapter 55). For more details see `src/backend/utils/fmgr/README` in the source distribution.

37.10.4. Writing Code

Before we turn to the more advanced topics, we should discuss some coding rules for PostgreSQL C-language functions. While it might be possible to load functions written in languages other than C into PostgreSQL, this is usually difficult (when it is possible at all) because other languages, such as C++,

FORTRAN, or Pascal often do not follow the same calling convention as C. That is, other languages do not pass argument and return values between functions in the same way. For this reason, we will assume that your C-language functions are actually written in C.

The basic rules for writing and building C functions are as follows:

- Use `pg_config --includedir-server` to find out where the PostgreSQL server header files are installed on your system (or the system that your users will be running on).
- Compiling and linking your code so that it can be dynamically loaded into PostgreSQL always requires special flags. See Section 37.10.5 for a detailed explanation of how to do it for your particular operating system.
- Remember to define a “magic block” for your shared library, as described in Section 37.10.1.
- When allocating memory, use the PostgreSQL functions `palloc` and `pfree` instead of the corresponding C library functions `malloc` and `free`. The memory allocated by `palloc` will be freed automatically at the end of each transaction, preventing memory leaks.
- Always zero the bytes of your structures using `memset` (or allocate them with `palloc0` in the first place). Even if you assign to each field of your structure, there might be alignment padding (holes in the structure) that contain garbage values. Without this, it's difficult to support hash indexes or hash joins, as you must pick out only the significant bits of your data structure to compute a hash. The planner also sometimes relies on comparing constants via bitwise equality, so you can get undesirable planning results if logically-equivalent values aren't bitwise equal.
- Most of the internal PostgreSQL types are declared in `postgres.h`, while the function manager interfaces (`PG_FUNCTION_ARGS`, etc.) are in `fmgr.h`, so you will need to include at least these two files. For portability reasons it's best to include `postgres.h` first, before any other system or user header files. Including `postgres.h` will also include `elog.h` and `palloc.h` for you.
- Symbol names defined within object files must not conflict with each other or with symbols defined in the PostgreSQL server executable. You will have to rename your functions or variables if you get error messages to this effect.

37.10.5. Compiling and Linking Dynamically-Loaded Functions

Before you are able to use your PostgreSQL extension functions written in C, they must be compiled and linked in a special way to produce a file that can be dynamically loaded by the server. To be precise, a *shared library* needs to be created.

For information beyond what is contained in this section you should read the documentation of your operating system, in particular the manual pages for the C compiler, `cc`, and the link editor, `ld`. In addition, the PostgreSQL source code contains several working examples in the `contrib` directory. If you rely on these examples you will make your modules dependent on the availability of the PostgreSQL source code, however.

Creating shared libraries is generally analogous to linking executables: first the source files are compiled into object files, then the object files are linked together. The object files need to be created as *position-independent code* (PIC), which conceptually means that they can be placed at an arbitrary location in memory when they are loaded by the executable. (Object files intended for executables are usually not compiled that way.) The command to link a shared library contains special flags to distinguish it from linking an executable (at least in theory — on some systems the practice is much uglier).

In the following examples we assume that your source code is in a file `f00.c` and we will create a shared library `f00.so`. The intermediate object file will be called `f00.o` unless otherwise noted. A shared library can contain more than one object file, but we only use one here.

FreeBSD

The compiler flag to create PIC is `-fPIC`. To create shared libraries the compiler flag is `-shared`.

```
gcc -fPIC -c foo.c
gcc -shared -o foo.so foo.o
```

This is applicable as of version 3.0 of FreeBSD.

HP-UX

The compiler flag of the system compiler to create PIC is `+z`. When using GCC it's `-fPIC`. The linker flag for shared libraries is `-b`. So:

```
cc +z -c foo.c

or:

gcc -fPIC -c foo.c
```

and then:

```
ld -b -o foo.sl foo.o
```

HP-UX uses the extension `.sl` for shared libraries, unlike most other systems.

Linux

The compiler flag to create PIC is `-fPIC`. The compiler flag to create a shared library is `-shared`. A complete example looks like this:

```
cc -fPIC -c foo.c
cc -shared -o foo.so foo.o
```

macOS

Here is an example. It assumes the developer tools are installed.

```
cc -c foo.c
cc -bundle -flat_namespace -undefined suppress -o foo.so foo.o
```

NetBSD

The compiler flag to create PIC is `-fPIC`. For ELF systems, the compiler with the flag `-shared` is used to link shared libraries. On the older non-ELF systems, `ld -Bshareable` is used.

```
gcc -fPIC -c foo.c
gcc -shared -o foo.so foo.o
```

OpenBSD

The compiler flag to create PIC is `-fPIC`. `ld -Bshareable` is used to link shared libraries.

```
gcc -fPIC -c foo.c
ld -Bshareable -o foo.so foo.o
```

Solaris

The compiler flag to create PIC is `-KPIC` with the Sun compiler and `-fPIC` with GCC. To link shared libraries, the compiler option is `-G` with either compiler or alternatively `-shared` with GCC.

```
cc -KPIC -c foo.c
cc -G -o foo.so foo.o
```

or

```
gcc -fPIC -c foo.c
gcc -G -o foo.so foo.o
```

Tip

If this is too complicated for you, you should consider using GNU Libtool¹, which hides the platform differences behind a uniform interface.

The resulting shared library file can then be loaded into PostgreSQL. When specifying the file name to the `CREATE FUNCTION` command, one must give it the name of the shared library file, not the intermediate object file. Note that the system's standard shared-library extension (usually `.so` or `.sl`) can be omitted from the `CREATE FUNCTION` command, and normally should be omitted for best portability.

Refer back to Section 37.10.1 about where the server expects to find the shared library files.

37.10.6. Composite-Type Arguments

Composite types do not have a fixed layout like C structures. Instances of a composite type can contain null fields. In addition, composite types that are part of an inheritance hierarchy can have different fields than other members of the same inheritance hierarchy. Therefore, PostgreSQL provides a function interface for accessing fields of composite types from C.

Suppose we want to write a function to answer the query:

```
SELECT name, c_overpaid(emp, 1500) AS overpaid
FROM emp
WHERE name = 'Bill' OR name = 'Sam';
```

Using the version-1 calling conventions, we can define `c_overpaid` as:

```
#include "postgres.h"
#include "executor/executor.h" /* for GetAttributeByName() */

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(c_overpaid);

Datum
c_overpaid(PG_FUNCTION_ARGS)
{
```

¹ <http://www.gnu.org/software/libtool/>

```

HeapTupleHeader t = PG_GETARG_HEAPTUPLEHEADER(0);
int32          limit = PG_GETARG_INT32(1);
bool isnull;
Datum salary;

salary = GetAttributeByName(t, "salary", &isnull);
if (isnull)
    PG_RETURN_BOOL(false);
/* Alternatively, we might prefer to do PG_RETURN_NULL() for
null salary. */

PG_RETURN_BOOL(DatumGetInt32(salary) > limit);
}

```

`GetAttributeByName` is the PostgreSQL system function that returns attributes out of the specified row. It has three arguments: the argument of type `HeapTupleHeader` passed into the function, the name of the desired attribute, and a return parameter that tells whether the attribute is null. `GetAttributeByName` returns a `Datum` value that you can convert to the proper data type by using the appropriate `DatumGetXXX()` macro. Note that the return value is meaningless if the null flag is set; always check the null flag before trying to do anything with the result.

There is also `GetAttributeByNum`, which selects the target attribute by column number instead of name.

The following command declares the function `c_overpaid` in SQL:

```

CREATE FUNCTION c_overpaid(emp, integer) RETURNS boolean
AS 'DIRECTORY/funcs', 'c_overpaid'
LANGUAGE C STRICT;

```

Notice we have used `STRICT` so that we did not have to check whether the input arguments were `NULL`.

37.10.7. Returning Rows (Composite Types)

To return a row or composite-type value from a C-language function, you can use a special API that provides macros and functions to hide most of the complexity of building composite data types. To use this API, the source file must include:

```
#include "funcapi.h"
```

There are two ways you can build a composite data value (henceforth a “tuple”): you can build it from an array of `Datum` values, or from an array of C strings that can be passed to the input conversion functions of the tuple's column data types. In either case, you first need to obtain or construct a `TupleDesc` descriptor for the tuple structure. When working with `Datums`, you pass the `TupleDesc` to `BlessTupleDesc`, and then call `heap_form_tuple` for each row. When working with C strings, you pass the `TupleDesc` to `TupleDescGetAttInMetadata`, and then call `BuildTupleFromCStrings` for each row. In the case of a function returning a set of tuples, the setup steps can all be done once during the first call of the function.

Several helper functions are available for setting up the needed `TupleDesc`. The recommended way to do this in most functions returning composite values is to call:

```

TypeFuncClass get_call_result_type(FunctionCallInfo fcinfo,
                                  Oid *resultTypeId,
                                  TupleDesc *resultTupleDesc)

```

passing the same `fcinfo` struct passed to the calling function itself. (This of course requires that you use the version-1 calling conventions.) `resultTypeId` can be specified as `NULL` or as the address of a local variable to receive the function's result type OID. `resultTupleDesc` should be the address of a local `TupleDesc` variable. Check that the result is `TYPEFUNC_COMPOSITE`; if so, `resultTupleDesc` has been filled with the needed `TupleDesc`. (If it is not, you can report an error along the lines of “function returning record called in context that cannot accept type record”.)

Tip

`get_call_result_type` can resolve the actual type of a polymorphic function result; so it is useful in functions that return scalar polymorphic results, not only functions that return composites. The `resultTypeId` output is primarily useful for functions returning polymorphic scalars.

Note

`get_call_result_type` has a sibling `get_expr_result_type`, which can be used to resolve the expected output type for a function call represented by an expression tree. This can be used when trying to determine the result type from outside the function itself. There is also `get_func_result_type`, which can be used when only the function's OID is available. However these functions are not able to deal with functions declared to return `record`, and `get_func_result_type` cannot resolve polymorphic types, so you should preferentially use `get_call_result_type`.

Older, now-deprecated functions for obtaining `TupleDesc`s are:

```
TupleDesc RelationNameGetTupleDesc(const char *relname)
```

to get a `TupleDesc` for the row type of a named relation, and:

```
TupleDesc TypeGetTupleDesc(Oid typeoid, List *colaliases)
```

to get a `TupleDesc` based on a type OID. This can be used to get a `TupleDesc` for a base or composite type. It will not work for a function that returns `record`, however, and it cannot resolve polymorphic types.

Once you have a `TupleDesc`, call:

```
TupleDesc BlessTupleDesc(TupleDesc tupdesc)
```

if you plan to work with `Datums`, or:

```
AttInMetadata *TupleDescGetAttInMetadata(TupleDesc tupdesc)
```

if you plan to work with C strings. If you are writing a function returning set, you can save the results of these functions in the `FuncCallContext` structure — use the `tuple_desc` or `attinmeta` field respectively.

When working with `Datums`, use:

```
HeapTuple heap_form_tuple(TupleDesc tupdesc, Datum *values, bool
    *isnull)
```

to build a `HeapTuple` given user data in `Datum` form.

When working with C strings, use:

```
HeapTuple BuildTupleFromCStrings(AttInMetadata *attinmeta, char
**values)
```

to build a `HeapTuple` given user data in C string form. *values* is an array of C strings, one for each attribute of the return row. Each C string should be in the form expected by the input function of the attribute data type. In order to return a null value for one of the attributes, the corresponding pointer in the *values* array should be set to `NULL`. This function will need to be called again for each row you return.

Once you have built a tuple to return from your function, it must be converted into a `Datum`. Use:

```
HeapTupleGetDatum(HeapTuple tuple)
```

to convert a `HeapTuple` into a valid `Datum`. This `Datum` can be returned directly if you intend to return just a single row, or it can be used as the current return value in a set-returning function.

An example appears in the next section.

37.10.8. Returning Sets

There is also a special API that provides support for returning sets (multiple rows) from a C-language function. A set-returning function must follow the version-1 calling conventions. Also, source files must include `funcapi.h`, as above.

A set-returning function (SRF) is called once for each item it returns. The SRF must therefore save enough state to remember what it was doing and return the next item on each call. The structure `FuncCallContext` is provided to help control this process. Within a function, `fcinfo->flinfo->fn_extra` is used to hold a pointer to `FuncCallContext` across calls.

```
typedef struct FuncCallContext
{
    /*
     * Number of times we've been called before
     *
     * call_cntr is initialized to 0 for you by
     SRF_FIRSTCALL_INIT(), and
     * incremented for you every time SRF_RETURN_NEXT() is called.
     */
    uint64 call_cntr;

    /*
     * OPTIONAL maximum number of calls
     *
     * max_calls is here for convenience only and setting it is
     optional.
     * If not set, you must provide alternative means to know when
     the
     * function is done.
     */
    uint64 max_calls;

    /*
     * OPTIONAL pointer to miscellaneous user-provided context
     information
     */
}
```

```

*
* user_fctx is for use as a pointer to your own data to retain
* arbitrary context information between calls of your
function.
*/
void *user_fctx;

/*
* OPTIONAL pointer to struct containing attribute type input
metadata
*
* attinmeta is for use when returning tuples (i.e., composite
data types)
* and is not used when returning base data types. It is only
needed
* if you intend to use BuildTupleFromCStrings() to create the
return
* tuple.
*/
AttInMetadata *attinmeta;

/*
* memory context used for structures that must live for
multiple calls
*
* multi_call_memory_ctx is set by SRF_FIRSTCALL_INIT() for
you, and used
* by SRF_RETURN_DONE() for cleanup. It is the most appropriate
memory
* context for any memory that is to be reused across multiple
calls
* of the SRF.
*/
MemoryContext multi_call_memory_ctx;

/*
* OPTIONAL pointer to struct containing tuple description
*
* tuple_desc is for use when returning tuples (i.e., composite
data types)
* and is only needed if you are going to build the tuples with
* heap_form_tuple() rather than with BuildTupleFromCStrings().
Note that
* the TupleDesc pointer stored here should usually have been
run through
* BlessTupleDesc() first.
*/
TupleDesc tuple_desc;
} FuncCallContext;

```

An SRF uses several functions and macros that automatically manipulate the FuncCallContext structure (and expect to find it via `fn_extra`). Use:

`SRF_IS_FIRSTCALL()`

to determine if your function is being called for the first or a subsequent time. On the first call (only) use:

`SRF_FIRSTCALL_INIT()`

to initialize the `FuncCallContext`. On every function call, including the first, use:

`SRF_PERCALL_SETUP()`

to properly set up for using the `FuncCallContext` and clearing any previously returned data left over from the previous pass.

If your function has data to return, use:

`SRF_RETURN_NEXT(funcctx, result)`

to return it to the caller. (`result` must be of type `Datum`, either a single value or a tuple prepared as described above.) Finally, when your function is finished returning data, use:

`SRF_RETURN_DONE(funcctx)`

to clean up and end the SRF.

The memory context that is current when the SRF is called is a transient context that will be cleared between calls. This means that you do not need to call `pfree` on everything you allocated using `malloc`; it will go away anyway. However, if you want to allocate any data structures to live across calls, you need to put them somewhere else. The memory context referenced by `multi_call_memory_ctx` is a suitable location for any data that needs to survive until the SRF is finished running. In most cases, this means that you should switch into `multi_call_memory_ctx` while doing the first-call setup.

Warning

While the actual arguments to the function remain unchanged between calls, if you detoast the argument values (which is normally done transparently by the `PG_GETARG_xxx` macro) in the transient context then the detoasted copies will be freed on each cycle. Accordingly, if you keep references to such values in your `user_fctx`, you must either copy them into the `multi_call_memory_ctx` after detoasting, or ensure that you detoast the values only in that context.

A complete pseudo-code example looks like the following:

```
Datum
my_set_returning_function(PG_FUNCTION_ARGS)
{
    FuncCallContext *funcctx;
    Datum          result;
    further declarations as needed

    if (SRF_IS_FIRSTCALL())
    {
        MemoryContext oldcontext;

        funcctx = SRF_FIRSTCALL_INIT();
        oldcontext = MemoryContextSwitchTo(funcctx->multi_call_memory_ctx);
```

```

        /* One-time setup code appears here: */
        user code
        if returning composite
            build TupleDesc, and perhaps AttInMetadata
        endif returning composite
        user code
        MemoryContextSwitchTo(oldcontext);
    }

    /* Each-time setup code appears here: */
    user code
    funcctx = SRF_PERCALL_SETUP();
    user code

    /* this is just one way we might test whether we are done: */
    if (funcctx->call_cntr < funcctx->max_calls)
    {
        /* Here we want to return another item: */
        user code
        obtain result Datum
        SRF_RETURN_NEXT(funcctx, result);
    }
    else
    {
        /* Here we are done returning items and just need to clean
up: */
        user code
        SRF_RETURN_DONE(funcctx);
    }
}

```

A complete example of a simple SRF returning a composite type looks like:

```

PG_FUNCTION_INFO_V1(retcomposite);

Datum
retcomposite(PG_FUNCTION_ARGS)
{
    FuncCallContext    *funcctx;
    int                 call_cntr;
    int                 max_calls;
    TupleDesc           tupdesc;
    AttInMetadata       *attinmeta;

    /* stuff done only on the first call of the function */
    if (SRF_IS_FIRSTCALL())
    {
        MemoryContext    oldcontext;

        /* create a function context for cross-call persistence */
        funcctx = SRF_FIRSTCALL_INIT();

        /* switch to memory context appropriate for multiple
function calls */
        oldcontext = MemoryContextSwitchTo(funcctx-
>multi_call_memory_ctx);
    }
}

```

```

/* total number of tuples to be returned */
funcctx->max_calls = PG_GETARG_UINT32(0);

/* Build a tuple descriptor for our result type */
if (get_call_result_type(fcinfo, NULL, &tupdesc) !=
TYPEFUNC_COMPOSITE)
ereport(ERROR,
        (errcode(ERRCODE_FEATURE_NOT_SUPPORTED),
         errmsg("function returning record called in
context "
                "that cannot accept type record")));

/*
 * generate attribute metadata needed later to produce
tuples from raw
 * C strings
 */
attinmeta = TupleDescGetAttInMetadata(tupdesc);
funcctx->attinmeta = attinmeta;

MemoryContextSwitchTo(oldcontext);
}

/* stuff done on every call of the function */
funcctx = SRF_PERCALL_SETUP();

call_cntr = funcctx->call_cntr;
max_calls = funcctx->max_calls;
attinmeta = funcctx->attinmeta;

if (call_cntr < max_calls) /* do when there is more left to
send */
{
    char        **values;
    HeapTuple   tuple;
    Datum       result;

    /*
     * Prepare a values array for building the returned tuple.
     * This should be an array of C strings which will
     * be processed later by the type input functions.
     */
    values = (char **) palloc(3 * sizeof(char *));
    values[0] = (char *) palloc(16 * sizeof(char));
    values[1] = (char *) palloc(16 * sizeof(char));
    values[2] = (char *) palloc(16 * sizeof(char));

    snprintf(values[0], 16, "%d", 1 * PG_GETARG_INT32(1));
    snprintf(values[1], 16, "%d", 2 * PG_GETARG_INT32(1));
    snprintf(values[2], 16, "%d", 3 * PG_GETARG_INT32(1));

    /* build a tuple */
    tuple = BuildTupleFromCStrings(attinmeta, values);

    /* make the tuple into a datum */
    result = HeapTupleGetDatum(tuple);

    /* clean up (this is not really necessary) */

```

```

        pfree(values[0]);
        pfree(values[1]);
        pfree(values[2]);
        pfree(values);

        SRF_RETURN_NEXT(funcctx, result);
    }
    else /* do when there is no more left */
    {
        SRF_RETURN_DONE(funcctx);
    }
}

```

One way to declare this function in SQL is:

```

CREATE TYPE __retcomposite AS (f1 integer, f2 integer, f3 integer);

CREATE OR REPLACE FUNCTION retcomposite(integer, integer)
    RETURNS SETOF __retcomposite
    AS 'filename', 'retcomposite'
    LANGUAGE C IMMUTABLE STRICT;

```

A different way is to use OUT parameters:

```

CREATE OR REPLACE FUNCTION retcomposite(IN integer, IN integer,
    OUT f1 integer, OUT f2 integer, OUT f3 integer)
    RETURNS SETOF record
    AS 'filename', 'retcomposite'
    LANGUAGE C IMMUTABLE STRICT;

```

Notice that in this method the output type of the function is formally an anonymous record type.

The directory contrib/tablefunc module in the source distribution contains more examples of set-returning functions.

37.10.9. Polymorphic Arguments and Return Types

C-language functions can be declared to accept and return the polymorphic types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`. See Section 37.2.5 for a more detailed explanation of polymorphic functions. When function arguments or return types are defined as polymorphic types, the function author cannot know in advance what data type it will be called with, or need to return. There are two routines provided in `fmgr.h` to allow a version-1 C function to discover the actual data types of its arguments and the type it is expected to return. The routines are called `get_fn_expr_rettype(FmgrInfo *flinfo)` and `get_fn_expr_argtype(FmgrInfo *flinfo, int argnum)`. They return the result or argument type OID, or `InvalidOid` if the information is not available. The structure `flinfo` is normally accessed as `fcinfo->flinfo`. The parameter `argnum` is zero based. `get_call_result_type` can also be used as an alternative to `get_fn_expr_rettype`. There is also `get_fn_expr_variadic`, which can be used to find out whether variadic arguments have been merged into an array. This is primarily useful for `VARIADIC "any"` functions, since such merging will always have occurred for variadic functions taking ordinary array types.

For example, suppose we want to write a function to accept a single element of any type, and return a one-dimensional array of that type:

```

PG_FUNCTION_INFO_V1(make_array);
Datum
make_array(PG_FUNCTION_ARGS)
{
    ArrayType *result;
    Oid        element_type = get_fn_expr_argtype(fcinfo->flinfo,
0);
    Datum      element;
    bool        isnull;
    int16       typlen;
    bool        typbyval;
    char        typalign;
    int         ndims;
    int         dims[MAXDIM];
    int         lbs[MAXDIM];

    if (!OidIsValid(element_type))
        elog(ERROR, "could not determine data type of input");

    /* get the provided element, being careful in case it's NULL */
    isnull = PG_ARGISNULL(0);
    if (isnull)
        element = (Datum) 0;
    else
        element = PG_GETARG_DATUM(0);

    /* we have one dimension */
    ndims = 1;
    /* and one element */
    dims[0] = 1;
    /* and lower bound is 1 */
    lbs[0] = 1;

    /* get required info about the element type */
    get_typlenbyvalalign(element_type, &typlen, &typbyval,
&typalign);

    /* now build the array */
    result = construct_md_array(&element, &isnull, ndims, dims,
lbs,
                                element_type, typlen, typbyval,
typalign);

    PG_RETURN_ARRAYTYPE_P(result);
}

```

The following command declares the function `make_array` in SQL:

```

CREATE FUNCTION make_array(anyelement) RETURNS anyarray
AS 'DIRECTORY/funcs', 'make_array'
LANGUAGE C IMMUTABLE;

```

There is a variant of polymorphism that is only available to C-language functions: they can be declared to take parameters of type "any". (Note that this type name must be double-quoted, since it's also a SQL reserved word.) This works like `anyelement` except that it does not constrain different "any" arguments to be the same type, nor do they help determine the function's result type. A C-language function can also declare its final parameter to be `VARIADIC "any"`. This will match one or more actual arguments of any type (not necessarily the same type). These arguments will *not* be gathered into

an array as happens with normal variadic functions; they will just be passed to the function separately. The `PG_NARGS()` macro and the methods described above must be used to determine the number of actual arguments and their types when using this feature. Also, users of such a function might wish to use the `VARIADIC` keyword in their function call, with the expectation that the function would treat the array elements as separate arguments. The function itself must implement that behavior if wanted, after using `get_fn_expr_variadic` to detect that the actual argument was marked with `VARIADIC`.

37.10.10. Shared Memory and LWLocks

Add-ins can reserve LWLocks and an allocation of shared memory on server startup. The add-in's shared library must be preloaded by specifying it in `shared_preload_libraries`. Shared memory is reserved by calling:

```
void RequestAddinShmemSpace(int size)
```

from your `_PG_init` function.

LWLocks are reserved by calling:

```
void RequestNamedLWLockTranche(const char *tranche_name, int
    num_lwlocks)
```

from `_PG_init`. This will ensure that an array of `num_lwlocks` LWLocks is available under the name `tranche_name`. Use `GetNamedLWLockTranche` to get a pointer to this array.

To avoid possible race-conditions, each backend should use the LWLock `AddinShmemInitLock` when connecting to and initializing its allocation of shared memory, as shown here:

```
static mystruct *ptr = NULL;

if (!ptr)
{
    bool    found;

    LWLockAcquire(AddinShmemInitLock, LW_EXCLUSIVE);
    ptr = ShmemInitStruct("my struct name", size, &found);
    if (!found)
    {
        initialize contents of shmem area;
        acquire any requested LWLocks using:
        ptr->locks = GetNamedLWLockTranche("my tranche
name");
    }
    LWLockRelease(AddinShmemInitLock);
}
```

37.10.11. Using C++ for Extensibility

Although the PostgreSQL backend is written in C, it is possible to write extensions in C++ if these guidelines are followed:

- All functions accessed by the backend must present a C interface to the backend; these C functions can then call C++ functions. For example, `extern C` linkage is required for backend-accessed functions. This is also necessary for any functions that are passed as pointers between the backend and C++ code.

- Free memory using the appropriate deallocation method. For example, most backend memory is allocated using `palloc()`, so use `pfree()` to free it. Using C++ `delete` in such cases will fail.
- Prevent exceptions from propagating into the C code (use a catch-all block at the top level of all `extern C` functions). This is necessary even if the C++ code does not explicitly throw any exceptions, because events like out-of-memory can still throw exceptions. Any exceptions must be caught and appropriate errors passed back to the C interface. If possible, compile C++ with `-fno-exceptions` to eliminate exceptions entirely; in such cases, you must check for failures in your C++ code, e.g. check for NULL returned by `new()`.
- If calling backend functions from C++ code, be sure that the C++ call stack contains only plain old data structures (POD). This is necessary because backend errors generate a distant `longjmp()` that does not properly unroll a C++ call stack with non-POD objects.

In summary, it is best to place C++ code behind a wall of `extern C` functions that interface to the backend, and avoid exception, memory, and call stack leakage.

37.11. Function Optimization Information

By default, a function is just a “black box” that the database system knows very little about the behavior of. However, that means that queries using the function may be executed much less efficiently than they could be. It is possible to supply additional knowledge that helps the planner optimize function calls.

Some basic facts can be supplied by declarative annotations provided in the `CREATE FUNCTION` command. Most important of these is the function's volatility category (`IMMUTABLE`, `STABLE`, or `VOLATILE`); one should always be careful to specify this correctly when defining a function. The parallel safety property (`PARALLEL UNSAFE`, `PARALLEL RESTRICTED`, or `PARALLEL SAFE`) must also be specified if you hope to use the function in parallelized queries. It can also be useful to specify the function's estimated execution cost, and/or the number of rows a set-returning function is estimated to return. However, the declarative way of specifying those two facts only allows specifying a constant value, which is often inadequate.

It is also possible to attach a *planner support function* to a SQL-callable function (called its *target function*), and thereby provide knowledge about the target function that is too complex to be represented declaratively. Planner support functions have to be written in C (although their target functions might not be), so this is an advanced feature that relatively few people will use.

A planner support function must have the SQL signature

```
supportfn(internal) returns internal
```

It is attached to its target function by specifying the `SUPPORT` clause when creating the target function.

The details of the API for planner support functions can be found in file `src/include/nodes/supportnodes.h` in the PostgreSQL source code. Here we provide just an overview of what planner support functions can do. The set of possible requests to a support function is extensible, so more things might be possible in future versions.

Some function calls can be simplified during planning based on properties specific to the function. For example, `int4mul(n, 1)` could be simplified to just `n`. This type of transformation can be performed by a planner support function, by having it implement the `SupportRequestSimplify` request type. The support function will be called for each instance of its target function found in a query parse tree. If it finds that the particular call can be simplified into some other form, it can build and return a parse tree representing that expression. This will automatically work for operators based on the function, too — in the example just given, `n * 1` would also be simplified to `n`. (But note that this is just an example; this particular optimization is not actually performed by standard PostgreSQL.)

We make no guarantee that PostgreSQL will never call the target function in cases that the support function could simplify. Ensure rigorous equivalence between the simplified expression and an actual execution of the target function.

For target functions that return `boolean`, it is often useful to estimate the fraction of rows that will be selected by a `WHERE` clause using that function. This can be done by a support function that implements the `SupportRequestSelectivity` request type.

If the target function's run time is highly dependent on its inputs, it may be useful to provide a non-constant cost estimate for it. This can be done by a support function that implements the `SupportRequestCost` request type.

For target functions that return sets, it is often useful to provide a non-constant estimate for the number of rows that will be returned. This can be done by a support function that implements the `SupportRequestRows` request type.

For target functions that return `boolean`, it may be possible to convert a function call appearing in `WHERE` into an indexable operator clause or clauses. The converted clauses might be exactly equivalent to the function's condition, or they could be somewhat weaker (that is, they might accept some values that the function condition does not). In the latter case the index condition is said to be *lossy*; it can still be used to scan an index, but the function call will have to be executed for each row returned by the index to see if it really passes the `WHERE` condition or not. To create such conditions, the support function must implement the `SupportRequestIndexCondition` request type.

37.12. User-Defined Aggregates

Aggregate functions in PostgreSQL are defined in terms of *state values* and *state transition functions*. That is, an aggregate operates using a state value that is updated as each successive input row is processed. To define a new aggregate function, one selects a data type for the state value, an initial value for the state, and a state transition function. The state transition function takes the previous state value and the aggregate's input value(s) for the current row, and returns a new state value. A *final function* can also be specified, in case the desired result of the aggregate is different from the data that needs to be kept in the running state value. The final function takes the ending state value and returns whatever is wanted as the aggregate result. In principle, the transition and final functions are just ordinary functions that could also be used outside the context of the aggregate. (In practice, it's often helpful for performance reasons to create specialized transition functions that can only work when called as part of an aggregate.)

Thus, in addition to the argument and result data types seen by a user of the aggregate, there is an internal state-value data type that might be different from both the argument and result types.

If we define an aggregate that does not use a final function, we have an aggregate that computes a running function of the column values from each row. `sum` is an example of this kind of aggregate. `sum` starts at zero and always adds the current row's value to its running total. For example, if we want to make a `sum` aggregate to work on a data type for complex numbers, we only need the addition function for that data type. The aggregate definition would be:

```
CREATE AGGREGATE sum (complex)
(
    sfunc = complex_add,
    stype = complex,
    initcond = '(0,0)'
);
```

which we might use like this:

```
SELECT sum(a) FROM test_complex;

      sum
-----
(34,53.9)
```

(Notice that we are relying on function overloading: there is more than one aggregate named `sum`, but PostgreSQL can figure out which kind of `sum` applies to a column of type `complex`.)

The above definition of `sum` will return zero (the initial state value) if there are no nonnull input values. Perhaps we want to return null in that case instead — the SQL standard expects `sum` to behave that way. We can do this simply by omitting the `initcond` phrase, so that the initial state value is null. Ordinarily this would mean that the `sfunc` would need to check for a null state-value input. But for `sum` and some other simple aggregates like `max` and `min`, it is sufficient to insert the first nonnull input value into the state variable and then start applying the transition function at the second nonnull input value. PostgreSQL will do that automatically if the initial state value is null and the transition function is marked “strict” (i.e., not to be called for null inputs).

Another bit of default behavior for a “strict” transition function is that the previous state value is retained unchanged whenever a null input value is encountered. Thus, null values are ignored. If you need some other behavior for null inputs, do not declare your transition function as strict; instead code it to test for null inputs and do whatever is needed.

`avg` (average) is a more complex example of an aggregate. It requires two pieces of running state: the sum of the inputs and the count of the number of inputs. The final result is obtained by dividing these quantities. Average is typically implemented by using an array as the state value. For example, the built-in implementation of `avg(float8)` looks like:

```
CREATE AGGREGATE avg (float8)
(
    sfunc = float8_accum,
    stype = float8[],
    finalfunc = float8_avg,
    initcond = '{0,0,0}'
);
```

Note

`float8_accum` requires a three-element array, not just two elements, because it accumulates the sum of squares as well as the sum and count of the inputs. This is so that it can be used for some other aggregates as well as `avg`.

Aggregate function calls in SQL allow `DISTINCT` and `ORDER BY` options that control which rows are fed to the aggregate's transition function and in what order. These options are implemented behind the scenes and are not the concern of the aggregate's support functions.

For further details see the `CREATE AGGREGATE` command.

37.12.1. Moving-Aggregate Mode

Aggregate functions can optionally support *moving-aggregate mode*, which allows substantially faster execution of aggregate functions within windows with moving frame starting points. (See Section 3.5 and Section 4.2.8 for information about use of aggregate functions as window functions.) The basic idea is that in addition to a normal “forward” transition function, the aggregate provides an *inverse transition function*, which allows rows to be removed from the aggregate's running state value when

they exit the window frame. For example a sum aggregate, which uses addition as the forward transition function, would use subtraction as the inverse transition function. Without an inverse transition function, the window function mechanism must recalculate the aggregate from scratch each time the frame starting point moves, resulting in run time proportional to the number of input rows times the average frame length. With an inverse transition function, the run time is only proportional to the number of input rows.

The inverse transition function is passed the current state value and the aggregate input value(s) for the earliest row included in the current state. It must reconstruct what the state value would have been if the given input row had never been aggregated, but only the rows following it. This sometimes requires that the forward transition function keep more state than is needed for plain aggregation mode. Therefore, the moving-aggregate mode uses a completely separate implementation from the plain mode: it has its own state data type, its own forward transition function, and its own final function if needed. These can be the same as the plain mode's data type and functions, if there is no need for extra state.

As an example, we could extend the sum aggregate given above to support moving-aggregate mode like this:

```
CREATE AGGREGATE sum (complex)
(
    sfunc = complex_add,
    stype = complex,
    initcond = '(0,0)',
    msfunc = complex_add,
    minvfunc = complex_sub,
    mstype = complex,
    minitcond = '(0,0)'
);
```

The parameters whose names begin with `m` define the moving-aggregate implementation. Except for the inverse transition function `minvfunc`, they correspond to the plain-aggregate parameters without `m`.

The forward transition function for moving-aggregate mode is not allowed to return null as the new state value. If the inverse transition function returns null, this is taken as an indication that the inverse function cannot reverse the state calculation for this particular input, and so the aggregate calculation will be redone from scratch for the current frame starting position. This convention allows moving-aggregate mode to be used in situations where there are some infrequent cases that are impractical to reverse out of the running state value. The inverse transition function can “punt” on these cases, and yet still come out ahead so long as it can work for most cases. As an example, an aggregate working with floating-point numbers might choose to punt when a NaN (not a number) input has to be removed from the running state value.

When writing moving-aggregate support functions, it is important to be sure that the inverse transition function can reconstruct the correct state value exactly. Otherwise there might be user-visible differences in results depending on whether the moving-aggregate mode is used. An example of an aggregate for which adding an inverse transition function seems easy at first, yet where this requirement cannot be met is `sum` over `float4` or `float8` inputs. A naive declaration of `sum(float8)` could be

```
CREATE AGGREGATE unsafe_sum (float8)
(
    stype = float8,
    sfunc = float8pl,
    mstype = float8,
    msfunc = float8pl,
    minvfunc = float8mi
```

```
);
```

This aggregate, however, can give wildly different results than it would have without the inverse transition function. For example, consider

```
SELECT
  unsafe_sum(x) OVER (ORDER BY n ROWS BETWEEN CURRENT ROW AND 1
    FOLLOWING)
FROM (VALUES (1, 1.0e20::float8),
        (2, 1.0::float8)) AS v (n,x);
```

This query returns 0 as its second result, rather than the expected answer of 1. The cause is the limited precision of floating-point values: adding 1 to 1e20 results in 1e20 again, and so subtracting 1e20 from that yields 0, not 1. Note that this is a limitation of floating-point arithmetic in general, not a limitation of PostgreSQL.

37.12.2. Polymorphic and Variadic Aggregates

Aggregate functions can use polymorphic state transition functions or final functions, so that the same functions can be used to implement multiple aggregates. See Section 37.2.5 for an explanation of polymorphic functions. Going a step further, the aggregate function itself can be specified with polymorphic input type(s) and state type, allowing a single aggregate definition to serve for multiple input data types. Here is an example of a polymorphic aggregate:

```
CREATE AGGREGATE array_accum (anyelement)
(
  sfunc = array_append,
  stype = anyarray,
  initcond = '{}'
);
```

Here, the actual state type for any given aggregate call is the array type having the actual input type as elements. The behavior of the aggregate is to concatenate all the inputs into an array of that type. (Note: the built-in aggregate `array_agg` provides similar functionality, with better performance than this definition would have.)

Here's the output using two different actual data types as arguments:

```
SELECT attrelid::regclass, array_accum(attname)
FROM pg_attribute
WHERE attnum > 0 AND attrelid = 'pg_tablespace'::regclass
GROUP BY attrelid;
```

attrelid	array_accum
pg_tablespace	{spcname,spcowner,spcacl,spcoptions}

(1 row)

```
SELECT attrelid::regclass, array_accum(atttypeid::regtype)
FROM pg_attribute
WHERE attnum > 0 AND attrelid = 'pg_tablespace'::regclass
GROUP BY attrelid;
```

attrelid	array_accum
pg_tablespace	{name,oid,aclitem[],text[]}

(1 row)

Ordinarily, an aggregate function with a polymorphic result type has a polymorphic state type, as in the above example. This is necessary because otherwise the final function cannot be declared sensibly: it would need to have a polymorphic result type but no polymorphic argument type, which CREATE FUNCTION will reject on the grounds that the result type cannot be deduced from a call. But sometimes it is inconvenient to use a polymorphic state type. The most common case is where the aggregate support functions are to be written in C and the state type should be declared as `internal` because there is no SQL-level equivalent for it. To address this case, it is possible to declare the final function as taking extra “dummy” arguments that match the input arguments of the aggregate. Such dummy arguments are always passed as null values since no specific value is available when the final function is called. Their only use is to allow a polymorphic final function's result type to be connected to the aggregate's input type(s). For example, the definition of the built-in aggregate `array_agg` is equivalent to

```
CREATE FUNCTION array_agg_transfn(internal, anynonarray)
  RETURNS internal ...;
CREATE FUNCTION array_agg_finalfn(internal, anynonarray)
  RETURNS anyarray ...;

CREATE AGGREGATE array_agg (anynonarray)
(
  sfunc = array_agg_transfn,
  stype = internal,
  finalfunc = array_agg_finalfn,
  finalfunc_extra
);
```

Here, the `finalfunc_extra` option specifies that the final function receives, in addition to the state value, extra dummy argument(s) corresponding to the aggregate's input argument(s). The extra `anynonarray` argument allows the declaration of `array_agg_finalfn` to be valid.

An aggregate function can be made to accept a varying number of arguments by declaring its last argument as a VARIADIC array, in much the same fashion as for regular functions; see Section 37.5.5. The aggregate's transition function(s) must have the same array type as their last argument. The transition function(s) typically would also be marked VARIADIC, but this is not strictly required.

Note

Variadic aggregates are easily misused in connection with the `ORDER BY` option (see Section 4.2.7), since the parser cannot tell whether the wrong number of actual arguments have been given in such a combination. Keep in mind that everything to the right of `ORDER BY` is a sort key, not an argument to the aggregate. For example, in

```
SELECT myaggregate(a ORDER BY a, b, c) FROM ...
```

the parser will see this as a single aggregate function argument and three sort keys. However, the user might have intended

```
SELECT myaggregate(a, b, c ORDER BY a) FROM ...
```

If `myaggregate` is variadic, both these calls could be perfectly valid.

For the same reason, it's wise to think twice before creating aggregate functions with the same names and different numbers of regular arguments.

37.12.3. Ordered-Set Aggregates

The aggregates we have been describing so far are “normal” aggregates. PostgreSQL also supports *ordered-set aggregates*, which differ from normal aggregates in two key ways. First, in addition to ordinary aggregated arguments that are evaluated once per input row, an ordered-set aggregate can have “direct” arguments that are evaluated only once per aggregation operation. Second, the syntax for the ordinary aggregated arguments specifies a sort ordering for them explicitly. An ordered-set aggregate is usually used to implement a computation that depends on a specific row ordering, for instance rank or percentile, so that the sort ordering is a required aspect of any call. For example, the built-in definition of `percentile_disc` is equivalent to:

```
CREATE FUNCTION ordered_set_transition(internal, anyelement)
  RETURNS internal ...;
CREATE FUNCTION percentile_disc_final(internal, float8, anyelement)
  RETURNS anyelement ...;

CREATE AGGREGATE percentile_disc (float8 ORDER BY anyelement)
(
  sfunc = ordered_set_transition,
  stype = internal,
  finalfunc = percentile_disc_final,
  finalfunc_extra
);
```

This aggregate takes a `float8` direct argument (the percentile fraction) and an aggregated input that can be of any sortable data type. It could be used to obtain a median household income like this:

```
SELECT percentile_disc(0.5) WITHIN GROUP (ORDER BY income) FROM
  households;
percentile_disc
-----
           50489
```

Here, `0.5` is a direct argument; it would make no sense for the percentile fraction to be a value varying across rows.

Unlike the case for normal aggregates, the sorting of input rows for an ordered-set aggregate is *not* done behind the scenes, but is the responsibility of the aggregate's support functions. The typical implementation approach is to keep a reference to a “tuplesort” object in the aggregate's state value, feed the incoming rows into that object, and then complete the sorting and read out the data in the final function. This design allows the final function to perform special operations such as injecting additional “hypothetical” rows into the data to be sorted. While normal aggregates can often be implemented with support functions written in PL/pgSQL or another PL language, ordered-set aggregates generally have to be written in C, since their state values aren't definable as any SQL data type. (In the above example, notice that the state value is declared as type `internal` — this is typical.) Also, because the final function performs the sort, it is not possible to continue adding input rows by executing the transition function again later. This means the final function is not `READ_ONLY`; it must be declared in `CREATE AGGREGATE` as `READ_WRITE`, or as `SHAREABLE` if it's possible for additional final-function calls to make use of the already-sorted state.

The state transition function for an ordered-set aggregate receives the current state value plus the aggregated input values for each row, and returns the updated state value. This is the same definition as for normal aggregates, but note that the direct arguments (if any) are not provided. The final function receives the last state value, the values of the direct arguments if any, and (if `finalfunc_extra` is specified) null values corresponding to the aggregated input(s). As with normal aggregates, `finalfunc_extra` is only really useful if the aggregate is polymorphic; then the extra dummy argument(s) are needed to connect the final function's result type to the aggregate's input type(s).

Currently, ordered-set aggregates cannot be used as window functions, and therefore there is no need for them to support moving-aggregate mode.

37.12.4. Partial Aggregation

Optionally, an aggregate function can support *partial aggregation*. The idea of partial aggregation is to run the aggregate's state transition function over different subsets of the input data independently, and then to combine the state values resulting from those subsets to produce the same state value that would have resulted from scanning all the input in a single operation. This mode can be used for parallel aggregation by having different worker processes scan different portions of a table. Each worker produces a partial state value, and at the end those state values are combined to produce a final state value. (In the future this mode might also be used for purposes such as combining aggregations over local and remote tables; but that is not implemented yet.)

To support partial aggregation, the aggregate definition must provide a *combine function*, which takes two values of the aggregate's state type (representing the results of aggregating over two subsets of the input rows) and produces a new value of the state type, representing what the state would have been after aggregating over the combination of those sets of rows. It is unspecified what the relative order of the input rows from the two sets would have been. This means that it's usually impossible to define a useful combine function for aggregates that are sensitive to input row order.

As simple examples, `MAX` and `MIN` aggregates can be made to support partial aggregation by specifying the combine function as the same greater-of-two or lesser-of-two comparison function that is used as their transition function. `SUM` aggregates just need an addition function as combine function. (Again, this is the same as their transition function, unless the state value is wider than the input data type.)

The combine function is treated much like a transition function that happens to take a value of the state type, not of the underlying input type, as its second argument. In particular, the rules for dealing with null values and strict functions are similar. Also, if the aggregate definition specifies a non-null `initcond`, keep in mind that that will be used not only as the initial state for each partial aggregation run, but also as the initial state for the combine function, which will be called to combine each partial result into that state.

If the aggregate's state type is declared as `internal`, it is the combine function's responsibility that its result is allocated in the correct memory context for aggregate state values. This means in particular that when the first input is `NULL` it's invalid to simply return the second input, as that value will be in the wrong context and will not have sufficient lifespan.

When the aggregate's state type is declared as `internal`, it is usually also appropriate for the aggregate definition to provide a *serialization function* and a *deserialization function*, which allow such a state value to be copied from one process to another. Without these functions, parallel aggregation cannot be performed, and future applications such as local/remote aggregation will probably not work either.

A serialization function must take a single argument of type `internal` and return a result of type `bytea`, which represents the state value packaged up into a flat blob of bytes. Conversely, a deserialization function reverses that conversion. It must take two arguments of types `bytea` and `internal`, and return a result of type `internal`. (The second argument is unused and is always zero, but it is required for type-safety reasons.) The result of the deserialization function should simply be allocated in the current memory context, as unlike the combine function's result, it is not long-lived.

Worth noting also is that for an aggregate to be executed in parallel, the aggregate itself must be marked `PARALLEL SAFE`. The parallel-safety markings on its support functions are not consulted.

37.12.5. Support Functions for Aggregates

A function written in C can detect that it is being called as an aggregate support function by calling `AggCheckCallContext`, for example:

```
if (AggCheckCallContext(fcinfo, NULL))
```

One reason for checking this is that when it is true, the first input must be a temporary state value and can therefore safely be modified in-place rather than allocating a new copy. See `int8inc()` for an example. (While aggregate transition functions are always allowed to modify the transition value in-place, aggregate final functions are generally discouraged from doing so; if they do so, the behavior must be declared when creating the aggregate. See `CREATE AGGREGATE` for more detail.)

The second argument of `AggCheckCallContext` can be used to retrieve the memory context in which aggregate state values are being kept. This is useful for transition functions that wish to use “expanded” objects (see Section 37.13.1) as their state values. On first call, the transition function should return an expanded object whose memory context is a child of the aggregate state context, and then keep returning the same expanded object on subsequent calls. See `array_append()` for an example. (`array_append()` is not the transition function of any built-in aggregate, but it is written to behave efficiently when used as transition function of a custom aggregate.)

Another support routine available to aggregate functions written in C is `AggGetAggref`, which returns the `Aggref` parse node that defines the aggregate call. This is mainly useful for ordered-set aggregates, which can inspect the substructure of the `Aggref` node to find out what sort ordering they are supposed to implement. Examples can be found in `orderedsetaggs.c` in the PostgreSQL source code.

37.13. User-Defined Types

As described in Section 37.2, PostgreSQL can be extended to support new data types. This section describes how to define new base types, which are data types defined below the level of the SQL language. Creating a new base type requires implementing functions to operate on the type in a low-level language, usually C.

The examples in this section can be found in `complex.sql` and `complex.c` in the `src/tutorial` directory of the source distribution. See the `README` file in that directory for instructions about running the examples.

A user-defined type must always have input and output functions. These functions determine how the type appears in strings (for input by the user and output to the user) and how the type is organized in memory. The input function takes a null-terminated character string as its argument and returns the internal (in memory) representation of the type. The output function takes the internal representation of the type as argument and returns a null-terminated character string. If we want to do anything more with the type than merely store it, we must provide additional functions to implement whatever operations we'd like to have for the type.

Suppose we want to define a type `complex` that represents complex numbers. A natural way to represent a complex number in memory would be the following C structure:

```
typedef struct Complex {
    double    x;
    double    y;
} Complex;
```

We will need to make this a pass-by-reference type, since it's too large to fit into a single `Datum` value.

As the external string representation of the type, we choose a string of the form `(x,y)`.

The input and output functions are usually not hard to write, especially the output function. But when defining the external string representation of the type, remember that you must eventually write a complete and robust parser for that representation as your input function. For instance:

```

PG_FUNCTION_INFO_V1(complex_in);

Datum
complex_in(PG_FUNCTION_ARGS)
{
    char          *str = PG_GETARG_CSTRING(0);
    double        x,
                 y;
    Complex       *result;

    if (sscanf(str, " ( %lf , %lf )", &x, &y) != 2)
        ereport(ERROR,
                (errcode(ERRCODE_INVALID_TEXT_REPRESENTATION),
                 errmsg("invalid input syntax for type %s: \"%s\"",
                        "complex", str)));

    result = (Complex *) palloc(sizeof(Complex));
    result->x = x;
    result->y = y;
    PG_RETURN_POINTER(result);
}

```

The output function can simply be:

```

PG_FUNCTION_INFO_V1(complex_out);

Datum
complex_out(PG_FUNCTION_ARGS)
{
    Complex       *complex = (Complex *) PG_GETARG_POINTER(0);
    char          *result;

    result = psprintf("(%g,%g)", complex->x, complex->y);
    PG_RETURN_CSTRING(result);
}

```

You should be careful to make the input and output functions inverses of each other. If you do not, you will have severe problems when you need to dump your data into a file and then read it back in. This is a particularly common problem when floating-point numbers are involved.

Optionally, a user-defined type can provide binary input and output routines. Binary I/O is normally faster but less portable than textual I/O. As with textual I/O, it is up to you to define exactly what the external binary representation is. Most of the built-in data types try to provide a machine-independent binary representation. For `complex`, we will piggy-back on the binary I/O converters for type `float8`:

```

PG_FUNCTION_INFO_V1(complex_recv);

Datum
complex_recv(PG_FUNCTION_ARGS)
{
    StringInfo    buf = (StringInfo) PG_GETARG_POINTER(0);
    Complex       *result;

    result = (Complex *) palloc(sizeof(Complex));

```

```

        result->x = pq_getmsgfloat8(buf);
        result->y = pq_getmsgfloat8(buf);
        PG_RETURN_POINTER(result);
    }

PG_FUNCTION_INFO_V1(complex_send);

Datum
complex_send(PG_FUNCTION_ARGS)
{
    Complex    *complex = (Complex *) PG_GETARG_POINTER(0);
    StringInfoData buf;

    pq_begintypsend(&buf);
    pq_sendfloat8(&buf, complex->x);
    pq_sendfloat8(&buf, complex->y);
    PG_RETURN_BYTEA_P(pq_endtypsend(&buf));
}

```

Once we have written the I/O functions and compiled them into a shared library, we can define the complex type in SQL. First we declare it as a shell type:

```
CREATE TYPE complex;
```

This serves as a placeholder that allows us to reference the type while defining its I/O functions. Now we can define the I/O functions:

```

CREATE FUNCTION complex_in(cstring)
    RETURNS complex
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_out(complex)
    RETURNS cstring
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_recv(internal)
    RETURNS complex
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_send(complex)
    RETURNS bytea
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

```

Finally, we can provide the full definition of the data type:

```

CREATE TYPE complex (
    internallength = 16,
    input = complex_in,
    output = complex_out,
    receive = complex_recv,
    send = complex_send,

```

```

    alignment = double
);

```

When you define a new base type, PostgreSQL automatically provides support for arrays of that type. The array type typically has the same name as the base type with the underscore character (`_`) prepended.

Once the data type exists, we can declare additional functions to provide useful operations on the data type. Operators can then be defined atop the functions, and if needed, operator classes can be created to support indexing of the data type. These additional layers are discussed in following sections.

If the internal representation of the data type is variable-length, the internal representation must follow the standard layout for variable-length data: the first four bytes must be a `char[4]` field which is never accessed directly (customarily named `vl_len_`). You must use the `SET_VARSIZE()` macro to store the total size of the datum (including the length field itself) in this field and `VARSIZE()` to retrieve it. (These macros exist because the length field may be encoded depending on platform.)

For further details see the description of the `CREATE TYPE` command.

37.13.1. TOAST Considerations

If the values of your data type vary in size (in internal form), it's usually desirable to make the data type TOAST-able (see Section 68.2). You should do this even if the values are always too small to be compressed or stored externally, because TOAST can save space on small data too, by reducing header overhead.

To support TOAST storage, the C functions operating on the data type must always be careful to unpack any toasted values they are handed by using `PG_DETOAST_DATUM`. (This detail is customarily hidden by defining type-specific `GETARG_DATATYPE_P` macros.) Then, when running the `CREATE TYPE` command, specify the internal length as `variable` and select some appropriate storage option other than `plain`.

If data alignment is unimportant (either just for a specific function or because the data type specifies byte alignment anyway) then it's possible to avoid some of the overhead of `PG_DETOAST_DATUM`. You can use `PG_DETOAST_DATUM_PACKED` instead (customarily hidden by defining a `GETARG_DATATYPE_PP` macro) and using the macros `VARSIZE_ANY_EXHDR` and `VARDATA_ANY` to access a potentially-packed datum. Again, the data returned by these macros is not aligned even if the data type definition specifies an alignment. If the alignment is important you must go through the regular `PG_DETOAST_DATUM` interface.

Note

Older code frequently declares `vl_len_` as an `int32` field instead of `char[4]`. This is OK as long as the struct definition has other fields that have at least `int32` alignment. But it is dangerous to use such a struct definition when working with a potentially unaligned datum; the compiler may take it as license to assume the datum actually is aligned, leading to core dumps on architectures that are strict about alignment.

Another feature that's enabled by TOAST support is the possibility of having an *expanded* in-memory data representation that is more convenient to work with than the format that is stored on disk. The regular or "flat" varlena storage format is ultimately just a blob of bytes; it cannot for example contain pointers, since it may get copied to other locations in memory. For complex data types, the flat format may be quite expensive to work with, so PostgreSQL provides a way to "expand" the flat format into a representation that is more suited to computation, and then pass that format in-memory between functions of the data type.

To use expanded storage, a data type must define an expanded format that follows the rules given in `src/include/utils/expandeddatum.h`, and provide functions to "expand" a flat varlena

value into expanded format and “flatten” the expanded format back to the regular varlena representation. Then ensure that all C functions for the data type can accept either representation, possibly by converting one into the other immediately upon receipt. This does not require fixing all existing functions for the data type at once, because the standard `PG_DETOAST_DATUM` macro is defined to convert expanded inputs into regular flat format. Therefore, existing functions that work with the flat varlena format will continue to work, though slightly inefficiently, with expanded inputs; they need not be converted until and unless better performance is important.

C functions that know how to work with an expanded representation typically fall into two categories: those that can only handle expanded format, and those that can handle either expanded or flat varlena inputs. The former are easier to write but may be less efficient overall, because converting a flat input to expanded form for use by a single function may cost more than is saved by operating on the expanded format. When only expanded format need be handled, conversion of flat inputs to expanded form can be hidden inside an argument-fetching macro, so that the function appears no more complex than one working with traditional varlena input. To handle both types of input, write an argument-fetching function that will detoast external, short-header, and compressed varlena inputs, but not expanded inputs. Such a function can be defined as returning a pointer to a union of the flat varlena format and the expanded format. Callers can use the `VARATT_IS_EXPANDED_HEADER()` macro to determine which format they received.

The TOAST infrastructure not only allows regular varlena values to be distinguished from expanded values, but also distinguishes “read-write” and “read-only” pointers to expanded values. C functions that only need to examine an expanded value, or will only change it in safe and non-semantically-visible ways, need not care which type of pointer they receive. C functions that produce a modified version of an input value are allowed to modify an expanded input value in-place if they receive a read-write pointer, but must not modify the input if they receive a read-only pointer; in that case they have to copy the value first, producing a new value to modify. A C function that has constructed a new expanded value should always return a read-write pointer to it. Also, a C function that is modifying a read-write expanded value in-place should take care to leave the value in a sane state if it fails partway through.

For examples of working with expanded values, see the standard array infrastructure, particularly `src/backend/utils/adt/array_expanded.c`.

37.14. User-Defined Operators

Every operator is “syntactic sugar” for a call to an underlying function that does the real work; so you must first create the underlying function before you can create the operator. However, an operator is *not merely* syntactic sugar, because it carries additional information that helps the query planner optimize queries that use the operator. The next section will be devoted to explaining that additional information.

PostgreSQL supports left unary, right unary, and binary operators. Operators can be overloaded; that is, the same operator name can be used for different operators that have different numbers and types of operands. When a query is executed, the system determines the operator to call from the number and types of the provided operands.

Here is an example of creating an operator for adding two complex numbers. We assume we've already created the definition of type `complex` (see Section 37.13). First we need a function that does the work, then we can define the operator:

```
CREATE FUNCTION complex_add(complex, complex)
    RETURNS complex
    AS 'filename', 'complex_add'
    LANGUAGE C IMMUTABLE STRICT;

CREATE OPERATOR + (
    leftarg = complex,
```

```

    rightarg = complex,
    function = complex_add,
    commutator = +
);

```

Now we could execute a query like this:

```

SELECT (a + b) AS c FROM test_complex;

      c
-----
(5.2,6.05)
(133.42,144.95)

```

We've shown how to create a binary operator here. To create unary operators, just omit one of `leftarg` (for left unary) or `rightarg` (for right unary). The `function` clause and the argument clauses are the only required items in `CREATE OPERATOR`. The `commutator` clause shown in the example is an optional hint to the query optimizer. Further details about `commutator` and other optimizer hints appear in the next section.

37.15. Operator Optimization Information

A PostgreSQL operator definition can include several optional clauses that tell the system useful things about how the operator behaves. These clauses should be provided whenever appropriate, because they can make for considerable speedups in execution of queries that use the operator. But if you provide them, you must be sure that they are right! Incorrect use of an optimization clause can result in slow queries, subtly wrong output, or other Bad Things. You can always leave out an optimization clause if you are not sure about it; the only consequence is that queries might run slower than they need to.

Additional optimization clauses might be added in future versions of PostgreSQL. The ones described here are all the ones that release 12.1 understands.

It is also possible to attach a planner support function to the function that underlies an operator, providing another way of telling the system about the behavior of the operator. See Section 37.11 for more information.

37.15.1. COMMUTATOR

The `COMMUTATOR` clause, if provided, names an operator that is the commutator of the operator being defined. We say that operator A is the commutator of operator B if $(x \ A \ y)$ equals $(y \ B \ x)$ for all possible input values x, y . Notice that B is also the commutator of A. For example, operators `<` and `>` for a particular data type are usually each others' commutators, and operator `+` is usually commutative with itself. But operator `-` is usually not commutative with anything.

The left operand type of a commutable operator is the same as the right operand type of its commutator, and vice versa. So the name of the commutator operator is all that PostgreSQL needs to be given to look up the commutator, and that's all that needs to be provided in the `COMMUTATOR` clause.

It's critical to provide commutator information for operators that will be used in indexes and join clauses, because this allows the query optimizer to “flip around” such a clause to the forms needed for different plan types. For example, consider a query with a `WHERE` clause like `tab1.x = tab2.y`, where `tab1.x` and `tab2.y` are of a user-defined type, and suppose that `tab2.y` is indexed. The optimizer cannot generate an index scan unless it can determine how to flip the clause around to `tab2.y = tab1.x`, because the index-scan machinery expects to see the indexed column on the left of the operator it is given. PostgreSQL will *not* simply assume that this is a valid transformation — the creator of the `=` operator must specify that it is valid, by marking the operator with commutator information.

When you are defining a self-commutative operator, you just do it. When you are defining a pair of commutative operators, things are a little trickier: how can the first one to be defined refer to the other one, which you haven't defined yet? There are two solutions to this problem:

- One way is to omit the `COMMUTATOR` clause in the first operator that you define, and then provide one in the second operator's definition. Since PostgreSQL knows that commutative operators come in pairs, when it sees the second definition it will automatically go back and fill in the missing `COMMUTATOR` clause in the first definition.
- The other, more straightforward way is just to include `COMMUTATOR` clauses in both definitions. When PostgreSQL processes the first definition and realizes that `COMMUTATOR` refers to a nonexistent operator, the system will make a dummy entry for that operator in the system catalog. This dummy entry will have valid data only for the operator name, left and right operand types, and result type, since that's all that PostgreSQL can deduce at this point. The first operator's catalog entry will link to this dummy entry. Later, when you define the second operator, the system updates the dummy entry with the additional information from the second definition. If you try to use the dummy operator before it's been filled in, you'll just get an error message.

37.15.2. NEGATOR

The `NEGATOR` clause, if provided, names an operator that is the negator of the operator being defined. We say that operator *A* is the negator of operator *B* if both return Boolean results and $(x \ A \ y)$ equals `NOT (x B y)` for all possible inputs *x*, *y*. Notice that *B* is also the negator of *A*. For example, `<` and `>=` are a negator pair for most data types. An operator can never validly be its own negator.

Unlike commutators, a pair of unary operators could validly be marked as each other's negators; that would mean $(A \ x)$ equals `NOT (B x)` for all *x*, or the equivalent for right unary operators.

An operator's negator must have the same left and/or right operand types as the operator to be defined, so just as with `COMMUTATOR`, only the operator name need be given in the `NEGATOR` clause.

Providing a negator is very helpful to the query optimizer since it allows expressions like `NOT (x = y)` to be simplified into `x <> y`. This comes up more often than you might think, because `NOT` operations can be inserted as a consequence of other rearrangements.

Pairs of negator operators can be defined using the same methods explained above for commutator pairs.

37.15.3. RESTRICT

The `RESTRICT` clause, if provided, names a restriction selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) `RESTRICT` clauses only make sense for binary operators that return `boolean`. The idea behind a restriction selectivity estimator is to guess what fraction of the rows in a table will satisfy a `WHERE`-clause condition of the form:

```
column OP constant
```

for the current operator and a particular constant value. This assists the optimizer by giving it some idea of how many rows will be eliminated by `WHERE` clauses that have this form. (What happens if the constant is on the left, you might be wondering? Well, that's one of the things that `COMMUTATOR` is for...)

Writing new restriction selectivity estimation functions is far beyond the scope of this chapter, but fortunately you can usually just use one of the system's standard estimators for many of your own operators. These are the standard restriction estimators:

```
eqsel for =
neqsel for <>
```

```

scalarltsel for <
scalarlesel for <=
scalargtsel for >
scalargesel for >=

```

You can frequently get away with using either `eqsel` or `neqsel` for operators that have very high or very low selectivity, even if they aren't really equality or inequality. For example, the approximate-equality geometric operators use `eqsel` on the assumption that they'll usually only match a small fraction of the entries in a table.

You can use `scalarltsel`, `scalarlesel`, `scalargtsel` and `scalargesel` for comparisons on data types that have some sensible means of being converted into numeric scalars for range comparisons. If possible, add the data type to those understood by the function `convert_to_scalar()` in `src/backend/utils/adt/selfuncs.c`. (Eventually, this function should be replaced by per-data-type functions identified through a column of the `pg_type` system catalog; but that hasn't happened yet.) If you do not do this, things will still work, but the optimizer's estimates won't be as good as they could be.

There are additional selectivity estimation functions designed for geometric operators in `src/backend/utils/adt/geo_selfuncs.c`: `areasel`, `positionsel`, and `contsel`. At this writing these are just stubs, but you might want to use them (or even better, improve them) anyway.

37.15.4. JOIN

The `JOIN` clause, if provided, names a join selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) `JOIN` clauses only make sense for binary operators that return `boolean`. The idea behind a join selectivity estimator is to guess what fraction of the rows in a pair of tables will satisfy a `WHERE`-clause condition of the form:

```
table1.column1 OP table2.column2
```

for the current operator. As with the `RESTRICT` clause, this helps the optimizer very substantially by letting it figure out which of several possible join sequences is likely to take the least work.

As before, this chapter will make no attempt to explain how to write a join selectivity estimator function, but will just suggest that you use one of the standard estimators if one is applicable:

```

eqjoinssel for =
neqjoinssel for <>
scalarltjoinssel for <
scalarlejoinssel for <=
scalargtjoinssel for >
scalargejoinssel for >=
areajoinssel for 2D area-based comparisons
positionjoinssel for 2D position-based comparisons
contjoinssel for 2D containment-based comparisons

```

37.15.5. HASHES

The `HASHES` clause, if present, tells the system that it is permissible to use the hash join method for a join based on this operator. `HASHES` only makes sense for a binary operator that returns `boolean`, and in practice the operator must represent equality for some data type or pair of data types.

The assumption underlying hash join is that the join operator can only return true for pairs of left and right values that hash to the same hash code. If two values get put in different hash buckets, the join will never compare them at all, implicitly assuming that the result of the join operator must be false. So it never makes sense to specify `HASHES` for operators that do not represent some form of equality. In most cases it is only practical to support hashing for operators that take the same data type on both

sides. However, sometimes it is possible to design compatible hash functions for two or more data types; that is, functions that will generate the same hash codes for “equal” values, even though the values have different representations. For example, it’s fairly simple to arrange this property when hashing integers of different widths.

To be marked `HASHES`, the join operator must appear in a hash index operator family. This is not enforced when you create the operator, since of course the referencing operator family couldn’t exist yet. But attempts to use the operator in hash joins will fail at run time if no such operator family exists. The system needs the operator family to find the data-type-specific hash function(s) for the operator’s input data type(s). Of course, you must also create suitable hash functions before you can create the operator family.

Care should be exercised when preparing a hash function, because there are machine-dependent ways in which it might fail to do the right thing. For example, if your data type is a structure in which there might be uninteresting pad bits, you cannot simply pass the whole structure to `hash_any`. (Unless you write your other operators and functions to ensure that the unused bits are always zero, which is the recommended strategy.) Another example is that on machines that meet the IEEE floating-point standard, negative zero and positive zero are different values (different bit patterns) but they are defined to compare equal. If a float value might contain negative zero then extra steps are needed to ensure it generates the same hash value as positive zero.

A hash-joinable operator must have a commutator (itself if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. If this is not the case, planner errors might occur when the operator is used. Also, it is a good idea (but not strictly required) for a hash operator family that supports multiple data types to provide equality operators for every combination of the data types; this allows better optimization.

Note

The function underlying a hash-joinable operator must be marked `immutable` or `stable`. If it is `volatile`, the system will never attempt to use the operator for a hash join.

Note

If a hash-joinable operator has an underlying function that is marked `strict`, the function must also be `complete`: that is, it should return `true` or `false`, never `null`, for any two nonnull inputs. If this rule is not followed, hash-optimization of `IN` operations might generate wrong results. (Specifically, `IN` might return `false` where the correct answer according to the standard would be `null`; or it might yield an error complaining that it wasn’t prepared for a null result.)

37.15.6. MERGES

The `MERGES` clause, if present, tells the system that it is permissible to use the merge-join method for a join based on this operator. `MERGES` only makes sense for a binary operator that returns `boolean`, and in practice the operator must represent equality for some data type or pair of data types.

Merge join is based on the idea of sorting the left- and right-hand tables into order and then scanning them in parallel. So, both data types must be capable of being fully ordered, and the join operator must be one that can only succeed for pairs of values that fall at the “same place” in the sort order. In practice this means that the join operator must behave like equality. But it is possible to merge-join two distinct data types so long as they are logically compatible. For example, the `smallint-versus-integer` equality operator is merge-joinable. We only need sorting operators that will bring both data types into a logically compatible sequence.

To be marked `MERGES`, the join operator must appear as an equality member of a `btree` index operator family. This is not enforced when you create the operator, since of course the referencing operator family couldn't exist yet. But the operator will not actually be used for merge joins unless a matching operator family can be found. The `MERGES` flag thus acts as a hint to the planner that it's worth looking for a matching operator family.

A merge-joinable operator must have a commutator (itself if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. If this is not the case, planner errors might occur when the operator is used. Also, it is a good idea (but not strictly required) for a `btree` operator family that supports multiple data types to provide equality operators for every combination of the data types; this allows better optimization.

Note

The function underlying a merge-joinable operator must be marked immutable or stable. If it is volatile, the system will never attempt to use the operator for a merge join.

37.16. Interfacing Extensions to Indexes

The procedures described thus far let you define new types, new functions, and new operators. However, we cannot yet define an index on a column of a new data type. To do this, we must define an *operator class* for the new data type. Later in this section, we will illustrate this concept in an example: a new operator class for the B-tree index method that stores and sorts complex numbers in ascending absolute value order.

Operator classes can be grouped into *operator families* to show the relationships between semantically compatible classes. When only a single data type is involved, an operator class is sufficient, so we'll focus on that case first and then return to operator families.

37.16.1. Index Methods and Operator Classes

The `pg_am` table contains one row for every index method (internally known as access method). Support for regular access to tables is built into PostgreSQL, but all index methods are described in `pg_am`. It is possible to add a new index access method by writing the necessary code and then creating an entry in `pg_am` — but that is beyond the scope of this chapter (see Chapter 61).

The routines for an index method do not directly know anything about the data types that the index method will operate on. Instead, an *operator class* identifies the set of operations that the index method needs to use to work with a particular data type. Operator classes are so called because one thing they specify is the set of `WHERE`-clause operators that can be used with an index (i.e., can be converted into an index-scan qualification). An operator class can also specify some *support function* that are needed by the internal operations of the index method, but do not directly correspond to any `WHERE`-clause operator that can be used with the index.

It is possible to define multiple operator classes for the same data type and index method. By doing this, multiple sets of indexing semantics can be defined for a single data type. For example, a B-tree index requires a sort ordering to be defined for each data type it works on. It might be useful for a complex-number data type to have one B-tree operator class that sorts the data by complex absolute value, another that sorts by real part, and so on. Typically, one of the operator classes will be deemed most commonly useful and will be marked as the default operator class for that data type and index method.

The same operator class name can be used for several different index methods (for example, both B-tree and hash index methods have operator classes named `int4_ops`), but each such class is an independent entity and must be defined separately.

37.16.2. Index Method Strategies

The operators associated with an operator class are identified by “strategy numbers”, which serve to identify the semantics of each operator within the context of its operator class. For example, B-trees impose a strict ordering on keys, lesser to greater, and so operators like “less than” and “greater than or equal to” are interesting with respect to a B-tree. Because PostgreSQL allows the user to define operators, PostgreSQL cannot look at the name of an operator (e.g., < or >=) and tell what kind of comparison it is. Instead, the index method defines a set of “strategies”, which can be thought of as generalized operators. Each operator class specifies which actual operator corresponds to each strategy for a particular data type and interpretation of the index semantics.

The B-tree index method defines five strategies, shown in Table 37.2.

Table 37.2. B-Tree Strategies

Operation	Strategy Number
less than	1
less than or equal	2
equal	3
greater than or equal	4
greater than	5

Hash indexes support only equality comparisons, and so they use only one strategy, shown in Table 37.3.

Table 37.3. Hash Strategies

Operation	Strategy Number
equal	1

GiST indexes are more flexible: they do not have a fixed set of strategies at all. Instead, the “consistency” support routine of each particular GiST operator class interprets the strategy numbers however it likes. As an example, several of the built-in GiST index operator classes index two-dimensional geometric objects, providing the “R-tree” strategies shown in Table 37.4. Four of these are true two-dimensional tests (overlaps, same, contains, contained by); four of them consider only the X direction; and the other four provide the same tests in the Y direction.

Table 37.4. GiST Two-Dimensional “R-tree” Strategies

Operation	Strategy Number
strictly left of	1
does not extend to right of	2
overlaps	3
does not extend to left of	4
strictly right of	5
same	6
contains	7
contained by	8
does not extend above	9
strictly below	10
strictly above	11
does not extend below	12

SP-GiST indexes are similar to GiST indexes in flexibility: they don't have a fixed set of strategies. Instead the support routines of each operator class interpret the strategy numbers according to the operator class's definition. As an example, the strategy numbers used by the built-in operator classes for points are shown in Table 37.5.

Table 37.5. SP-GiST Point Strategies

Operation	Strategy Number
strictly left of	1
strictly right of	5
same	6
contained by	8
strictly below	10
strictly above	11

GIN indexes are similar to GiST and SP-GiST indexes, in that they don't have a fixed set of strategies either. Instead the support routines of each operator class interpret the strategy numbers according to the operator class's definition. As an example, the strategy numbers used by the built-in operator class for arrays are shown in Table 37.6.

Table 37.6. GIN Array Strategies

Operation	Strategy Number
overlap	1
contains	2
is contained by	3
equal	4

BRIN indexes are similar to GiST, SP-GiST and GIN indexes in that they don't have a fixed set of strategies either. Instead the support routines of each operator class interpret the strategy numbers according to the operator class's definition. As an example, the strategy numbers used by the built-in Minmax operator classes are shown in Table 37.7.

Table 37.7. BRIN Minmax Strategies

Operation	Strategy Number
less than	1
less than or equal	2
equal	3
greater than or equal	4
greater than	5

Notice that all the operators listed above return Boolean values. In practice, all operators defined as index method search operators must return type `boolean`, since they must appear at the top level of a `WHERE` clause to be used with an index. (Some index access methods also support *ordering operators*, which typically don't return Boolean values; that feature is discussed in Section 37.16.7.)

37.16.3. Index Method Support Routines

Strategies aren't usually enough information for the system to figure out how to use an index. In practice, the index methods require additional support routines in order to work. For example, the B-tree index method must be able to compare two keys and determine whether one is greater than, equal

to, or less than the other. Similarly, the hash index method must be able to compute hash codes for key values. These operations do not correspond to operators used in qualifications in SQL commands; they are administrative routines used by the index methods, internally.

Just as with strategies, the operator class identifies which specific functions should play each of these roles for a given data type and semantic interpretation. The index method defines the set of functions it needs, and the operator class identifies the correct functions to use by assigning them to the “support function numbers” specified by the index method.

B-trees require a comparison support function, and allow two additional support functions to be supplied at the operator class author's option, as shown in Table 37.8. The requirements for these support functions are explained further in Section 63.3.

Table 37.8. B-Tree Support Functions

Function	Support Number
Compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second	1
Return the addresses of C-callable sort support function(s) (optional)	2
Compare a test value to a base value plus/minus an offset, and return true or false according to the comparison result (optional)	3

Hash indexes require one support function, and allow a second one to be supplied at the operator class author's option, as shown in Table 37.9.

Table 37.9. Hash Support Functions

Function	Support Number
Compute the 32-bit hash value for a key	1
Compute the 64-bit hash value for a key given a 64-bit salt; if the salt is 0, the low 32 bits of the result must match the value that would have been computed by function 1 (optional)	2

GiST indexes have nine support functions, two of which are optional, as shown in Table 37.10. (For more information see Chapter 64.)

Table 37.10. GiST Support Functions

Function	Description	Support Number
consistent	determine whether key satisfies the query qualifier	1
union	compute union of a set of keys	2
compress	compute a compressed representation of a key or value to be indexed	3
decompress	compute a decompressed representation of a compressed key	4
penalty	compute penalty for inserting new key into subtree with given subtree's key	5

Function	Description	Support Number
<code>picksplit</code>	determine which entries of a page are to be moved to the new page and compute the union keys for resulting pages	6
<code>equal</code>	compare two keys and return true if they are equal	7
<code>distance</code>	determine distance from key to query value (optional)	8
<code>fetch</code>	compute original representation of a compressed key for index-only scans (optional)	9

SP-GiST indexes require five support functions, as shown in Table 37.11. (For more information see Chapter 65.)

Table 37.11. SP-GiST Support Functions

Function	Description	Support Number
<code>config</code>	provide basic information about the operator class	1
<code>choose</code>	determine how to insert a new value into an inner tuple	2
<code>picksplit</code>	determine how to partition a set of values	3
<code>inner_consistent</code>	determine which sub-partitions need to be searched for a query	4
<code>leaf_consistent</code>	determine whether key satisfies the query qualifier	5

GIN indexes have six support functions, three of which are optional, as shown in Table 37.12. (For more information see Chapter 66.)

Table 37.12. GIN Support Functions

Function	Description	Support Number
<code>compare</code>	compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second	1
<code>extractValue</code>	extract keys from a value to be indexed	2
<code>extractQuery</code>	extract keys from a query condition	3
<code>consistent</code>	determine whether value matches query condition (Boolean variant) (optional if support function 6 is present)	4
<code>comparePartial</code>	compare partial key from query and key from index, and return an integer less than zero, zero,	5

Function	Description	Support Number
	or greater than zero, indicating whether GIN should ignore this index entry, treat the entry as a match, or stop the index scan (optional)	
triConsistent	determine whether value matches query condition (ternary variant) (optional if support function 4 is present)	6

BRIN indexes have four basic support functions, as shown in Table 37.13; those basic functions may require additional support functions to be provided. (For more information see Section 67.3.)

Table 37.13. BRIN Support Functions

Function	Description	Support Number
opcInfo	return internal information describing the indexed columns' summary data	1
add_value	add a new value to an existing summary index tuple	2
consistent	determine whether value matches query condition	3
union	compute union of two summary tuples	4

Unlike search operators, support functions return whichever data type the particular index method expects; for example in the case of the comparison function for B-trees, a signed integer. The number and types of the arguments to each support function are likewise dependent on the index method. For B-tree and hash the comparison and hashing support functions take the same input data types as do the operators included in the operator class, but this is not the case for most GiST, SP-GiST, GIN, and BRIN support functions.

37.16.4. An Example

Now that we have seen the ideas, here is the promised example of creating a new operator class. (You can find a working copy of this example in `src/tutorial/complex.c` and `src/tutorial/complex.sql` in the source distribution.) The operator class encapsulates operators that sort complex numbers in absolute value order, so we choose the name `complex_abs_ops`. First, we need a set of operators. The procedure for defining operators was discussed in Section 37.14. For an operator class on B-trees, the operators we require are:

- absolute-value less-than (strategy 1)
- absolute-value less-than-or-equal (strategy 2)
- absolute-value equal (strategy 3)
- absolute-value greater-than-or-equal (strategy 4)
- absolute-value greater-than (strategy 5)

The least error-prone way to define a related set of comparison operators is to write the B-tree comparison support function first, and then write the other functions as one-line wrappers around the support function. This reduces the odds of getting inconsistent results for corner cases. Following this approach, we first write:

```
#define Mag(c) ((c)->x*(c)->x + (c)->y*(c)->y)
```

```
static int
complex_abs_cmp_internal(Complex *a, Complex *b)
{
    double    amag = Mag(a),
             bmag = Mag(b);

    if (amag < bmag)
        return -1;
    if (amag > bmag)
        return 1;
    return 0;
}
```

Now the less-than function looks like:

```
PG_FUNCTION_INFO_V1(complex_abs_lt);

Datum
complex_abs_lt(PG_FUNCTION_ARGS)
{
    Complex    *a = (Complex *) PG_GETARG_POINTER(0);
    Complex    *b = (Complex *) PG_GETARG_POINTER(1);

    PG_RETURN_BOOL(complex_abs_cmp_internal(a, b) < 0);
}
```

The other four functions differ only in how they compare the internal function's result to zero.

Next we declare the functions and the operators based on the functions to SQL:

```
CREATE FUNCTION complex_abs_lt(complex, complex) RETURNS bool
    AS 'filename', 'complex_abs_lt'
    LANGUAGE C IMMUTABLE STRICT;

CREATE OPERATOR < (
    leftarg = complex, rightarg = complex, procedure =
    complex_abs_lt,
    commutator = > , negator = >= ,
    restrict = scalarltsel, join = scalarltjoinsel
);
```

It is important to specify the correct commutator and negator operators, as well as suitable restriction and join selectivity functions, otherwise the optimizer will be unable to make effective use of the index.

Other things worth noting are happening here:

- There can only be one operator named, say, = and taking type complex for both operands. In this case we don't have any other operator = for complex, but if we were building a practical data type we'd probably want = to be the ordinary equality operation for complex numbers (and not the equality of the absolute values). In that case, we'd need to use some other operator name for complex_abs_eq.
- Although PostgreSQL can cope with functions having the same SQL name as long as they have different argument data types, C can only cope with one global function having a given name. So we shouldn't name the C function something simple like abs_eq. Usually it's a good practice to

include the data type name in the C function name, so as not to conflict with functions for other data types.

- We could have made the SQL name of the function `abs_eq`, relying on PostgreSQL to distinguish it by argument data types from any other SQL function of the same name. To keep the example simple, we make the function have the same names at the C level and SQL level.

The next step is the registration of the support routine required by B-trees. The example C code that implements this is in the same file that contains the operator functions. This is how we declare the function:

```
CREATE FUNCTION complex_abs_cmp(complex, complex)
    RETURNS integer
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;
```

Now that we have the required operators and support routine, we can finally create the operator class:

```
CREATE OPERATOR CLASS complex_abs_ops
    DEFAULT FOR TYPE complex USING btree AS
    OPERATOR          1          < ,
    OPERATOR          2          <= ,
    OPERATOR          3          = ,
    OPERATOR          4          >= ,
    OPERATOR          5          > ,
    FUNCTION          1          complex_abs_cmp(complex, complex);
```

And we're done! It should now be possible to create and use B-tree indexes on `complex` columns.

We could have written the operator entries more verbosely, as in:

```
OPERATOR          1          < (complex, complex) ,
```

but there is no need to do so when the operators take the same data type we are defining the operator class for.

The above example assumes that you want to make this new operator class the default B-tree operator class for the `complex` data type. If you don't, just leave out the word `DEFAULT`.

37.16.5. Operator Classes and Operator Families

So far we have implicitly assumed that an operator class deals with only one data type. While there certainly can be only one data type in a particular index column, it is often useful to index operations that compare an indexed column to a value of a different data type. Also, if there is use for a cross-data-type operator in connection with an operator class, it is often the case that the other data type has a related operator class of its own. It is helpful to make the connections between related classes explicit, because this can aid the planner in optimizing SQL queries (particularly for B-tree operator classes, since the planner contains a great deal of knowledge about how to work with them).

To handle these needs, PostgreSQL uses the concept of an *operator family*. An operator family contains one or more operator classes, and can also contain indexable operators and corresponding support functions that belong to the family as a whole but not to any single class within the family. We say that such operators and functions are “loose” within the family, as opposed to being bound into a specific class. Typically each operator class contains single-data-type operators while cross-data-type operators are loose in the family.

All the operators and functions in an operator family must have compatible semantics, where the compatibility requirements are set by the index method. You might therefore wonder why bother to single out particular subsets of the family as operator classes; and indeed for many purposes the class divisions are irrelevant and the family is the only interesting grouping. The reason for defining operator classes is that they specify how much of the family is needed to support any particular index. If there is an index using an operator class, then that operator class cannot be dropped without dropping the index — but other parts of the operator family, namely other operator classes and loose operators, could be dropped. Thus, an operator class should be specified to contain the minimum set of operators and functions that are reasonably needed to work with an index on a specific data type, and then related but non-essential operators can be added as loose members of the operator family.

As an example, PostgreSQL has a built-in B-tree operator family `integer_ops`, which includes operator classes `int8_ops`, `int4_ops`, and `int2_ops` for indexes on `bigint` (`int8`), `integer` (`int4`), and `smallint` (`int2`) columns respectively. The family also contains cross-data-type comparison operators allowing any two of these types to be compared, so that an index on one of these types can be searched using a comparison value of another type. The family could be duplicated by these definitions:

```
CREATE OPERATOR FAMILY integer_ops USING btree;

CREATE OPERATOR CLASS int8_ops
DEFAULT FOR TYPE int8 USING btree FAMILY integer_ops AS
  -- standard int8 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
  FUNCTION 1 btint8cmp(int8, int8) ,
  FUNCTION 2 btint8sortsupport(internal) ,
  FUNCTION 3 in_range(int8, int8, int8, boolean, boolean) ;

CREATE OPERATOR CLASS int4_ops
DEFAULT FOR TYPE int4 USING btree FAMILY integer_ops AS
  -- standard int4 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
  FUNCTION 1 btint4cmp(int4, int4) ,
  FUNCTION 2 btint4sortsupport(internal) ,
  FUNCTION 3 in_range(int4, int4, int4, boolean, boolean) ;

CREATE OPERATOR CLASS int2_ops
DEFAULT FOR TYPE int2 USING btree FAMILY integer_ops AS
  -- standard int2 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
  FUNCTION 1 btint2cmp(int2, int2) ,
  FUNCTION 2 btint2sortsupport(internal) ,
  FUNCTION 3 in_range(int2, int2, int2, boolean, boolean) ;

ALTER OPERATOR FAMILY integer_ops USING btree ADD
```

```

-- cross-type comparisons int8 vs int2
OPERATOR 1 < (int8, int2) ,
OPERATOR 2 <= (int8, int2) ,
OPERATOR 3 = (int8, int2) ,
OPERATOR 4 >= (int8, int2) ,
OPERATOR 5 > (int8, int2) ,
FUNCTION 1 btint82cmp(int8, int2) ,

-- cross-type comparisons int8 vs int4
OPERATOR 1 < (int8, int4) ,
OPERATOR 2 <= (int8, int4) ,
OPERATOR 3 = (int8, int4) ,
OPERATOR 4 >= (int8, int4) ,
OPERATOR 5 > (int8, int4) ,
FUNCTION 1 btint84cmp(int8, int4) ,

-- cross-type comparisons int4 vs int2
OPERATOR 1 < (int4, int2) ,
OPERATOR 2 <= (int4, int2) ,
OPERATOR 3 = (int4, int2) ,
OPERATOR 4 >= (int4, int2) ,
OPERATOR 5 > (int4, int2) ,
FUNCTION 1 btint42cmp(int4, int2) ,

-- cross-type comparisons int4 vs int8
OPERATOR 1 < (int4, int8) ,
OPERATOR 2 <= (int4, int8) ,
OPERATOR 3 = (int4, int8) ,
OPERATOR 4 >= (int4, int8) ,
OPERATOR 5 > (int4, int8) ,
FUNCTION 1 btint48cmp(int4, int8) ,

-- cross-type comparisons int2 vs int8
OPERATOR 1 < (int2, int8) ,
OPERATOR 2 <= (int2, int8) ,
OPERATOR 3 = (int2, int8) ,
OPERATOR 4 >= (int2, int8) ,
OPERATOR 5 > (int2, int8) ,
FUNCTION 1 btint28cmp(int2, int8) ,

-- cross-type comparisons int2 vs int4
OPERATOR 1 < (int2, int4) ,
OPERATOR 2 <= (int2, int4) ,
OPERATOR 3 = (int2, int4) ,
OPERATOR 4 >= (int2, int4) ,
OPERATOR 5 > (int2, int4) ,
FUNCTION 1 btint24cmp(int2, int4) ,

-- cross-type in_range functions
FUNCTION 3 in_range(int4, int4, int8, boolean, boolean) ,
FUNCTION 3 in_range(int4, int4, int2, boolean, boolean) ,
FUNCTION 3 in_range(int2, int2, int8, boolean, boolean) ,
FUNCTION 3 in_range(int2, int2, int4, boolean, boolean) ;

```

Notice that this definition “overloads” the operator strategy and support function numbers: each number occurs multiple times within the family. This is allowed so long as each instance of a particular number has distinct input data types. The instances that have both input types equal to an operator

class's input type are the primary operators and support functions for that operator class, and in most cases should be declared as part of the operator class rather than as loose members of the family.

In a B-tree operator family, all the operators in the family must sort compatibly, as is specified in detail in Section 63.2. For each operator in the family there must be a support function having the same two input data types as the operator. It is recommended that a family be complete, i.e., for each combination of data types, all operators are included. Each operator class should include just the non-cross-type operators and support function for its data type.

To build a multiple-data-type hash operator family, compatible hash support functions must be created for each data type supported by the family. Here compatibility means that the functions are guaranteed to return the same hash code for any two values that are considered equal by the family's equality operators, even when the values are of different types. This is usually difficult to accomplish when the types have different physical representations, but it can be done in some cases. Furthermore, casting a value from one data type represented in the operator family to another data type also represented in the operator family via an implicit or binary coercion cast must not change the computed hash value. Notice that there is only one support function per data type, not one per equality operator. It is recommended that a family be complete, i.e., provide an equality operator for each combination of data types. Each operator class should include just the non-cross-type equality operator and the support function for its data type.

GiST, SP-GiST, and GIN indexes do not have any explicit notion of cross-data-type operations. The set of operators supported is just whatever the primary support functions for a given operator class can handle.

In BRIN, the requirements depends on the framework that provides the operator classes. For operator classes based on `minmax`, the behavior required is the same as for B-tree operator families: all the operators in the family must sort compatibly, and casts must not change the associated sort ordering.

Note

Prior to PostgreSQL 8.3, there was no concept of operator families, and so any cross-data-type operators intended to be used with an index had to be bound directly into the index's operator class. While this approach still works, it is deprecated because it makes an index's dependencies too broad, and because the planner can handle cross-data-type comparisons more effectively when both data types have operators in the same operator family.

37.16.6. System Dependencies on Operator Classes

PostgreSQL uses operator classes to infer the properties of operators in more ways than just whether they can be used with indexes. Therefore, you might want to create operator classes even if you have no intention of indexing any columns of your data type.

In particular, there are SQL features such as `ORDER BY` and `DISTINCT` that require comparison and sorting of values. To implement these features on a user-defined data type, PostgreSQL looks for the default B-tree operator class for the data type. The “equals” member of this operator class defines the system's notion of equality of values for `GROUP BY` and `DISTINCT`, and the sort ordering imposed by the operator class defines the default `ORDER BY` ordering.

If there is no default B-tree operator class for a data type, the system will look for a default hash operator class. But since that kind of operator class only provides equality, it is only able to support grouping not sorting.

When there is no default operator class for a data type, you will get errors like “could not identify an ordering operator” if you try to use these SQL features with the data type.

Note

In PostgreSQL versions before 7.4, sorting and grouping operations would implicitly use operators named =, <, and >. The new behavior of relying on default operator classes avoids having to make any assumption about the behavior of operators with particular names.

Sorting by a non-default B-tree operator class is possible by specifying the class's less-than operator in a USING option, for example

```
SELECT * FROM mytable ORDER BY somecol USING ~<~;
```

Alternatively, specifying the class's greater-than operator in USING selects a descending-order sort.

Comparison of arrays of a user-defined type also relies on the semantics defined by the type's default B-tree operator class. If there is no default B-tree operator class, but there is a default hash operator class, then array equality is supported, but not ordering comparisons.

Another SQL feature that requires even more data-type-specific knowledge is the RANGE *offset* PRECEDING/FOLLOWING framing option for window functions (see Section 4.2.8). For a query such as

```
SELECT sum(x) OVER (ORDER BY x RANGE BETWEEN 5 PRECEDING AND 10
    FOLLOWING)
    FROM mytable;
```

it is not sufficient to know how to order by *x*; the database must also understand how to “subtract 5” or “add 10” to the current row's value of *x* to identify the bounds of the current window frame. Comparing the resulting bounds to other rows' values of *x* is possible using the comparison operators provided by the B-tree operator class that defines the ORDER BY ordering — but addition and subtraction operators are not part of the operator class, so which ones should be used? Hard-wiring that choice would be undesirable, because different sort orders (different B-tree operator classes) might need different behavior. Therefore, a B-tree operator class can specify an *in_range* support function that encapsulates the addition and subtraction behaviors that make sense for its sort order. It can even provide more than one *in_range* support function, in case there is more than one data type that makes sense to use as the offset in RANGE clauses. If the B-tree operator class associated with the window's ORDER BY clause does not have a matching *in_range* support function, the RANGE *offset* PRECEDING/FOLLOWING option is not supported.

Another important point is that an equality operator that appears in a hash operator family is a candidate for hash joins, hash aggregation, and related optimizations. The hash operator family is essential here since it identifies the hash function(s) to use.

37.16.7. Ordering Operators

Some index access methods (currently, only GiST and SP-GiST) support the concept of *ordering operators*. What we have been discussing so far are *search operators*. A search operator is one for which the index can be searched to find all rows satisfying WHERE *indexed_column operator constant*. Note that nothing is promised about the order in which the matching rows will be returned. In contrast, an ordering operator does not restrict the set of rows that can be returned, but instead determines their order. An ordering operator is one for which the index can be scanned to return rows in the order represented by ORDER BY *indexed_column operator constant*. The reason for defining ordering operators that way is that it supports nearest-neighbor searches, if the operator is one that measures distance. For example, a query like

```
SELECT * FROM places ORDER BY location <-> point '(101,456)' LIMIT
10;
```

finds the ten places closest to a given target point. A GiST index on the location column can do this efficiently because <-> is an ordering operator.

While search operators have to return Boolean results, ordering operators usually return some other type, such as float or numeric for distances. This type is normally not the same as the data type being indexed. To avoid hard-wiring assumptions about the behavior of different data types, the definition of an ordering operator is required to name a B-tree operator family that specifies the sort ordering of the result data type. As was stated in the previous section, B-tree operator families define PostgreSQL's notion of ordering, so this is a natural representation. Since the point <-> operator returns float8, it could be specified in an operator class creation command like this:

```
OPERATOR 15 <-> (point, point) FOR ORDER BY float_ops
```

where float_ops is the built-in operator family that includes operations on float8. This declaration states that the index is able to return rows in order of increasing values of the <-> operator.

37.16.8. Special Features of Operator Classes

There are two special features of operator classes that we have not discussed yet, mainly because they are not useful with the most commonly used index methods.

Normally, declaring an operator as a member of an operator class (or family) means that the index method can retrieve exactly the set of rows that satisfy a WHERE condition using the operator. For example:

```
SELECT * FROM table WHERE integer_column < 4;
```

can be satisfied exactly by a B-tree index on the integer column. But there are cases where an index is useful as an inexact guide to the matching rows. For example, if a GiST index stores only bounding boxes for geometric objects, then it cannot exactly satisfy a WHERE condition that tests overlap between nonrectangular objects such as polygons. Yet we could use the index to find objects whose bounding box overlaps the bounding box of the target object, and then do the exact overlap test only on the objects found by the index. If this scenario applies, the index is said to be “lossy” for the operator. Lossy index searches are implemented by having the index method return a *recheck* flag when a row might or might not really satisfy the query condition. The core system will then test the original query condition on the retrieved row to see whether it should be returned as a valid match. This approach works if the index is guaranteed to return all the required rows, plus perhaps some additional rows, which can be eliminated by performing the original operator invocation. The index methods that support lossy searches (currently, GiST, SP-GiST and GIN) allow the support functions of individual operator classes to set the recheck flag, and so this is essentially an operator-class feature.

Consider again the situation where we are storing in the index only the bounding box of a complex object such as a polygon. In this case there's not much value in storing the whole polygon in the index entry — we might as well store just a simpler object of type box. This situation is expressed by the STORAGE option in CREATE OPERATOR CLASS: we'd write something like:

```
CREATE OPERATOR CLASS polygon_ops
    DEFAULT FOR TYPE polygon USING gist AS
    ...
    STORAGE box;
```

At present, only the GiST, GIN and BRIN index methods support a `STORAGE` type that's different from the column data type. The GiST `compress` and `decompress` support routines must deal with data-type conversion when `STORAGE` is used. In GIN, the `STORAGE` type identifies the type of the “key” values, which normally is different from the type of the indexed column — for example, an operator class for integer-array columns might have keys that are just integers. The GIN `extract-Value` and `extractQuery` support routines are responsible for extracting keys from indexed values. BRIN is similar to GIN: the `STORAGE` type identifies the type of the stored summary values, and operator classes' support procedures are responsible for interpreting the summary values correctly.

37.17. Packaging Related Objects into an Extension

A useful extension to PostgreSQL typically includes multiple SQL objects; for example, a new data type will require new functions, new operators, and probably new index operator classes. It is helpful to collect all these objects into a single package to simplify database management. PostgreSQL calls such a package an *extension*. To define an extension, you need at least a *script file* that contains the SQL commands to create the extension's objects, and a *control file* that specifies a few basic properties of the extension itself. If the extension includes C code, there will typically also be a shared library file into which the C code has been built. Once you have these files, a simple `CREATE EXTENSION` command loads the objects into your database.

The main advantage of using an extension, rather than just running the SQL script to load a bunch of “loose” objects into your database, is that PostgreSQL will then understand that the objects of the extension go together. You can drop all the objects with a single `DROP EXTENSION` command (no need to maintain a separate “uninstall” script). Even more useful, `pg_dump` knows that it should not dump the individual member objects of the extension — it will just include a `CREATE EXTENSION` command in dumps, instead. This vastly simplifies migration to a new version of the extension that might contain more or different objects than the old version. Note however that you must have the extension's control, script, and other files available when loading such a dump into a new database.

PostgreSQL will not let you drop an individual object contained in an extension, except by dropping the whole extension. Also, while you can change the definition of an extension member object (for example, via `CREATE OR REPLACE FUNCTION` for a function), bear in mind that the modified definition will not be dumped by `pg_dump`. Such a change is usually only sensible if you concurrently make the same change in the extension's script file. (But there are special provisions for tables containing configuration data; see Section 37.17.4.) In production situations, it's generally better to create an extension update script to perform changes to extension member objects.

The extension script may set privileges on objects that are part of the extension via `GRANT` and `REVOKE` statements. The final set of privileges for each object (if any are set) will be stored in the `pg_init_privs` system catalog. When `pg_dump` is used, the `CREATE EXTENSION` command will be included in the dump, followed by the set of `GRANT` and `REVOKE` statements necessary to set the privileges on the objects to what they were at the time the dump was taken.

PostgreSQL does not currently support extension scripts issuing `CREATE POLICY` or `SECURITY LABEL` statements. These are expected to be set after the extension has been created. All RLS policies and security labels on extension objects will be included in dumps created by `pg_dump`.

The extension mechanism also has provisions for packaging modification scripts that adjust the definitions of the SQL objects contained in an extension. For example, if version 1.1 of an extension adds one function and changes the body of another function compared to 1.0, the extension author can provide an *update script* that makes just those two changes. The `ALTER EXTENSION UPDATE` command can then be used to apply these changes and track which version of the extension is actually installed in a given database.

The kinds of SQL objects that can be members of an extension are shown in the description of `ALTER EXTENSION`. Notably, objects that are database-cluster-wide, such as databases, roles, and tablespaces, cannot be extension members since an extension is only known within one database. (Al-

though an extension script is not prohibited from creating such objects, if it does so they will not be tracked as part of the extension.) Also notice that while a table can be a member of an extension, its subsidiary objects such as indexes are not directly considered members of the extension. Another important point is that schemas can belong to extensions, but not vice versa: an extension as such has an unqualified name and does not exist “within” any schema. The extension’s member objects, however, will belong to schemas whenever appropriate for their object types. It may or may not be appropriate for an extension to own the schema(s) its member objects are within.

If an extension’s script creates any temporary objects (such as temp tables), those objects are treated as extension members for the remainder of the current session, but are automatically dropped at session end, as any temporary object would be. This is an exception to the rule that extension member objects cannot be dropped without dropping the whole extension.

37.17.1. Defining Extension Objects

Widely-distributed extensions should assume little about the database they occupy. In particular, unless you issued `SET search_path = pg_temp`, assume each unqualified name could resolve to an object that a malicious user has defined. Beware of constructs that depend on `search_path` implicitly: `IN` and `CASE expression WHEN` always select an operator using the search path. In their place, use `OPERATOR(schema.=) ANY` and `CASE WHEN expression`.

37.17.2. Extension Files

The `CREATE EXTENSION` command relies on a control file for each extension, which must be named the same as the extension with a suffix of `.control`, and must be placed in the installation’s `SHAREDIR/extension` directory. There must also be at least one SQL script file, which follows the naming pattern `extension--version.sql` (for example, `foo--1.0.sql` for version 1.0 of extension `foo`). By default, the script file(s) are also placed in the `SHAREDIR/extension` directory; but the control file can specify a different directory for the script file(s).

The file format for an extension control file is the same as for the `postgresql.conf` file, namely a list of `parameter_name = value` assignments, one per line. Blank lines and comments introduced by `#` are allowed. Be sure to quote any value that is not a single word or number.

A control file can set the following parameters:

`directory (string)`

The directory containing the extension’s SQL script file(s). Unless an absolute path is given, the name is relative to the installation’s `SHAREDIR` directory. The default behavior is equivalent to specifying `directory = 'extension'`.

`default_version (string)`

The default version of the extension (the one that will be installed if no version is specified in `CREATE EXTENSION`). Although this can be omitted, that will result in `CREATE EXTENSION` failing if no `VERSION` option appears, so you generally don’t want to do that.

`comment (string)`

A comment (any string) about the extension. The comment is applied when initially creating an extension, but not during extension updates (since that might override user-added comments). Alternatively, the extension’s comment can be set by writing a `COMMENT` command in the script file.

`encoding (string)`

The character set encoding used by the script file(s). This should be specified if the script files contain any non-ASCII characters. Otherwise the files will be assumed to be in the database encoding.

`module_pathname` (string)

The value of this parameter will be substituted for each occurrence of `MODULE_PATHNAME` in the script file(s). If it is not set, no substitution is made. Typically, this is set to `$lib-dir/shared_library_name` and then `MODULE_PATHNAME` is used in `CREATE FUNCTION` commands for C-language functions, so that the script files do not need to hard-wire the name of the shared library.

`requires` (string)

A list of names of extensions that this extension depends on, for example `requires = 'foo, bar'`. Those extensions must be installed before this one can be installed.

`superuser` (boolean)

If this parameter is `true` (which is the default), only superusers can create the extension or update it to a new version. If it is set to `false`, just the privileges required to execute the commands in the installation or update script are required.

`relocatable` (boolean)

An extension is *relocatable* if it is possible to move its contained objects into a different schema after initial creation of the extension. The default is `false`, i.e. the extension is not relocatable. See Section 37.17.3 for more information.

`schema` (string)

This parameter can only be set for non-relocatable extensions. It forces the extension to be loaded into exactly the named schema and not any other. The `schema` parameter is consulted only when initially creating an extension, not during extension updates. See Section 37.17.3 for more information.

In addition to the primary control file `extension.control`, an extension can have secondary control files named in the style `extension--version.control`. If supplied, these must be located in the script file directory. Secondary control files follow the same format as the primary control file. Any parameters set in a secondary control file override the primary control file when installing or updating to that version of the extension. However, the parameters `directory` and `default_version` cannot be set in a secondary control file.

An extension's SQL script files can contain any SQL commands, except for transaction control commands (`BEGIN`, `COMMIT`, etc) and commands that cannot be executed inside a transaction block (such as `VACUUM`). This is because the script files are implicitly executed within a transaction block.

An extension's SQL script files can also contain lines beginning with `\echo`, which will be ignored (treated as comments) by the extension mechanism. This provision is commonly used to throw an error if the script file is fed to `psql` rather than being loaded via `CREATE EXTENSION` (see example script in Section 37.17.7). Without that, users might accidentally load the extension's contents as “loose” objects rather than as an extension, a state of affairs that's a bit tedious to recover from.

While the script files can contain any characters allowed by the specified encoding, control files should contain only plain ASCII, because there is no way for PostgreSQL to know what encoding a control file is in. In practice this is only an issue if you want to use non-ASCII characters in the extension's comment. Recommended practice in that case is to not use the control file `comment` parameter, but instead use `COMMENT ON EXTENSION` within a script file to set the comment.

37.17.3. Extension Relocatability

Users often wish to load the objects contained in an extension into a different schema than the extension's author had in mind. There are three supported levels of relocatability:

- A fully relocatable extension can be moved into another schema at any time, even after it's been loaded into a database. This is done with the `ALTER EXTENSION SET SCHEMA` command, which automatically renames all the member objects into the new schema. Normally, this is only possible if the extension contains no internal assumptions about what schema any of its objects are in. Also, the extension's objects must all be in one schema to begin with (ignoring objects that do not belong to any schema, such as procedural languages). Mark a fully relocatable extension by setting `relocatable = true` in its control file.
- An extension might be relocatable during installation but not afterwards. This is typically the case if the extension's script file needs to reference the target schema explicitly, for example in setting `search_path` properties for SQL functions. For such an extension, set `relocatable = false` in its control file, and use `@extschema@` to refer to the target schema in the script file. All occurrences of this string will be replaced by the actual target schema's name before the script is executed. The user can set the target schema using the `SCHEMA` option of `CREATE EXTENSION`.
- If the extension does not support relocation at all, set `relocatable = false` in its control file, and also set `schema` to the name of the intended target schema. This will prevent use of the `SCHEMA` option of `CREATE EXTENSION`, unless it specifies the same schema named in the control file. This choice is typically necessary if the extension contains internal assumptions about schema names that can't be replaced by uses of `@extschema@`. The `@extschema@` substitution mechanism is available in this case too, although it is of limited use since the schema name is determined by the control file.

In all cases, the script file will be executed with `search_path` initially set to point to the target schema; that is, `CREATE EXTENSION` does the equivalent of this:

```
SET LOCAL search_path TO @extschema@;
```

This allows the objects created by the script file to go into the target schema. The script file can change `search_path` if it wishes, but that is generally undesirable. `search_path` is restored to its previous setting upon completion of `CREATE EXTENSION`.

The target schema is determined by the `schema` parameter in the control file if that is given, otherwise by the `SCHEMA` option of `CREATE EXTENSION` if that is given, otherwise the current default object creation schema (the first one in the caller's `search_path`). When the control file `schema` parameter is used, the target schema will be created if it doesn't already exist, but in the other two cases it must already exist.

If any prerequisite extensions are listed in `requires` in the control file, their target schemas are appended to the initial setting of `search_path`. This allows their objects to be visible to the new extension's script file.

Although a non-relocatable extension can contain objects spread across multiple schemas, it is usually desirable to place all the objects meant for external use into a single schema, which is considered the extension's target schema. Such an arrangement works conveniently with the default setting of `search_path` during creation of dependent extensions.

37.17.4. Extension Configuration Tables

Some extensions include configuration tables, which contain data that might be added or changed by the user after installation of the extension. Ordinarily, if a table is part of an extension, neither the table's definition nor its content will be dumped by `pg_dump`. But that behavior is undesirable for a configuration table; any data changes made by the user need to be included in dumps, or the extension will behave differently after a dump and reload.

To solve this problem, an extension's script file can mark a table or a sequence it has created as a configuration relation, which will cause `pg_dump` to include the table's or the sequence's contents (not its

definition) in dumps. To do that, call the function `pg_extension_config_dump(regclass, text)` after creating the table or the sequence, for example

```
CREATE TABLE my_config (key text, value text);
CREATE SEQUENCE my_config_seq;

SELECT pg_catalog.pg_extension_config_dump('my_config', '');
SELECT pg_catalog.pg_extension_config_dump('my_config_seq', '');
```

Any number of tables or sequences can be marked this way. Sequences associated with `serial` or `bigserial` columns can be marked as well.

When the second argument of `pg_extension_config_dump` is an empty string, the entire contents of the table are dumped by `pg_dump`. This is usually only correct if the table is initially empty as created by the extension script. If there is a mixture of initial data and user-provided data in the table, the second argument of `pg_extension_config_dump` provides a `WHERE` condition that selects the data to be dumped. For example, you might do

```
CREATE TABLE my_config (key text, value text, standard_entry
    boolean);

SELECT pg_catalog.pg_extension_config_dump('my_config', 'WHERE NOT
    standard_entry');
```

and then make sure that `standard_entry` is true only in the rows created by the extension's script.

For sequences, the second argument of `pg_extension_config_dump` has no effect.

More complicated situations, such as initially-provided rows that might be modified by users, can be handled by creating triggers on the configuration table to ensure that modified rows are marked correctly.

You can alter the filter condition associated with a configuration table by calling `pg_extension_config_dump` again. (This would typically be useful in an extension update script.) The only way to mark a table as no longer a configuration table is to dissociate it from the extension with `ALTER EXTENSION ... DROP TABLE`.

Note that foreign key relationships between these tables will dictate the order in which the tables are dumped out by `pg_dump`. Specifically, `pg_dump` will attempt to dump the referenced-by table before the referencing table. As the foreign key relationships are set up at `CREATE EXTENSION` time (prior to data being loaded into the tables) circular dependencies are not supported. When circular dependencies exist, the data will still be dumped out but the dump will not be able to be restored directly and user intervention will be required.

Sequences associated with `serial` or `bigserial` columns need to be directly marked to dump their state. Marking their parent relation is not enough for this purpose.

37.17.5. Extension Updates

One advantage of the extension mechanism is that it provides convenient ways to manage updates to the SQL commands that define an extension's objects. This is done by associating a version name or number with each released version of the extension's installation script. In addition, if you want users to be able to update their databases dynamically from one version to the next, you should provide *update scripts* that make the necessary changes to go from one version to the next. Update scripts have names following the pattern `extension--old_version--target_version.sql` (for example, `foo--1.0--1.1.sql` contains the commands to modify version 1.0 of extension `foo` into version 1.1).

Given that a suitable update script is available, the command `ALTER EXTENSION UPDATE` will update an installed extension to the specified new version. The update script is run in the same environment that `CREATE EXTENSION` provides for installation scripts: in particular, `search_path` is set up in the same way, and any new objects created by the script are automatically added to the extension. Also, if the script chooses to drop extension member objects, they are automatically dissociated from the extension.

If an extension has secondary control files, the control parameters that are used for an update script are those associated with the script's target (new) version.

The update mechanism can be used to solve an important special case: converting a “loose” collection of objects into an extension. Before the extension mechanism was added to PostgreSQL (in 9.1), many people wrote extension modules that simply created assorted unpackaged objects. Given an existing database containing such objects, how can we convert the objects into a properly packaged extension? Dropping them and then doing a plain `CREATE EXTENSION` is one way, but it's not desirable if the objects have dependencies (for example, if there are table columns of a data type created by the extension). The way to fix this situation is to create an empty extension, then use `ALTER EXTENSION ADD` to attach each pre-existing object to the extension, then finally create any new objects that are in the current extension version but were not in the unpackaged release. `CREATE EXTENSION` supports this case with its `FROM old_version` option, which causes it to not run the normal installation script for the target version, but instead the update script named `extension--old_version--target_version.sql`. The choice of the dummy version name to use as `old_version` is up to the extension author, though `unpackaged` is a common convention. If you have multiple prior versions you need to be able to update into extension style, use multiple dummy version names to identify them.

`ALTER EXTENSION` is able to execute sequences of update script files to achieve a requested update. For example, if only `foo--1.0--1.1.sql` and `foo--1.1--2.0.sql` are available, `ALTER EXTENSION` will apply them in sequence if an update to version 2.0 is requested when 1.0 is currently installed.

PostgreSQL doesn't assume anything about the properties of version names: for example, it does not know whether 1.1 follows 1.0. It just matches up the available version names and follows the path that requires applying the fewest update scripts. (A version name can actually be any string that doesn't contain `--` or leading or trailing `-`.)

Sometimes it is useful to provide “downgrade” scripts, for example `foo--1.1--1.0.sql` to allow reverting the changes associated with version 1.1. If you do that, be careful of the possibility that a downgrade script might unexpectedly get applied because it yields a shorter path. The risky case is where there is a “fast path” update script that jumps ahead several versions as well as a downgrade script to the fast path's start point. It might take fewer steps to apply the downgrade and then the fast path than to move ahead one version at a time. If the downgrade script drops any irreplaceable objects, this will yield undesirable results.

To check for unexpected update paths, use this command:

```
SELECT * FROM pg_extension_update_paths('extension_name');
```

This shows each pair of distinct known version names for the specified extension, together with the update path sequence that would be taken to get from the source version to the target version, or `NULL` if there is no available update path. The path is shown in textual form with `--` separators. You can use `regexp_split_to_array(path, '--')` if you prefer an array format.

37.17.6. Installing Extensions Using Update Scripts

An extension that has been around for awhile will probably exist in several versions, for which the author will need to write update scripts. For example, if you have released a `foo` extension in versions 1.0, 1.1, and 1.2, there should be update scripts `foo--1.0--1.1.sql` and `foo--1.1--1.2.sql`. Before PostgreSQL 10, it was necessary to also create new script

files `foo--1.1.sql` and `foo--1.2.sql` that directly build the newer extension versions, or else the newer versions could not be installed directly, only by installing 1.0 and then updating. That was tedious and duplicative, but now it's unnecessary, because `CREATE EXTENSION` can follow update chains automatically. For example, if only the script files `foo--1.0.sql`, `foo--1.0--1.1.sql`, and `foo--1.1--1.2.sql` are available then a request to install version 1.2 is honored by running those three scripts in sequence. The processing is the same as if you'd first installed 1.0 and then updated to 1.2. (As with `ALTER EXTENSION UPDATE`, if multiple pathways are available then the shortest is preferred.) Arranging an extension's script files in this style can reduce the amount of maintenance effort needed to produce small updates.

If you use secondary (version-specific) control files with an extension maintained in this style, keep in mind that each version needs a control file even if it has no stand-alone installation script, as that control file will determine how the implicit update to that version is performed. For example, if `foo--1.0.control` specifies `requires = 'bar'` but `foo`'s other control files do not, the extension's dependency on `bar` will be dropped when updating from 1.0 to another version.

37.17.7. Extension Example

Here is a complete example of an SQL-only extension, a two-element composite type that can store any type of value in its slots, which are named “k” and “v”. Non-text values are automatically coerced to text for storage.

The script file `pair--1.0.sql` looks like this:

```
-- complain if script is sourced in psql, rather than via CREATE
EXTENSION
\echo Use "CREATE EXTENSION pair" to load this file. \quit

CREATE TYPE pair AS ( k text, v text );

CREATE OR REPLACE FUNCTION pair(text, text)
RETURNS pair LANGUAGE SQL AS 'SELECT ROW($1,
    $2)::@extschema@.pair;';

CREATE OPERATOR ~> (LEFTARG = text, RIGHTARG = text, FUNCTION =
    pair);

-- "SET search_path" is easy to get right, but qualified names
    perform better.
CREATE OR REPLACE FUNCTION lower(pair)
RETURNS pair LANGUAGE SQL
AS 'SELECT ROW(lower($1.k), lower($1.v))::@extschema@.pair;';
SET search_path = pg_temp;

CREATE OR REPLACE FUNCTION pair_concat(pair, pair)
RETURNS pair LANGUAGE SQL
AS 'SELECT ROW($1.k OPERATOR(pg_catalog.||) $2.k,
    $1.v OPERATOR(pg_catalog.||)
    $2.v)::@extschema@.pair;';
```

The control file `pair.control` looks like this:

```
# pair extension
comment = 'A key/value pair data type'
default_version = '1.0'
```

```
relocatable = false
```

While you hardly need a makefile to install these two files into the correct directory, you could use a Makefile containing this:

```
EXTENSION = pair
DATA = pair--1.0.sql

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

This makefile relies on PGXS, which is described in Section 37.18. The command `make install` will install the control and script files into the correct directory as reported by `pg_config`.

Once the files are installed, use the `CREATE EXTENSION` command to load the objects into any particular database.

37.18. Extension Building Infrastructure

If you are thinking about distributing your PostgreSQL extension modules, setting up a portable build system for them can be fairly difficult. Therefore the PostgreSQL installation provides a build infrastructure for extensions, called PGXS, so that simple extension modules can be built simply against an already installed server. PGXS is mainly intended for extensions that include C code, although it can be used for pure-SQL extensions too. Note that PGXS is not intended to be a universal build system framework that can be used to build any software interfacing to PostgreSQL; it simply automates common build rules for simple server extension modules. For more complicated packages, you might need to write your own build system.

To use the PGXS infrastructure for your extension, you must write a simple makefile. In the makefile, you need to set some variables and include the global PGXS makefile. Here is an example that builds an extension module named `isbn_issn`, consisting of a shared library containing some C code, an extension control file, a SQL script, an include file (only needed if other modules might need to access the extension functions without going via SQL), and a documentation text file:

```
MODULES = isbn_issn
EXTENSION = isbn_issn
DATA = isbn_issn--1.0.sql
DOCS = README.isbn_issn
HEADERS_isbn_issn = isbn_issn.h

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

The last three lines should always be the same. Earlier in the file, you assign variables or add custom make rules.

Set one of these three variables to specify what is built:

`MODULES`

list of shared-library objects to be built from source files with same stem (do not include library suffixes in this list)

`MODULE_big`

a shared library to build from multiple source files (list object files in `OBJS`)

PROGRAM

an executable program to build (list object files in OBJS)

The following variables can also be set:

EXTENSION

extension name(s); for each name you must provide an *extension.control* file, which will be installed into *prefix/share/extension*

MODULEDIR

subdirectory of *prefix/share* into which DATA and DOCS files should be installed (if not set, default is *extension* if EXTENSION is set, or *contrib* if not)

DATA

random files to install into *prefix/share/\$MODULEDIR*

DATA_built

random files to install into *prefix/share/\$MODULEDIR*, which need to be built first

DATA_TSEARCH

random files to install under *prefix/share/tsearch_data*

DOCS

random files to install under *prefix/doc/\$MODULEDIR*

HEADERS

HEADERS_built

Files to (optionally build and) install under *prefix/include/server/\$MODULEDIR/\$MODULE_big*.

Unlike DATA_built, files in HEADERS_built are not removed by the `clean` target; if you want them removed, also add them to EXTRA_CLEAN or add your own rules to do it.

HEADERS_\$MODULE

HEADERS_built_\$MODULE

Files to install (after building if specified) under *prefix/include/server/\$MODULEDIR/\$MODULE*, where \$MODULE must be a module name used in MODULES or MODULE_big.

Unlike DATA_built, files in HEADERS_built_\$MODULE are not removed by the `clean` target; if you want them removed, also add them to EXTRA_CLEAN or add your own rules to do it.

It is legal to use both variables for the same module, or any combination, unless you have two module names in the MODULES list that differ only by the presence of a prefix `built_`, which would cause ambiguity. In that (hopefully unlikely) case, you should use only the HEADERS_built_\$MODULE variables.

SCRIPTS

script files (not binaries) to install into *prefix/bin*

SCRIPTS_built

script files (not binaries) to install into *prefix/bin*, which need to be built first

REGRESS

list of regression test cases (without suffix), see below

REGRESS_OPTS

additional switches to pass to `pg_regress`

ISOLATION

list of isolation test cases, see below for more details

ISOLATION_OPTS

additional switches to pass to `pg_isolation_regress`

TAP_TESTS

switch defining if TAP tests need to be run, see below

NO_INSTALLCHECK

don't define an `installcheck` target, useful e.g. if tests require special configuration, or don't use `pg_regress`

EXTRA_CLEAN

extra files to remove in `make clean`

PG_CPPFLAGS

will be prepended to `CPPFLAGS`

PG_CFLAGS

will be appended to `CFLAGS`

PG_CXXFLAGS

will be appended to `CXXFLAGS`

PG_LDFLAGS

will be prepended to `LDLIBS`

PG_LIBS

will be added to `PROGRAM` link line

SHLIB_LINK

will be added to `MODULE_big` link line

PG_CONFIG

path to `pg_config` program for the PostgreSQL installation to build against (typically just `pg_config` to use the first one in your `PATH`)

Put this makefile as `Makefile` in the directory which holds your extension. Then you can do `make` to compile, and then `make install` to install your module. By default, the extension is compiled and installed for the PostgreSQL installation that corresponds to the first `pg_config` program found in your `PATH`. You can use a different installation by setting `PG_CONFIG` to point to its `pg_config` program, either within the makefile or on the `make` command line.

You can also run `make` in a directory outside the source tree of your extension, if you want to keep the build directory separate. This procedure is also called a *VPATH* build. Here's how:

```
mkdir build_dir
cd build_dir
make -f /path/to/extension/source/tree/Makefile
make -f /path/to/extension/source/tree/Makefile install
```

Alternatively, you can set up a directory for a *VPATH* build in a similar way to how it is done for the core code. One way to do this is using the core script `config/prepare_buildtree`. Once this has been done you can build by setting the `make` variable `VPATH` like this:

```
make VPATH=/path/to/extension/source/tree
make VPATH=/path/to/extension/source/tree install
```

This procedure can work with a greater variety of directory layouts.

The scripts listed in the `REGRESS` variable are used for regression testing of your module, which can be invoked by `make installcheck` after doing `make install`. For this to work you must have a running PostgreSQL server. The script files listed in `REGRESS` must appear in a subdirectory named `sql/` in your extension's directory. These files must have extension `.sql`, which must not be included in the `REGRESS` list in the makefile. For each test there should also be a file containing the expected output in a subdirectory named `expected/`, with the same stem and extension `.out`. `make installcheck` executes each test script with `psql`, and compares the resulting output to the matching expected file. Any differences will be written to the file `regression.diffs` in `diff -c` format. Note that trying to run a test that is missing its expected file will be reported as “trouble”, so make sure you have all expected files.

The scripts listed in the `ISOLATION` variable are used for tests stressing behavior of concurrent session with your module, which can be invoked by `make installcheck` after doing `make install`. For this to work you must have a running PostgreSQL server. The script files listed in `ISOLATION` must appear in a subdirectory named `specs/` in your extension's directory. These files must have extension `.spec`, which must not be included in the `ISOLATION` list in the makefile. For each test there should also be a file containing the expected output in a subdirectory named `expected/`, with the same stem and extension `.out`. `make installcheck` executes each test script, and compares the resulting output to the matching expected file. Any differences will be written to the file `output_iso/regression.diffs` in `diff -c` format. Note that trying to run a test that is missing its expected file will be reported as “trouble”, so make sure you have all expected files.

`TAP_TESTS` enables the use of TAP tests. Data from each run is present in a subdirectory named `tmp_check/`. See also Section 32.4 for more details.

Tip

The easiest way to create the expected files is to create empty files, then do a test run (which will of course report differences). Inspect the actual result files found in the `results/` directory (for tests in `REGRESS`), or `output_iso/results/` directory (for tests in `ISOLATION`), then copy them to `expected/` if they match what you expect from the test.

Chapter 38. Triggers

This chapter provides general information about writing trigger functions. Trigger functions can be written in most of the available procedural languages, including PL/pgSQL (Chapter 42), PL/Tcl (Chapter 43), PL/Perl (Chapter 44), and PL/Python (Chapter 45). After reading this chapter, you should consult the chapter for your favorite procedural language to find out the language-specific details of writing a trigger in it.

It is also possible to write a trigger function in C, although most people find it easier to use one of the procedural languages. It is not currently possible to write a trigger function in the plain SQL function language.

38.1. Overview of Trigger Behavior

A trigger is a specification that the database should automatically execute a particular function whenever a certain type of operation is performed. Triggers can be attached to tables (partitioned or not), views, and foreign tables.

On tables and foreign tables, triggers can be defined to execute either before or after any INSERT, UPDATE, or DELETE operation, either once per modified row, or once per SQL statement. UPDATE triggers can moreover be set to fire only if certain columns are mentioned in the SET clause of the UPDATE statement. Triggers can also fire for TRUNCATE statements. If a trigger event occurs, the trigger's function is called at the appropriate time to handle the event.

On views, triggers can be defined to execute instead of INSERT, UPDATE, or DELETE operations. Such INSTEAD OF triggers are fired once for each row that needs to be modified in the view. It is the responsibility of the trigger's function to perform the necessary modifications to the view's underlying base table(s) and, where appropriate, return the modified row as it will appear in the view. Triggers on views can also be defined to execute once per SQL statement, before or after INSERT, UPDATE, or DELETE operations. However, such triggers are fired only if there is also an INSTEAD OF trigger on the view. Otherwise, any statement targeting the view must be rewritten into a statement affecting its underlying base table(s), and then the triggers that will be fired are the ones attached to the base table(s).

The trigger function must be defined before the trigger itself can be created. The trigger function must be declared as a function taking no arguments and returning type `trigger`. (The trigger function receives its input through a specially-passed `TriggerData` structure, not in the form of ordinary function arguments.)

Once a suitable trigger function has been created, the trigger is established with CREATE TRIGGER. The same trigger function can be used for multiple triggers.

PostgreSQL offers both *per-row* triggers and *per-statement* triggers. With a per-row trigger, the trigger function is invoked once for each row that is affected by the statement that fired the trigger. In contrast, a per-statement trigger is invoked only once when an appropriate statement is executed, regardless of the number of rows affected by that statement. In particular, a statement that affects zero rows will still result in the execution of any applicable per-statement triggers. These two types of triggers are sometimes called *row-level* triggers and *statement-level* triggers, respectively. Triggers on TRUNCATE may only be defined at statement level, not per-row.

Triggers are also classified according to whether they fire *before*, *after*, or *instead of* the operation. These are referred to as BEFORE triggers, AFTER triggers, and INSTEAD OF triggers respectively. Statement-level BEFORE triggers naturally fire before the statement starts to do anything, while statement-level AFTER triggers fire at the very end of the statement. These types of triggers may be defined on tables, views, or foreign tables. Row-level BEFORE triggers fire immediately before a particular row is operated on, while row-level AFTER triggers fire at the end of the statement (but before any statement-level AFTER triggers). These types of triggers may only be defined on non-partitioned

tables and foreign tables, not views. `INSTEAD OF` triggers may only be defined on views, and only at row level; they fire immediately as each row in the view is identified as needing to be operated on.

A statement that targets a parent table in an inheritance or partitioning hierarchy does not cause the statement-level triggers of affected child tables to be fired; only the parent table's statement-level triggers are fired. However, row-level triggers of any affected child tables will be fired.

If an `INSERT` contains an `ON CONFLICT DO UPDATE` clause, it is possible that the effects of row-level `BEFORE INSERT` triggers and row-level `BEFORE UPDATE` triggers can both be applied in a way that is apparent from the final state of the updated row, if an `EXCLUDED` column is referenced. There need not be an `EXCLUDED` column reference for both sets of row-level `BEFORE` triggers to execute, though. The possibility of surprising outcomes should be considered when there are both `BEFORE INSERT` and `BEFORE UPDATE` row-level triggers that change a row being inserted/updated (this can be problematic even if the modifications are more or less equivalent, if they're not also idempotent). Note that statement-level `UPDATE` triggers are executed when `ON CONFLICT DO UPDATE` is specified, regardless of whether or not any rows were affected by the `UPDATE` (and regardless of whether the alternative `UPDATE` path was ever taken). An `INSERT` with an `ON CONFLICT DO UPDATE` clause will execute statement-level `BEFORE INSERT` triggers first, then statement-level `BEFORE UPDATE` triggers, followed by statement-level `AFTER UPDATE` triggers and finally statement-level `AFTER INSERT` triggers.

If an `UPDATE` on a partitioned table causes a row to move to another partition, it will be performed as a `DELETE` from the original partition followed by an `INSERT` into the new partition. In this case, all row-level `BEFORE UPDATE` triggers and all row-level `BEFORE DELETE` triggers are fired on the original partition. Then all row-level `BEFORE INSERT` triggers are fired on the destination partition. The possibility of surprising outcomes should be considered when all these triggers affect the row being moved. As far as `AFTER ROW` triggers are concerned, `AFTER DELETE` and `AFTER INSERT` triggers are applied; but `AFTER UPDATE` triggers are not applied because the `UPDATE` has been converted to a `DELETE` and an `INSERT`. As far as statement-level triggers are concerned, none of the `DELETE` or `INSERT` triggers are fired, even if row movement occurs; only the `UPDATE` triggers defined on the target table used in the `UPDATE` statement will be fired.

Trigger functions invoked by per-statement triggers should always return `NULL`. Trigger functions invoked by per-row triggers can return a table row (a value of type `HeapTuple`) to the calling executor, if they choose. A row-level trigger fired before an operation has the following choices:

- It can return `NULL` to skip the operation for the current row. This instructs the executor to not perform the row-level operation that invoked the trigger (the insertion, modification, or deletion of a particular table row).
- For row-level `INSERT` and `UPDATE` triggers only, the returned row becomes the row that will be inserted or will replace the row being updated. This allows the trigger function to modify the row being inserted or updated.

A row-level `BEFORE` trigger that does not intend to cause either of these behaviors must be careful to return as its result the same row that was passed in (that is, the `NEW` row for `INSERT` and `UPDATE` triggers, the `OLD` row for `DELETE` triggers).

A row-level `INSTEAD OF` trigger should either return `NULL` to indicate that it did not modify any data from the view's underlying base tables, or it should return the view row that was passed in (the `NEW` row for `INSERT` and `UPDATE` operations, or the `OLD` row for `DELETE` operations). A nonnull return value is used to signal that the trigger performed the necessary data modifications in the view. This will cause the count of the number of rows affected by the command to be incremented. For `INSERT` and `UPDATE` operations, the trigger may modify the `NEW` row before returning it. This will change the data returned by `INSERT RETURNING` or `UPDATE RETURNING`, and is useful when the view will not show exactly the same data that was provided.

The return value is ignored for row-level triggers fired after an operation, and so they can return `NULL`.

Some considerations apply for generated columns. Stored generated columns are computed after `BEFORE` triggers and before `AFTER` triggers. Therefore, the generated value can be inspected in `AFTER`

triggers. In `BEFORE` triggers, the `OLD` row contains the old generated value, as one would expect, but the `NEW` row does not yet contain the new generated value and should not be accessed. In the C language interface, the content of the column is undefined at this point; a higher-level programming language should prevent access to a stored generated column in the `NEW` row in a `BEFORE` trigger. Changes to the value of a generated column in a `BEFORE` trigger are ignored and will be overwritten.

If more than one trigger is defined for the same event on the same relation, the triggers will be fired in alphabetical order by trigger name. In the case of `BEFORE` and `INSTEAD OF` triggers, the possibly-modified row returned by each trigger becomes the input to the next trigger. If any `BEFORE` or `INSTEAD OF` trigger returns `NULL`, the operation is abandoned for that row and subsequent triggers are not fired (for that row).

A trigger definition can also specify a Boolean `WHEN` condition, which will be tested to see whether the trigger should be fired. In row-level triggers the `WHEN` condition can examine the old and/or new values of columns of the row. (Statement-level triggers can also have `WHEN` conditions, although the feature is not so useful for them.) In a `BEFORE` trigger, the `WHEN` condition is evaluated just before the function is or would be executed, so using `WHEN` is not materially different from testing the same condition at the beginning of the trigger function. However, in an `AFTER` trigger, the `WHEN` condition is evaluated just after the row update occurs, and it determines whether an event is queued to fire the trigger at the end of statement. So when an `AFTER` trigger's `WHEN` condition does not return true, it is not necessary to queue an event nor to re-fetch the row at end of statement. This can result in significant speedups in statements that modify many rows, if the trigger only needs to be fired for a few of the rows. `INSTEAD OF` triggers do not support `WHEN` conditions.

Typically, row-level `BEFORE` triggers are used for checking or modifying the data that will be inserted or updated. For example, a `BEFORE` trigger might be used to insert the current time into a `timestamp` column, or to check that two elements of the row are consistent. Row-level `AFTER` triggers are most sensibly used to propagate the updates to other tables, or make consistency checks against other tables. The reason for this division of labor is that an `AFTER` trigger can be certain it is seeing the final value of the row, while a `BEFORE` trigger cannot; there might be other `BEFORE` triggers firing after it. If you have no specific reason to make a trigger `BEFORE` or `AFTER`, the `BEFORE` case is more efficient, since the information about the operation doesn't have to be saved until end of statement.

If a trigger function executes SQL commands then these commands might fire triggers again. This is known as cascading triggers. There is no direct limitation on the number of cascade levels. It is possible for cascades to cause a recursive invocation of the same trigger; for example, an `INSERT` trigger might execute a command that inserts an additional row into the same table, causing the `INSERT` trigger to be fired again. It is the trigger programmer's responsibility to avoid infinite recursion in such scenarios.

When a trigger is being defined, arguments can be specified for it. The purpose of including arguments in the trigger definition is to allow different triggers with similar requirements to call the same function. As an example, there could be a generalized trigger function that takes as its arguments two column names and puts the current user in one and the current time stamp in the other. Properly written, this trigger function would be independent of the specific table it is triggering on. So the same function could be used for `INSERT` events on any table with suitable columns, to automatically track creation of records in a transaction table for example. It could also be used to track last-update events if defined as an `UPDATE` trigger.

Each programming language that supports triggers has its own method for making the trigger input data available to the trigger function. This input data includes the type of trigger event (e.g., `INSERT` or `UPDATE`) as well as any arguments that were listed in `CREATE TRIGGER`. For a row-level trigger, the input data also includes the `NEW` row for `INSERT` and `UPDATE` triggers, and/or the `OLD` row for `UPDATE` and `DELETE` triggers.

By default, statement-level triggers do not have any way to examine the individual row(s) modified by the statement. But an `AFTER STATEMENT` trigger can request that *transition tables* be created to make the sets of affected rows available to the trigger. `AFTER ROW` triggers can also request transition tables, so that they can see the total changes in the table as well as the change in the individual row they are currently being fired for. The method for examining the transition tables again depends on the programming language that is being used, but the typical approach is to make the transition tables

act like read-only temporary tables that can be accessed by SQL commands issued within the trigger function.

38.2. Visibility of Data Changes

If you execute SQL commands in your trigger function, and these commands access the table that the trigger is for, then you need to be aware of the data visibility rules, because they determine whether these SQL commands will see the data change that the trigger is fired for. Briefly:

- Statement-level triggers follow simple visibility rules: none of the changes made by a statement are visible to statement-level `BEFORE` triggers, whereas all modifications are visible to statement-level `AFTER` triggers.
- The data change (insertion, update, or deletion) causing the trigger to fire is naturally *not* visible to SQL commands executed in a row-level `BEFORE` trigger, because it hasn't happened yet.
- However, SQL commands executed in a row-level `BEFORE` trigger *will* see the effects of data changes for rows previously processed in the same outer command. This requires caution, since the ordering of these change events is not in general predictable; a SQL command that affects multiple rows can visit the rows in any order.
- Similarly, a row-level `INSTEAD OF` trigger will see the effects of data changes made by previous firings of `INSTEAD OF` triggers in the same outer command.
- When a row-level `AFTER` trigger is fired, all data changes made by the outer command are already complete, and are visible to the invoked trigger function.

If your trigger function is written in any of the standard procedural languages, then the above statements apply only if the function is declared `VOLATILE`. Functions that are declared `STABLE` or `IMMUTABLE` will not see changes made by the calling command in any case.

Further information about data visibility rules can be found in Section 46.5. The example in Section 38.4 contains a demonstration of these rules.

38.3. Writing Trigger Functions in C

This section describes the low-level details of the interface to a trigger function. This information is only needed when writing trigger functions in C. If you are using a higher-level language then these details are handled for you. In most cases you should consider using a procedural language before writing your triggers in C. The documentation of each procedural language explains how to write a trigger in that language.

Trigger functions must use the “version 1” function manager interface.

When a function is called by the trigger manager, it is not passed any normal arguments, but it is passed a “context” pointer pointing to a `TriggerData` structure. C functions can check whether they were called from the trigger manager or not by executing the macro:

```
CALLED_AS_TRIGGER(fcinfo)
```

which expands to:

```
((fcinfo)->context != NULL && IsA((fcinfo)->context, TriggerData))
```

If this returns true, then it is safe to cast `fcinfo->context` to type `TriggerData *` and make use of the pointed-to `TriggerData` structure. The function must *not* alter the `TriggerData` structure or any of the data it points to.

`struct TriggerData` is defined in `commands/trigger.h`:

```

typedef struct TriggerData
{
    NodeTag          type;
    TriggerEvent     tg_event;
    Relation         tg_relation;
    HeapTuple        tg_trigtuple;
    HeapTuple        tg_newtuple;
    Trigger          *tg_trigger;
    Buffer            tg_trigtuplebuf;
    Buffer            tg_newtuplebuf;
    Tuplestorestate *tg_oldtable;
    Tuplestorestate *tg_newtable;
} TriggerData;

```

where the members are defined as follows:

type

Always T_TriggerData.

tg_event

Describes the event for which the function is called. You can use the following macros to examine tg_event:

TRIGGER_FIRED_BEFORE(tg_event)

Returns true if the trigger fired before the operation.

TRIGGER_FIRED_AFTER(tg_event)

Returns true if the trigger fired after the operation.

TRIGGER_FIRED_INSTEAD(tg_event)

Returns true if the trigger fired instead of the operation.

TRIGGER_FIRED_FOR_ROW(tg_event)

Returns true if the trigger fired for a row-level event.

TRIGGER_FIRED_FOR_STATEMENT(tg_event)

Returns true if the trigger fired for a statement-level event.

TRIGGER_FIRED_BY_INSERT(tg_event)

Returns true if the trigger was fired by an INSERT command.

TRIGGER_FIRED_BY_UPDATE(tg_event)

Returns true if the trigger was fired by an UPDATE command.

TRIGGER_FIRED_BY_DELETE(tg_event)

Returns true if the trigger was fired by a DELETE command.

TRIGGER_FIRED_BY_TRUNCATE(tg_event)

Returns true if the trigger was fired by a TRUNCATE command.

tg_relation

A pointer to a structure describing the relation that the trigger fired for. Look at `utils/rel.h` for details about this structure. The most interesting things are `tg_relation->rd_att` (de-

scriptor of the relation tuples) and `tg_relation->rd_rel->relname` (relation name; the type is not `char*` but `NameData`; use `SPI_getrelname(tg_relation)` to get a `char*` if you need a copy of the name).

`tg_trigtuple`

A pointer to the row for which the trigger was fired. This is the row being inserted, updated, or deleted. If this trigger was fired for an `INSERT` or `DELETE` then this is what you should return from the function if you don't want to replace the row with a different one (in the case of `INSERT`) or skip the operation. For triggers on foreign tables, values of system columns herein are unspecified.

`tg_newtuple`

A pointer to the new version of the row, if the trigger was fired for an `UPDATE`, and `NULL` if it is for an `INSERT` or a `DELETE`. This is what you have to return from the function if the event is an `UPDATE` and you don't want to replace this row by a different one or skip the operation. For triggers on foreign tables, values of system columns herein are unspecified.

`tg_trigger`

A pointer to a structure of type `Trigger`, defined in `utils/reltrigger.h`:

```
typedef struct Trigger
{
    Oid          tgoid;
    char        *tgname;
    Oid          tgfoid;
    int16       tgtype;
    char        tgenabled;
    bool        tgisinternal;
    Oid          tgconstrrelid;
    Oid          tgconstrindid;
    Oid          tgconstraint;
    bool        tgdeferrable;
    bool        tginitdeferred;
    int16       tgnargs;
    int16       tgnattr;
    int16       *tgattr;
    char        **tgargs;
    char        *tgqual;
    char        *tgoldtable;
    char        *tgnewtable;
} Trigger;
```

where `tgname` is the trigger's name, `tgnargs` is the number of arguments in `tgargs`, and `tgargs` is an array of pointers to the arguments specified in the `CREATE TRIGGER` statement. The other members are for internal use only.

`tg_trigtuplebuf`

The buffer containing `tg_trigtuple`, or `InvalidBuffer` if there is no such tuple or it is not stored in a disk buffer.

`tg_newtuplebuf`

The buffer containing `tg_newtuple`, or `InvalidBuffer` if there is no such tuple or it is not stored in a disk buffer.

`tg_oldtable`

A pointer to a structure of type `Tuplestorestate` containing zero or more rows in the format specified by `tg_relation`, or a NULL pointer if there is no OLD TABLE transition relation.

`tg_newtable`

A pointer to a structure of type `Tuplestorestate` containing zero or more rows in the format specified by `tg_relation`, or a NULL pointer if there is no NEW TABLE transition relation.

To allow queries issued through SPI to reference transition tables, see `SPI_register_trigger_data`.

A trigger function must return either a `HeapTuple` pointer or a NULL pointer (*not* an SQL null value, that is, do not set `isNull` true). Be careful to return either `tg_trigtuple` or `tg_newtuple`, as appropriate, if you don't want to modify the row being operated on.

38.4. A Complete Trigger Example

Here is a very simple example of a trigger function written in C. (Examples of triggers written in procedural languages can be found in the documentation of the procedural languages.)

The function `trigf` reports the number of rows in the table `ttest` and skips the actual operation if the command attempts to insert a null value into the column `x`. (So the trigger acts as a not-null constraint but doesn't abort the transaction.)

First, the table definition:

```
CREATE TABLE ttest (
    x integer
);
```

This is the source code of the trigger function:

```
#include "postgres.h"
#include "fmgr.h"
#include "executor/spi.h"      /* this is what you need to work
    with SPI */
#include "commands/trigger.h" /* ... triggers ... */
#include "utils/rel.h"        /* ... and relations */

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(trigf);

Datum
trigf(PG_FUNCTION_ARGS)
{
    TriggerData *trigdata = (TriggerData *) fcinfo->context;
    TupleDesc   tupdesc;
    HeapTuple   rettuple;
    char        *when;
    bool        checknull = false;
    bool        isnull;
    int         ret, i;

    /* make sure it's called as a trigger at all */
    if (!CALLED_AS_TRIGGER(fcinfo))
```

```

        elog(ERROR, "trigf: not called by trigger manager");

/* tuple to return to executor */
if (TRIGGER_FIRED_BY_UPDATE(trigdata->tg_event))
    rettuple = trigdata->tg_newtuple;
else
    rettuple = trigdata->tg_trigtuple;

/* check for null values */
if (!TRIGGER_FIRED_BY_DELETE(trigdata->tg_event)
    && TRIGGER_FIRED_BEFORE(trigdata->tg_event))
    checknull = true;

if (TRIGGER_FIRED_BEFORE(trigdata->tg_event))
    when = "before";
else
    when = "after ";

tupdesc = trigdata->tg_relation->rd_att;

/* connect to SPI manager */
if ((ret = SPI_connect()) < 0)
    elog(ERROR, "trigf (fired %s): SPI_connect returned %d",
when, ret);

/* get number of rows in table */
ret = SPI_exec("SELECT count(*) FROM ttest", 0);

if (ret < 0)
    elog(ERROR, "trigf (fired %s): SPI_exec returned %d", when,
ret);

/* count(*) returns int8, so be careful to convert */
i = DatumGetInt64(SPI_getbinval(SPI_tuptable->vals[0],
                                SPI_tuptable->tupdesc,
                                1,
                                &isnull));

    elog (INFO, "trigf (fired %s): there are %d rows in ttest",
when, i);

    SPI_finish();

    if (checknull)
    {
        SPI_getbinval(rettuple, tupdesc, 1, &isnull);
        if (isnull)
            rettuple = NULL;
    }

    return PointerGetDatum(rettuple);
}

```

After you have compiled the source code (see Section 37.10.5), declare the function and the triggers:

```
CREATE FUNCTION trigf() RETURNS trigger
```

```
AS 'filename'
LANGUAGE C;
```

```
CREATE TRIGGER tbefore BEFORE INSERT OR UPDATE OR DELETE ON ttest
FOR EACH ROW EXECUTE FUNCTION trigf();
```

```
CREATE TRIGGER tafter AFTER INSERT OR UPDATE OR DELETE ON ttest
FOR EACH ROW EXECUTE FUNCTION trigf();
```

Now you can test the operation of the trigger:

```
=> INSERT INTO ttest VALUES (NULL);
INFO:  trigf (fired before): there are 0 rows in ttest
INSERT 0 0
```

-- Insertion skipped and AFTER trigger is not fired

```
=> SELECT * FROM ttest;
 x
---
(0 rows)
```

```
=> INSERT INTO ttest VALUES (1);
INFO:  trigf (fired before): there are 0 rows in ttest
INFO:  trigf (fired after ) : there are 1 rows in ttest
          ^^^^^^^
```

remember what we said about

```
visibility.
INSERT 167793 1
vac=> SELECT * FROM ttest;
 x
---
 1
(1 row)
```

```
=> INSERT INTO ttest SELECT x * 2 FROM ttest;
INFO:  trigf (fired before): there are 1 rows in ttest
INFO:  trigf (fired after ) : there are 2 rows in ttest
          ^^^^^
```

remember what we said about

```
visibility.
INSERT 167794 1
=> SELECT * FROM ttest;
 x
---
 1
 2
(2 rows)
```

```
=> UPDATE ttest SET x = NULL WHERE x = 2;
INFO:  trigf (fired before): there are 2 rows in ttest
UPDATE 0
```

```
=> UPDATE ttest SET x = 4 WHERE x = 2;
INFO:  trigf (fired before): there are 2 rows in ttest
INFO:  trigf (fired after ) : there are 2 rows in ttest
UPDATE 1
```

```
vac=> SELECT * FROM ttest;
```

```
x
---
1
4
(2 rows)
```

```
=> DELETE FROM ttest;
```

```
INFO:  trigf (fired before): there are 2 rows in ttest
INFO:  trigf (fired before): there are 1 rows in ttest
INFO:  trigf (fired after ): there are 0 rows in ttest
INFO:  trigf (fired after ): there are 0 rows in ttest
      ^^^^^^
```

remember what we said about

visibility.

```
DELETE 2
```

```
=> SELECT * FROM ttest;
```

```
x
---
(0 rows)
```

There are more complex examples in `src/test/regress/regress.c` and in `spi`.

Chapter 39. Event Triggers

To supplement the trigger mechanism discussed in Chapter 38, PostgreSQL also provides event triggers. Unlike regular triggers, which are attached to a single table and capture only DML events, event triggers are global to a particular database and are capable of capturing DDL events.

Like regular triggers, event triggers can be written in any procedural language that includes event trigger support, or in C, but not in plain SQL.

39.1. Overview of Event Trigger Behavior

An event trigger fires whenever the event with which it is associated occurs in the database in which it is defined. Currently, the only supported events are `ddl_command_start`, `ddl_command_end`, `table_rewrite` and `sql_drop`. Support for additional events may be added in future releases.

The `ddl_command_start` event occurs just before the execution of a `CREATE`, `ALTER`, `DROP`, `SECURITY LABEL`, `COMMENT`, `GRANT` or `REVOKE` command. No check whether the affected object exists or doesn't exist is performed before the event trigger fires. As an exception, however, this event does not occur for DDL commands targeting shared objects — databases, roles, and tablespaces — or for commands targeting event triggers themselves. The event trigger mechanism does not support these object types. `ddl_command_start` also occurs just before the execution of a `SELECT INTO` command, since this is equivalent to `CREATE TABLE AS`.

The `ddl_command_end` event occurs just after the execution of this same set of commands. To obtain more details on the DDL operations that took place, use the set-returning function `pg_event_trigger_ddl_commands()` from the `ddl_command_end` event trigger code (see Section 9.28). Note that the trigger fires after the actions have taken place (but before the transaction commits), and thus the system catalogs can be read as already changed.

The `sql_drop` event occurs just before the `ddl_command_end` event trigger for any operation that drops database objects. To list the objects that have been dropped, use the set-returning function `pg_event_trigger_dropped_objects()` from the `sql_drop` event trigger code (see Section 9.28). Note that the trigger is executed after the objects have been deleted from the system catalogs, so it's not possible to look them up anymore.

The `table_rewrite` event occurs just before a table is rewritten by some actions of the commands `ALTER TABLE` and `ALTER TYPE`. While other control statements are available to rewrite a table, like `CLUSTER` and `VACUUM`, the `table_rewrite` event is not triggered by them.

Event triggers (like other functions) cannot be executed in an aborted transaction. Thus, if a DDL command fails with an error, any associated `ddl_command_end` triggers will not be executed. Conversely, if a `ddl_command_start` trigger fails with an error, no further event triggers will fire, and no attempt will be made to execute the command itself. Similarly, if a `ddl_command_end` trigger fails with an error, the effects of the DDL statement will be rolled back, just as they would be in any other case where the containing transaction aborts.

For a complete list of commands supported by the event trigger mechanism, see Section 39.2.

Event triggers are created using the command `CREATE EVENT TRIGGER`. In order to create an event trigger, you must first create a function with the special return type `event_trigger`. This function need not (and may not) return a value; the return type serves merely as a signal that the function is to be invoked as an event trigger.

If more than one event trigger is defined for a particular event, they will fire in alphabetical order by trigger name.

A trigger definition can also specify a `WHEN` condition so that, for example, a `ddl_command_start` trigger can be fired only for particular commands which the user wishes to intercept. A common use of such triggers is to restrict the range of DDL operations which users may perform.

39.2. Event Trigger Firing Matrix

Table 39.1 lists all commands for which event triggers are supported.

Table 39.1. Event Trigger Support by Command Tag

Command Tag	ddl_command_start	ddl_command_end	sql_drop	table_rewrite	Notes
ALTER AGGREGATE	X	X	-	-	
ALTER COLLATION	X	X	-	-	
ALTER CONVERSION	X	X	-	-	
ALTER DOMAIN	X	X	-	-	
ALTER DEFAULT PRIVILEGES	X	X	-	-	
ALTER EXTENSION	X	X	-	-	
ALTER FOREIGN DATA WRAPPER	X	X	-	-	
ALTER FOREIGN TABLE	X	X	X	-	
ALTER FUNCTION	X	X	-	-	
ALTER LANGUAGE	X	X	-	-	
ALTER LARGE OBJECT	X	X	-	-	
ALTER MATERIALIZED VIEW	X	X	-	-	
ALTER OPERATOR	X	X	-	-	
ALTER OPERATOR CLASS	X	X	-	-	
ALTER OPERATOR FAMILY	X	X	-	-	
ALTER POLICY	X	X	-	-	
ALTER PROCEDURE	X	X	-	-	

Event Triggers

Command Tag	ddl_command_start	ddl_command_end	sql_drop	table_rewrite	Notes
ALTER PUBLICATION	X	X	-	-	
ALTER SCHEMA	X	X	-	-	
ALTER SEQUENCE	X	X	-	-	
ALTER SERVER	X	X	-	-	
ALTER STATISTICS	X	X	-	-	
ALTER SUBSCRIPTION	X	X	-	-	
ALTER TABLE	X	X	X	X	
ALTER TEXT SEARCH CONFIGURATION	X	X	-	-	
ALTER TEXT SEARCH DICTIONARY	X	X	-	-	
ALTER TEXT SEARCH PARSER	X	X	-	-	
ALTER TEXT SEARCH TEMPLATE	X	X	-	-	
ALTER TRIGGER	X	X	-	-	
ALTER TYPE	X	X	-	X	
ALTER USER MAPPING	X	X	-	-	
ALTER VIEW	X	X	-	-	
COMMENT	X	X	-	-	Only for local objects
CREATE ACCESS METHOD	X	X	-	-	
CREATE AGGREGATE	X	X	-	-	
CREATE CAST	X	X	-	-	
CREATE COLLATION	X	X	-	-	
CREATE CONVERSION	X	X	-	-	

Event Triggers

Command Tag	ddl_com- mand_start	ddl_com- mand_end	sql_drop	ta- ble_rewrite	Notes
CREATE DO- MAIN	X	X	-	-	
CREATE EX- TENSION	X	X	-	-	
CREATE FOREIGN DATA WRAP- PER	X	X	-	-	
CREATE FOREIGN TABLE	X	X	-	-	
CREATE FUNCTION	X	X	-	-	
CREATE IN- DEX	X	X	-	-	
CREATE LANGUAGE	X	X	-	-	
CREATE MATERIALIZED VIEW	X	X	-	-	
CREATE OP- ERATOR	X	X	-	-	
CREATE OP- ERATOR CLASS	X	X	-	-	
CREATE OP- ERATOR FAMILY	X	X	-	-	
CREATE POLICY	X	X	-	-	
CREATE PROCEDURE	X	X	-	-	
CREATE PUBLI- CATION	X	X	-	-	
CREATE RULE	X	X	-	-	
CREATE SCHEMA	X	X	-	-	
CREATE SE- QUENCE	X	X	-	-	
CREATE SERVER	X	X	-	-	
CREATE STATISTICS	X	X	-	-	
CREATE SUBSCRIP- TION	X	X	-	-	

Event Triggers

Command Tag	ddl_command_start	ddl_command_end	sql_drop	table_rewrite	Notes
CREATE TABLE	X	X	-	-	
CREATE TABLE AS	X	X	-	-	
CREATE TEXT SEARCH CONFIGURATION	X	X	-	-	
CREATE TEXT SEARCH DICTIONARY	X	X	-	-	
CREATE TEXT SEARCH PARSER	X	X	-	-	
CREATE TEXT SEARCH TEMPLATE	X	X	-	-	
CREATE TRIGGER	X	X	-	-	
CREATE TYPE	X	X	-	-	
CREATE USER MAPPING	X	X	-	-	
CREATE VIEW	X	X	-	-	
DROP ACCESS METHOD	X	X	X	-	
DROP AGGREGATE	X	X	X	-	
DROP CAST	X	X	X	-	
DROP COLLATION	X	X	X	-	
DROP CONVERSION	X	X	X	-	
DROP DOMAIN	X	X	X	-	
DROP EXTENSION	X	X	X	-	
DROP FOREIGN DATA WRAPPER	X	X	X	-	

Event Triggers

Command Tag	ddl_command_start	ddl_command_end	sql_drop	table_rewrite	Notes
DROP FOREIGN TABLE	X	X	X	-	
DROP FUNCTION	X	X	X	-	
DROP INDEX	X	X	X	-	
DROP LANGUAGE	X	X	X	-	
DROP MATERIALIZED VIEW	X	X	X	-	
DROP OPERATOR	X	X	X	-	
DROP OPERATOR CLASS	X	X	X	-	
DROP OPERATOR FAMILY	X	X	X	-	
DROP OWNED	X	X	X	-	
DROP POLICY	X	X	X	-	
DROP PROCEDURE	X	X	X	-	
DROP PUBLICATION	X	X	X	-	
DROP RULE	X	X	X	-	
DROP SCHEMA	X	X	X	-	
DROP SEQUENCE	X	X	X	-	
DROP SERVER	X	X	X	-	
DROP STATISTICS	X	X	X	-	
DROP SUBSCRIPTION	X	X	X	-	
DROP TABLE	X	X	X	-	
DROP TEXT SEARCH CONFIGURATION	X	X	X	-	
DROP TEXT SEARCH DICTIONARY	X	X	X	-	

Command Tag	ddl_command_start	ddl_command_end	sql_drop	table_rewrite	Notes
DROP TEXT SEARCH PARSER	X	X	X	-	
DROP TEXT SEARCH TEMPLATE	X	X	X	-	
DROP TRIGGER	X	X	X	-	
DROP TYPE	X	X	X	-	
DROP USER MAPPING	X	X	X	-	
DROP VIEW	X	X	X	-	
GRANT	X	X	-	-	Only for local objects
IMPORT FOREIGN SCHEMA	X	X	-	-	
REFRESH MATERIALIZED VIEW	X	X	-	-	
REVOKE	X	X	-	-	Only for local objects
SECURITY LABEL	X	X	-	-	Only for local objects
SELECT INTO	X	X	-	-	

39.3. Writing Event Trigger Functions in C

This section describes the low-level details of the interface to an event trigger function. This information is only needed when writing event trigger functions in C. If you are using a higher-level language then these details are handled for you. In most cases you should consider using a procedural language before writing your event triggers in C. The documentation of each procedural language explains how to write an event trigger in that language.

Event trigger functions must use the “version 1” function manager interface.

When a function is called by the event trigger manager, it is not passed any normal arguments, but it is passed a “context” pointer pointing to a `EventTriggerData` structure. C functions can check whether they were called from the event trigger manager or not by executing the macro:

```
CALLED_AS_EVENT_TRIGGER(fcinfo)
```

which expands to:

```
((fcinfo)->context != NULL && IsA((fcinfo)->context,
EventTriggerData))
```

If this returns true, then it is safe to cast `fcinfo->context` to type `EventTriggerData *` and make use of the pointed-to `EventTriggerData` structure. The function must *not* alter the `EventTriggerData` structure or any of the data it points to.

struct `EventTriggerData` is defined in `commands/event_trigger.h`:

```
typedef struct EventTriggerData
{
    NodeTag      type;
    const char *event;      /* event name */
    Node        *parsetree; /* parse tree */
    const char *tag;        /* command tag */
} EventTriggerData;
```

where the members are defined as follows:

type

Always `T_EventTriggerData`.

event

Describes the event for which the function is called, one of `"ddl_command_start"`, `"ddl_command_end"`, `"sql_drop"`, `"table_rewrite"`. See Section 39.1 for the meaning of these events.

parsetree

A pointer to the parse tree of the command. Check the PostgreSQL source code for details. The parse tree structure is subject to change without notice.

tag

The command tag associated with the event for which the event trigger is run, for example `"CREATE FUNCTION"`.

An event trigger function must return a NULL pointer (*not* an SQL null value, that is, do not set `isNull` true).

39.4. A Complete Event Trigger Example

Here is a very simple example of an event trigger function written in C. (Examples of triggers written in procedural languages can be found in the documentation of the procedural languages.)

The function `nodd1` raises an exception each time it is called. The event trigger definition associated the function with the `ddl_command_start` event. The effect is that all DDL commands (with the exceptions mentioned in Section 39.1) are prevented from running.

This is the source code of the trigger function:

```
#include "postgres.h"
#include "commands/event_trigger.h"

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(nodd1);
```

```

Datum
nodd1(PG_FUNCTION_ARGS)
{
    EventTriggerData *trigdata;

    if (!CALLED_AS_EVENT_TRIGGER(fcinfo)) /* internal error */
        elog(ERROR, "not fired by event trigger manager");

    trigdata = (EventTriggerData *) fcinfo->context;

    ereport(ERROR,
            (errcode(ERRCODE_INSUFFICIENT_PRIVILEGE),
             errmsg("command \"%s\" denied", trigdata->tag)));

    PG_RETURN_NULL();
}

```

After you have compiled the source code (see Section 37.10.5), declare the function and the triggers:

```

CREATE FUNCTION nodd1() RETURNS event_trigger
AS 'nodd1' LANGUAGE C;

CREATE EVENT TRIGGER nodd1 ON ddl_command_start
EXECUTE FUNCTION nodd1();

```

Now you can test the operation of the trigger:

```

=# \dy
                List of event triggers
  Name |          Event          | Owner | Enabled | Function | Tags
-----+-----+-----+-----+-----+-----
 nodd1 | ddl_command_start     | dim   | enabled | nodd1    |
(1 row)

=# CREATE TABLE foo(id serial);
ERROR:  command "CREATE TABLE" denied

```

In this situation, in order to be able to run some DDL commands when you need to do so, you have to either drop the event trigger or disable it. It can be convenient to disable the trigger for only the duration of a transaction:

```

BEGIN;
ALTER EVENT TRIGGER nodd1 DISABLE;
CREATE TABLE foo (id serial);
ALTER EVENT TRIGGER nodd1 ENABLE;
COMMIT;

```

(Recall that DDL commands on event triggers themselves are not affected by event triggers.)

39.5. A Table Rewrite Event Trigger Example

Thanks to the `table_rewrite` event, it is possible to implement a table rewriting policy only allowing the rewrite in maintenance windows.

Here's an example implementing such a policy.

```
CREATE OR REPLACE FUNCTION no_rewrite()
  RETURNS event_trigger
  LANGUAGE plpgsql AS
$$
---
--- Implement local Table Rewriting policy:
---   public.foo is not allowed rewriting, ever
---   other tables are only allowed rewriting between 1am and 6am
---   unless they have more than 100 blocks
---
DECLARE
  table_oid oid := pg_event_trigger_table_rewrite_oid();
  current_hour integer := extract('hour' from current_time);
  pages integer;
  max_pages integer := 100;
BEGIN
  IF pg_event_trigger_table_rewrite_oid() = 'public.foo'::regclass
  THEN
    RAISE EXCEPTION 'you're not allowed to rewrite the table
  %',
    table_oid::regclass;
  END IF;

  SELECT INTO pages relpages FROM pg_class WHERE oid = table_oid;
  IF pages > max_pages
  THEN
    RAISE EXCEPTION 'rewrites only allowed for table with less
  than % pages',
    max_pages;
  END IF;

  IF current_hour NOT BETWEEN 1 AND 6
  THEN
    RAISE EXCEPTION 'rewrites only allowed between 1am and
  6am';
  END IF;
END;
$$;

CREATE EVENT TRIGGER no_rewrite_allowed
  ON table_rewrite
  EXECUTE FUNCTION no_rewrite();
```

Chapter 40. The Rule System

This chapter discusses the rule system in PostgreSQL. Production rule systems are conceptually simple, but there are many subtle points involved in actually using them.

Some other database systems define active database rules, which are usually stored procedures and triggers. In PostgreSQL, these can be implemented using functions and triggers as well.

The rule system (more precisely speaking, the query rewrite rule system) is totally different from stored procedures and triggers. It modifies queries to take rules into consideration, and then passes the modified query to the query planner for planning and execution. It is very powerful, and can be used for many things such as query language procedures, views, and versions. The theoretical foundations and the power of this rule system are also discussed in [ston90b] and [ong90].

40.1. The Query Tree

To understand how the rule system works it is necessary to know when it is invoked and what its input and results are.

The rule system is located between the parser and the planner. It takes the output of the parser, one query tree, and the user-defined rewrite rules, which are also query trees with some extra information, and creates zero or more query trees as result. So its input and output are always things the parser itself could have produced and thus, anything it sees is basically representable as an SQL statement.

Now what is a query tree? It is an internal representation of an SQL statement where the single parts that it is built from are stored separately. These query trees can be shown in the server log if you set the configuration parameters `debug_print_parse`, `debug_print_rewritten`, or `debug_print_plan`. The rule actions are also stored as query trees, in the system catalog `pg_rewrite`. They are not formatted like the log output, but they contain exactly the same information.

Reading a raw query tree requires some experience. But since SQL representations of query trees are sufficient to understand the rule system, this chapter will not teach how to read them.

When reading the SQL representations of the query trees in this chapter it is necessary to be able to identify the parts the statement is broken into when it is in the query tree structure. The parts of a query tree are

the command type

This is a simple value telling which command (`SELECT`, `INSERT`, `UPDATE`, `DELETE`) produced the query tree.

the range table

The range table is a list of relations that are used in the query. In a `SELECT` statement these are the relations given after the `FROM` key word.

Every range table entry identifies a table or view and tells by which name it is called in the other parts of the query. In the query tree, the range table entries are referenced by number rather than by name, so here it doesn't matter if there are duplicate names as it would in an SQL statement. This can happen after the range tables of rules have been merged in. The examples in this chapter will not have this situation.

the result relation

This is an index into the range table that identifies the relation where the results of the query go.

`SELECT` queries don't have a result relation. (The special case of `SELECT INTO` is mostly identical to `CREATE TABLE` followed by `INSERT . . . SELECT`, and is not discussed separately here.)

For `INSERT`, `UPDATE`, and `DELETE` commands, the result relation is the table (or view!) where the changes are to take effect.

the target list

The target list is a list of expressions that define the result of the query. In the case of a `SELECT`, these expressions are the ones that build the final output of the query. They correspond to the expressions between the key words `SELECT` and `FROM`. (* is just an abbreviation for all the column names of a relation. It is expanded by the parser into the individual columns, so the rule system never sees it.)

`DELETE` commands don't need a normal target list because they don't produce any result. Instead, the planner adds a special `CTID` entry to the empty target list, to allow the executor to find the row to be deleted. (`CTID` is added when the result relation is an ordinary table. If it is a view, a whole-row variable is added instead, by the rule system, as described in Section 40.2.4.)

For `INSERT` commands, the target list describes the new rows that should go into the result relation. It consists of the expressions in the `VALUES` clause or the ones from the `SELECT` clause in `INSERT . . . SELECT`. The first step of the rewrite process adds target list entries for any columns that were not assigned to by the original command but have defaults. Any remaining columns (with neither a given value nor a default) will be filled in by the planner with a constant null expression.

For `UPDATE` commands, the target list describes the new rows that should replace the old ones. In the rule system, it contains just the expressions from the `SET column = expression` part of the command. The planner will handle missing columns by inserting expressions that copy the values from the old row into the new one. Just as for `DELETE`, a `CTID` or whole-row variable is added so that the executor can identify the old row to be updated.

Every entry in the target list contains an expression that can be a constant value, a variable pointing to a column of one of the relations in the range table, a parameter, or an expression tree made of function calls, constants, variables, operators, etc.

the qualification

The query's qualification is an expression much like one of those contained in the target list entries. The result value of this expression is a Boolean that tells whether the operation (`INSERT`, `UPDATE`, `DELETE`, or `SELECT`) for the final result row should be executed or not. It corresponds to the `WHERE` clause of an SQL statement.

the join tree

The query's join tree shows the structure of the `FROM` clause. For a simple query like `SELECT . . . FROM a, b, c`, the join tree is just a list of the `FROM` items, because we are allowed to join them in any order. But when `JOIN` expressions, particularly outer joins, are used, we have to join in the order shown by the joins. In that case, the join tree shows the structure of the `JOIN` expressions. The restrictions associated with particular `JOIN` clauses (from `ON` or `USING` expressions) are stored as qualification expressions attached to those join-tree nodes. It turns out to be convenient to store the top-level `WHERE` expression as a qualification attached to the top-level join-tree item, too. So really the join tree represents both the `FROM` and `WHERE` clauses of a `SELECT`.

the others

The other parts of the query tree like the `ORDER BY` clause aren't of interest here. The rule system substitutes some entries there while applying rules, but that doesn't have much to do with the fundamentals of the rule system.

40.2. Views and the Rule System

Views in PostgreSQL are implemented using the rule system. In fact, there is essentially no difference between:

```
CREATE VIEW myview AS SELECT * FROM mytab;
```

compared against the two commands:

```
CREATE TABLE myview (same column list as mytab);
CREATE RULE "_RETURN" AS ON SELECT TO myview DO INSTEAD
    SELECT * FROM mytab;
```

because this is exactly what the `CREATE VIEW` command does internally. This has some side effects. One of them is that the information about a view in the PostgreSQL system catalogs is exactly the same as it is for a table. So for the parser, there is absolutely no difference between a table and a view. They are the same thing: relations.

40.2.1. How `SELECT` Rules Work

Rules `ON SELECT` are applied to all queries as the last step, even if the command given is an `INSERT`, `UPDATE` or `DELETE`. And they have different semantics from rules on the other command types in that they modify the query tree in place instead of creating a new one. So `SELECT` rules are described first.

Currently, there can be only one action in an `ON SELECT` rule, and it must be an unconditional `SELECT` action that is `INSTEAD`. This restriction was required to make rules safe enough to open them for ordinary users, and it restricts `ON SELECT` rules to act like views.

The examples for this chapter are two join views that do some calculations and some more views using them in turn. One of the two first views is customized later by adding rules for `INSERT`, `UPDATE`, and `DELETE` operations so that the final result will be a view that behaves like a real table with some magic functionality. This is not such a simple example to start from and this makes things harder to get into. But it's better to have one example that covers all the points discussed step by step rather than having many different ones that might mix up in mind.

The real tables we need in the first two rule system descriptions are these:

```
CREATE TABLE shoe_data (
    shoename    text,           -- primary key
    sh_avail    integer,       -- available number of pairs
    slcolor     text,           -- preferred shoelace color
    slminlen    real,          -- minimum shoelace length
    slmaxlen    real,          -- maximum shoelace length
    slunit      text           -- length unit
);

CREATE TABLE shoelace_data (
    sl_name     text,           -- primary key
    sl_avail    integer,       -- available number of pairs
    sl_color    text,          -- shoelace color
    sl_len      real,          -- shoelace length
    sl_unit     text           -- length unit
);

CREATE TABLE unit (
    un_name     text,           -- primary key
    un_fact     real           -- factor to transform to cm
);
```

);

As you can see, they represent shoe-store data.

The views are created as:

```
CREATE VIEW shoe AS
  SELECT sh.shoename,
         sh.sh_avail,
         sh.slcolor,
         sh.slminlen,
         sh.slminlen * un.un_fact AS slminlen_cm,
         sh.slmaxlen,
         sh.slmaxlen * un.un_fact AS slmaxlen_cm,
         sh.slunit
  FROM shoe_data sh, unit un
  WHERE sh.slunit = un.un_name;

CREATE VIEW shoelace AS
  SELECT s.sl_name,
         s.sl_avail,
         s.sl_color,
         s.sl_len,
         s.sl_unit,
         s.sl_len * u.un_fact AS sl_len_cm
  FROM shoelace_data s, unit u
  WHERE s.sl_unit = u.un_name;

CREATE VIEW shoe_ready AS
  SELECT rsh.shoename,
         rsh.sh_avail,
         rsl.sl_name,
         rsl.sl_avail,
         least(rsh.sh_avail, rsl.sl_avail) AS total_avail
  FROM shoe rsh, shoelace rsl
  WHERE rsl.sl_color = rsh.slcolor
         AND rsl.sl_len_cm >= rsh.slminlen_cm
         AND rsl.sl_len_cm <= rsh.slmaxlen_cm;
```

The CREATE VIEW command for the shoelace view (which is the simplest one we have) will create a relation shoelace and an entry in pg_rewrite that tells that there is a rewrite rule that must be applied whenever the relation shoelace is referenced in a query's range table. The rule has no rule qualification (discussed later, with the non-SELECT rules, since SELECT rules currently cannot have them) and it is INSTEAD. Note that rule qualifications are not the same as query qualifications. The action of our rule has a query qualification. The action of the rule is one query tree that is a copy of the SELECT statement in the view creation command.

Note

The two extra range table entries for NEW and OLD that you can see in the pg_rewrite entry aren't of interest for SELECT rules.

Now we populate unit, shoe_data and shoelace_data and run a simple query on a view:

```
INSERT INTO unit VALUES ('cm', 1.0);
INSERT INTO unit VALUES ('m', 100.0);
```

```

INSERT INTO unit VALUES ('inch', 2.54);

INSERT INTO shoe_data VALUES ('sh1', 2, 'black', 70.0, 90.0, 'cm');
INSERT INTO shoe_data VALUES ('sh2', 0, 'black', 30.0, 40.0,
    'inch');
INSERT INTO shoe_data VALUES ('sh3', 4, 'brown', 50.0, 65.0, 'cm');
INSERT INTO shoe_data VALUES ('sh4', 3, 'brown', 40.0, 50.0,
    'inch');

INSERT INTO shoelace_data VALUES ('sl1', 5, 'black', 80.0, 'cm');
INSERT INTO shoelace_data VALUES ('sl2', 6, 'black', 100.0, 'cm');
INSERT INTO shoelace_data VALUES ('sl3', 0, 'black', 35.0 ,
    'inch');
INSERT INTO shoelace_data VALUES ('sl4', 8, 'black', 40.0 ,
    'inch');
INSERT INTO shoelace_data VALUES ('sl5', 4, 'brown', 1.0 , 'm');
INSERT INTO shoelace_data VALUES ('sl6', 0, 'brown', 0.9 , 'm');
INSERT INTO shoelace_data VALUES ('sl7', 7, 'brown', 60 , 'cm');
INSERT INTO shoelace_data VALUES ('sl8', 1, 'brown', 40 , 'inch');

SELECT * FROM shoelace;

```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl1	5	black	80	cm	80
sl2	6	black	100	cm	100
sl7	7	brown	60	cm	60
sl3	0	black	35	inch	88.9
sl4	8	black	40	inch	101.6
sl8	1	brown	40	inch	101.6
sl5	4	brown	1	m	100
sl6	0	brown	0.9	m	90

(8 rows)

This is the simplest SELECT you can do on our views, so we take this opportunity to explain the basics of view rules. The SELECT * FROM shoelace was interpreted by the parser and produced the query tree:

```

SELECT shoelace.sl_name, shoelace.sl_avail,
       shoelace.sl_color, shoelace.sl_len,
       shoelace.sl_unit, shoelace.sl_len_cm
FROM shoelace shoelace;

```

and this is given to the rule system. The rule system walks through the range table and checks if there are rules for any relation. When processing the range table entry for shoelace (the only one up to now) it finds the `_RETURN` rule with the query tree:

```

SELECT s.sl_name, s.sl_avail,
       s.sl_color, s.sl_len, s.sl_unit,
       s.sl_len * u.un_fact AS sl_len_cm
FROM shoelace old, shoelace new,
     shoelace_data s, unit u
WHERE s.sl_unit = u.un_name;

```

To expand the view, the rewriter simply creates a subquery range-table entry containing the rule's action query tree, and substitutes this range table entry for the original one that referenced the view. The resulting rewritten query tree is almost the same as if you had typed:

```

SELECT shoelace.sl_name, shoelace.sl_avail,
       shoelace.sl_color, shoelace.sl_len,
       shoelace.sl_unit, shoelace.sl_len_cm
FROM (SELECT s.sl_name,
            s.sl_avail,
            s.sl_color,
            s.sl_len,
            s.sl_unit,
            s.sl_len * u.un_fact AS sl_len_cm
      FROM shoelace_data s, unit u
      WHERE s.sl_unit = u.un_name) shoelace;

```

There is one difference however: the subquery's range table has two extra entries `shoelace old` and `shoelace new`. These entries don't participate directly in the query, since they aren't referenced by the subquery's join tree or target list. The rewriter uses them to store the access privilege check information that was originally present in the range-table entry that referenced the view. In this way, the executor will still check that the user has proper privileges to access the view, even though there's no direct use of the view in the rewritten query.

That was the first rule applied. The rule system will continue checking the remaining range-table entries in the top query (in this example there are no more), and it will recursively check the range-table entries in the added subquery to see if any of them reference views. (But it won't expand `old` or `new` — otherwise we'd have infinite recursion!) In this example, there are no rewrite rules for `shoelace_data` or `unit`, so rewriting is complete and the above is the final result given to the planner.

Now we want to write a query that finds out for which shoes currently in the store we have the matching shoelaces (color and length) and where the total number of exactly matching pairs is greater or equal to two.

```

SELECT * FROM shoe_ready WHERE total_avail >= 2;

```

shoename	sh_avail	sl_name	sl_avail	total_avail
sh1	2	sl1	5	2
sh3	4	sl7	7	4

(2 rows)

The output of the parser this time is the query tree:

```

SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
FROM shoe_ready shoe_ready
WHERE shoe_ready.total_avail >= 2;

```

The first rule applied will be the one for the `shoe_ready` view and it results in the query tree:

```

SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
FROM (SELECT rsh.shoename,
            rsh.sh_avail,
            rsl.sl_name,
            rsl.sl_avail,

```

```

        least(rsh.sh_avail, rsl.sl_avail) AS total_avail
    FROM shoe rsh, shoelace rsl
    WHERE rsl.sl_color = rsh.slcolor
        AND rsl.sl_len_cm >= rsh.slminlen_cm
        AND rsl.sl_len_cm <= rsh.slmaxlen_cm) shoe_ready
WHERE shoe_ready.total_avail >= 2;

```

Similarly, the rules for shoe and shoelace are substituted into the range table of the subquery, leading to a three-level final query tree:

```

SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
FROM (SELECT rsh.shoename,
            rsh.sh_avail,
            rsl.sl_name,
            rsl.sl_avail,
            least(rsh.sh_avail, rsl.sl_avail) AS total_avail
     FROM (SELECT sh.shoename,
                 sh.sh_avail,
                 sh.slcolor,
                 sh.slminlen,
                 sh.slminlen * un.un_fact AS slminlen_cm,
                 sh.slmaxlen,
                 sh.slmaxlen * un.un_fact AS slmaxlen_cm,
                 sh.slunit
            FROM shoe_data sh, unit un
            WHERE sh.slunit = un.un_name) rsh,
         (SELECT s.sl_name,
                 s.sl_avail,
                 s.sl_color,
                 s.sl_len,
                 s.sl_unit,
                 s.sl_len * u.un_fact AS sl_len_cm
            FROM shoelace_data s, unit u
            WHERE s.sl_unit = u.un_name) rsl
     WHERE rsl.sl_color = rsh.slcolor
        AND rsl.sl_len_cm >= rsh.slminlen_cm
        AND rsl.sl_len_cm <= rsh.slmaxlen_cm) shoe_ready
WHERE shoe_ready.total_avail > 2;

```

This might look inefficient, but the planner will collapse this into a single-level query tree by “pulling up” the subqueries, and then it will plan the joins just as if we'd written them out manually. So collapsing the query tree is an optimization that the rewrite system doesn't have to concern itself with.

40.2.2. View Rules in Non-SELECT Statements

Two details of the query tree aren't touched in the description of view rules above. These are the command type and the result relation. In fact, the command type is not needed by view rules, but the result relation may affect the way in which the query rewriter works, because special care needs to be taken if the result relation is a view.

There are only a few differences between a query tree for a SELECT and one for any other command. Obviously, they have a different command type and for a command other than a SELECT, the result relation points to the range-table entry where the result should go. Everything else is absolutely the same. So having two tables *t1* and *t2* with columns *a* and *b*, the query trees for the two statements:

```
SELECT t2.b FROM t1, t2 WHERE t1.a = t2.a;
```

```
UPDATE t1 SET b = t2.b FROM t2 WHERE t1.a = t2.a;
```

are nearly identical. In particular:

- The range tables contain entries for the tables `t1` and `t2`.
- The target lists contain one variable that points to column `b` of the range table entry for table `t2`.
- The qualification expressions compare the columns `a` of both range-table entries for equality.
- The join trees show a simple join between `t1` and `t2`.

The consequence is, that both query trees result in similar execution plans: They are both joins over the two tables. For the `UPDATE` the missing columns from `t1` are added to the target list by the planner and the final query tree will read as:

```
UPDATE t1 SET a = t1.a, b = t2.b FROM t2 WHERE t1.a = t2.a;
```

and thus the executor run over the join will produce exactly the same result set as:

```
SELECT t1.a, t2.b FROM t1, t2 WHERE t1.a = t2.a;
```

But there is a little problem in `UPDATE`: the part of the executor plan that does the join does not care what the results from the join are meant for. It just produces a result set of rows. The fact that one is a `SELECT` command and the other is an `UPDATE` is handled higher up in the executor, where it knows that this is an `UPDATE`, and it knows that this result should go into table `t1`. But which of the rows that are there has to be replaced by the new row?

To resolve this problem, another entry is added to the target list in `UPDATE` (and also in `DELETE`) statements: the current tuple ID (CTID). This is a system column containing the file block number and position in the block for the row. Knowing the table, the CTID can be used to retrieve the original row of `t1` to be updated. After adding the CTID to the target list, the query actually looks like:

```
SELECT t1.a, t2.b, t1.ctid FROM t1, t2 WHERE t1.a = t2.a;
```

Now another detail of PostgreSQL enters the stage. Old table rows aren't overwritten, and this is why `ROLLBACK` is fast. In an `UPDATE`, the new result row is inserted into the table (after stripping the CTID) and in the row header of the old row, which the CTID pointed to, the `cmx` and `xmx` entries are set to the current command counter and current transaction ID. Thus the old row is hidden, and after the transaction commits the vacuum cleaner can eventually remove the dead row.

Knowing all that, we can simply apply view rules in absolutely the same way to any command. There is no difference.

40.2.3. The Power of Views in PostgreSQL

The above demonstrates how the rule system incorporates view definitions into the original query tree. In the second example, a simple `SELECT` from one view created a final query tree that is a join of 4 tables (`unit` was used twice with different names).

The benefit of implementing views with the rule system is, that the planner has all the information about which tables have to be scanned plus the relationships between these tables plus the restrictive qualifications from the views plus the qualifications from the original query in one single query tree. And this is still the situation when the original query is already a join over views. The planner has to decide which is the best path to execute the query, and the more information the planner has, the

better this decision can be. And the rule system as implemented in PostgreSQL ensures, that this is all information available about the query up to that point.

40.2.4. Updating a View

What happens if a view is named as the target relation for an `INSERT`, `UPDATE`, or `DELETE`? Doing the substitutions described above would give a query tree in which the result relation points at a subquery range-table entry, which will not work. There are several ways in which PostgreSQL can support the appearance of updating a view, however.

If the subquery selects from a single base relation and is simple enough, the rewriter can automatically replace the subquery with the underlying base relation so that the `INSERT`, `UPDATE`, or `DELETE` is applied to the base relation in the appropriate way. Views that are “simple enough” for this are called *automatically updatable*. For detailed information on the kinds of view that can be automatically updated, see `CREATE VIEW`.

Alternatively, the operation may be handled by a user-provided `INSTEAD OF` trigger on the view. Rewriting works slightly differently in this case. For `INSERT`, the rewriter does nothing at all with the view, leaving it as the result relation for the query. For `UPDATE` and `DELETE`, it's still necessary to expand the view query to produce the “old” rows that the command will attempt to update or delete. So the view is expanded as normal, but another unexpanded range-table entry is added to the query to represent the view in its capacity as the result relation.

The problem that now arises is how to identify the rows to be updated in the view. Recall that when the result relation is a table, a special `CTID` entry is added to the target list to identify the physical locations of the rows to be updated. This does not work if the result relation is a view, because a view does not have any `CTID`, since its rows do not have actual physical locations. Instead, for an `UPDATE` or `DELETE` operation, a special `wholerow` entry is added to the target list, which expands to include all columns from the view. The executor uses this value to supply the “old” row to the `INSTEAD OF` trigger. It is up to the trigger to work out what to update based on the old and new row values.

Another possibility is for the user to define `INSTEAD` rules that specify substitute actions for `INSERT`, `UPDATE`, and `DELETE` commands on a view. These rules will rewrite the command, typically into a command that updates one or more tables, rather than views. That is the topic of Section 40.4.

Note that rules are evaluated first, rewriting the original query before it is planned and executed. Therefore, if a view has `INSTEAD OF` triggers as well as rules on `INSERT`, `UPDATE`, or `DELETE`, then the rules will be evaluated first, and depending on the result, the triggers may not be used at all.

Automatic rewriting of an `INSERT`, `UPDATE`, or `DELETE` query on a simple view is always tried last. Therefore, if a view has rules or triggers, they will override the default behavior of automatically updatable views.

If there are no `INSTEAD` rules or `INSTEAD OF` triggers for the view, and the rewriter cannot automatically rewrite the query as an update on the underlying base relation, an error will be thrown because the executor cannot update a view as such.

40.3. Materialized Views

Materialized views in PostgreSQL use the rule system like views do, but persist the results in a table-like form. The main differences between:

```
CREATE MATERIALIZED VIEW mymatview AS SELECT * FROM mytab;
```

and:

```
CREATE TABLE mymatview AS SELECT * FROM mytab;
```

are that the materialized view cannot subsequently be directly updated and that the query used to create the materialized view is stored in exactly the same way that a view's query is stored, so that fresh data can be generated for the materialized view with:

```
REFRESH MATERIALIZED VIEW mymatview;
```

The information about a materialized view in the PostgreSQL system catalogs is exactly the same as it is for a table or view. So for the parser, a materialized view is a relation, just like a table or a view. When a materialized view is referenced in a query, the data is returned directly from the materialized view, like from a table; the rule is only used for populating the materialized view.

While access to the data stored in a materialized view is often much faster than accessing the underlying tables directly or through a view, the data is not always current; yet sometimes current data is not needed. Consider a table which records sales:

```
CREATE TABLE invoice (  
    invoice_no    integer          PRIMARY KEY,  
    seller_no     integer,         -- ID of salesperson  
    invoice_date  date,           -- date of sale  
    invoice_amt   numeric(13,2)   -- amount of sale  
);
```

If people want to be able to quickly graph historical sales data, they might want to summarize, and they may not care about the incomplete data for the current date:

```
CREATE MATERIALIZED VIEW sales_summary AS  
SELECT  
    seller_no,  
    invoice_date,  
    sum(invoice_amt)::numeric(13,2) as sales_amt  
FROM invoice  
WHERE invoice_date < CURRENT_DATE  
GROUP BY  
    seller_no,  
    invoice_date  
ORDER BY  
    seller_no,  
    invoice_date;
```

```
CREATE UNIQUE INDEX sales_summary_seller  
ON sales_summary (seller_no, invoice_date);
```

This materialized view might be useful for displaying a graph in the dashboard created for salespeople. A job could be scheduled to update the statistics each night using this SQL statement:

```
REFRESH MATERIALIZED VIEW sales_summary;
```

Another use for a materialized view is to allow faster access to data brought across from a remote system through a foreign data wrapper. A simple example using `file_fdw` is below, with timings, but since this is using cache on the local system the performance difference compared to access to a remote system would usually be greater than shown here. Notice we are also exploiting the ability to put an index on the materialized view, whereas `file_fdw` does not support indexes; this advantage might not apply for other sorts of foreign data access.

Setup:

```

CREATE EXTENSION file_fdw;
CREATE SERVER local_file FOREIGN DATA WRAPPER file_fdw;
CREATE FOREIGN TABLE words (word text NOT NULL)
    SERVER local_file
    OPTIONS (filename '/usr/share/dict/words');
CREATE MATERIALIZED VIEW wrd AS SELECT * FROM words;
CREATE UNIQUE INDEX wrd_word ON wrd (word);
CREATE EXTENSION pg_trgm;
CREATE INDEX wrd_trgm ON wrd USING gist (word gist_trgm_ops);
VACUUM ANALYZE wrd;

```

Now let's spell-check a word. Using file_fdw directly:

```
SELECT count(*) FROM words WHERE word = 'caterpiler';
```

```

count
-----
      0
(1 row)

```

With EXPLAIN ANALYZE, we see:

```

Aggregate (cost=21763.99..21764.00 rows=1 width=0) (actual
time=188.180..188.181 rows=1 loops=1)
  -> Foreign Scan on words (cost=0.00..21761.41 rows=1032
width=0) (actual time=188.177..188.177 rows=0 loops=1)
    Filter: (word = 'caterpiler'::text)
    Rows Removed by Filter: 479829
    Foreign File: /usr/share/dict/words
    Foreign File Size: 4953699
Planning time: 0.118 ms
Execution time: 188.273 ms

```

If the materialized view is used instead, the query is much faster:

```

Aggregate (cost=4.44..4.45 rows=1 width=0) (actual
time=0.042..0.042 rows=1 loops=1)
  -> Index Only Scan using wrd_word on wrd (cost=0.42..4.44
rows=1 width=0) (actual time=0.039..0.039 rows=0 loops=1)
    Index Cond: (word = 'caterpiler'::text)
    Heap Fetches: 0
Planning time: 0.164 ms
Execution time: 0.117 ms

```

Either way, the word is spelled wrong, so let's look for what we might have wanted. Again using file_fdw:

```
SELECT word FROM words ORDER BY word <-> 'caterpiler' LIMIT 10;
```

```

word
-----
cater
caterpillar
Caterpillar
caterpillars

```

```
caterpillar's
Caterpillar's
caterer
caterer's
caters
catered
(10 rows)
```

```
Limit (cost=11583.61..11583.64 rows=10 width=32) (actual
time=1431.591..1431.594 rows=10 loops=1)
-> Sort (cost=11583.61..11804.76 rows=88459 width=32) (actual
time=1431.589..1431.591 rows=10 loops=1)
Sort Key: ((word <-> 'caterpiler'::text))
Sort Method: top-N heapsort Memory: 25kB
-> Foreign Scan on words (cost=0.00..9672.05 rows=88459
width=32) (actual time=0.057..1286.455 rows=479829 loops=1)
Foreign File: /usr/share/dict/words
Foreign File Size: 4953699
Planning time: 0.128 ms
Execution time: 1431.679 ms
```

Using the materialized view:

```
Limit (cost=0.29..1.06 rows=10 width=10) (actual
time=187.222..188.257 rows=10 loops=1)
-> Index Scan using wrd_trgm on wrd (cost=0.29..37020.87
rows=479829 width=10) (actual time=187.219..188.252 rows=10
loops=1)
Order By: (word <-> 'caterpiler'::text)
Planning time: 0.196 ms
Execution time: 198.640 ms
```

If you can tolerate periodic update of the remote data to the local database, the performance benefit can be substantial.

40.4. Rules on INSERT, UPDATE, and DELETE

Rules that are defined on INSERT, UPDATE, and DELETE are significantly different from the view rules described in the previous section. First, their CREATE RULE command allows more:

- They are allowed to have no action.
- They can have multiple actions.
- They can be INSTEAD or ALSO (the default).
- The pseudorelations NEW and OLD become useful.
- They can have rule qualifications.

Second, they don't modify the query tree in place. Instead they create zero or more new query trees and can throw away the original one.

Caution

In many cases, tasks that could be performed by rules on INSERT/UPDATE/DELETE are better done with triggers. Triggers are notationally a bit more complicated, but their

semantics are much simpler to understand. Rules tend to have surprising results when the original query contains volatile functions: volatile functions may get executed more times than expected in the process of carrying out the rules.

Also, there are some cases that are not supported by these types of rules at all, notably including `WITH` clauses in the original query and multiple-assignment sub-`SELECT`s in the `SET` list of `UPDATE` queries. This is because copying these constructs into a rule query would result in multiple evaluations of the sub-query, contrary to the express intent of the query's author.

40.4.1. How Update Rules Work

Keep the syntax:

```
CREATE [ OR REPLACE ] RULE name AS ON event
  TO table [ WHERE condition ]
  DO [ ALSO | INSTEAD ] { NOTHING | command | ( command ; command
  ... ) }
```

in mind. In the following, *update rules* means rules that are defined on `INSERT`, `UPDATE`, or `DELETE`.

Update rules get applied by the rule system when the result relation and the command type of a query tree are equal to the object and event given in the `CREATE RULE` command. For update rules, the rule system creates a list of query trees. Initially the query-tree list is empty. There can be zero (`NOTHING` key word), one, or multiple actions. To simplify, we will look at a rule with one action. This rule can have a qualification or not and it can be `INSTEAD` or `ALSO` (the default).

What is a rule qualification? It is a restriction that tells when the actions of the rule should be done and when not. This qualification can only reference the pseudorelations `NEW` and/or `OLD`, which basically represent the relation that was given as object (but with a special meaning).

So we have three cases that produce the following query trees for a one-action rule.

No qualification, with either `ALSO` or `INSTEAD`

the query tree from the rule action with the original query tree's qualification added

Qualification given and `ALSO`

the query tree from the rule action with the rule qualification and the original query tree's qualification added

Qualification given and `INSTEAD`

the query tree from the rule action with the rule qualification and the original query tree's qualification; and the original query tree with the negated rule qualification added

Finally, if the rule is `ALSO`, the unchanged original query tree is added to the list. Since only qualified `INSTEAD` rules already add the original query tree, we end up with either one or two output query trees for a rule with one action.

For `ON INSERT` rules, the original query (if not suppressed by `INSTEAD`) is done before any actions added by rules. This allows the actions to see the inserted row(s). But for `ON UPDATE` and `ON DELETE` rules, the original query is done after the actions added by rules. This ensures that the actions can see the to-be-updated or to-be-deleted rows; otherwise, the actions might do nothing because they find no rows matching their qualifications.

The query trees generated from rule actions are thrown into the rewrite system again, and maybe more rules get applied resulting in more or less query trees. So a rule's actions must have either a different

command type or a different result relation than the rule itself is on, otherwise this recursive process will end up in an infinite loop. (Recursive expansion of a rule will be detected and reported as an error.)

The query trees found in the actions of the `pg_rewrite` system catalog are only templates. Since they can reference the range-table entries for `NEW` and `OLD`, some substitutions have to be made before they can be used. For any reference to `NEW`, the target list of the original query is searched for a corresponding entry. If found, that entry's expression replaces the reference. Otherwise, `NEW` means the same as `OLD` (for an `UPDATE`) or is replaced by a null value (for an `INSERT`). Any reference to `OLD` is replaced by a reference to the range-table entry that is the result relation.

After the system is done applying update rules, it applies view rules to the produced query tree(s). Views cannot insert new update actions so there is no need to apply update rules to the output of view rewriting.

40.4.1.1. A First Rule Step by Step

Say we want to trace changes to the `sl_avail` column in the `shoelace_data` relation. So we set up a log table and a rule that conditionally writes a log entry when an `UPDATE` is performed on `shoelace_data`.

```
CREATE TABLE shoelace_log (
    sl_name      text,          -- shoelace changed
    sl_avail     integer,       -- new available value
    log_who      text,          -- who did it
    log_when     timestamp      -- when
);

CREATE RULE log_shoelace AS ON UPDATE TO shoelace_data
WHERE NEW.sl_avail <> OLD.sl_avail
DO INSERT INTO shoelace_log VALUES (
    NEW.sl_name,
    NEW.sl_avail,
    current_user,
    current_timestamp
);
```

Now someone does:

```
UPDATE shoelace_data SET sl_avail = 6 WHERE sl_name = 'sl7';
```

and we look at the log table:

```
SELECT * FROM shoelace_log;
```

sl_name	sl_avail	log_who	log_when
sl7	6	Al	Tue Oct 20 16:14:45 1998 MET DST

(1 row)

That's what we expected. What happened in the background is the following. The parser created the query tree:

```
UPDATE shoelace_data SET sl_avail = 6
FROM shoelace_data shoelace_data
WHERE shoelace_data.sl_name = 'sl7';
```

There is a rule `log_shoelace` that is ON UPDATE with the rule qualification expression:

```
NEW.sl_avail <> OLD.sl_avail
```

and the action:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old;
```

(This looks a little strange since you cannot normally write `INSERT ... VALUES ... FROM`. The `FROM` clause here is just to indicate that there are range-table entries in the query tree for `new` and `old`. These are needed so that they can be referenced by variables in the `INSERT` command's query tree.)

The rule is a qualified ALSO rule, so the rule system has to return two query trees: the modified rule action and the original query tree. In step 1, the range table of the original query is incorporated into the rule's action query tree. This results in:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
    shoelace_data shoelace_data;
```

In step 2, the rule qualification is added to it, so the result set is restricted to rows where `sl_avail` changes:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
    shoelace_data shoelace_data
WHERE new.sl_avail <> old.sl_avail;
```

(This looks even stranger, since `INSERT ... VALUES` doesn't have a `WHERE` clause either, but the planner and executor will have no difficulty with it. They need to support this same functionality anyway for `INSERT ... SELECT`.)

In step 3, the original query tree's qualification is added, restricting the result set further to only the rows that would have been touched by the original query:

```
INSERT INTO shoelace_log VALUES (
    new.sl_name, new.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
    shoelace_data shoelace_data
WHERE new.sl_avail <> old.sl_avail
    AND shoelace_data.sl_name = 'sl7';
```

Step 4 replaces references to `NEW` by the target list entries from the original query tree or by the matching variable references from the result relation:

```
INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, 6,
```

```

        current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
     shoelace_data shoelace_data
WHERE 6 <> old.sl_avail
     AND shoelace_data.sl_name = 'sl7';

```

Step 5 changes OLD references into result relation references:

```

INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, 6,
    current_user, current_timestamp )
FROM shoelace_data new, shoelace_data old,
     shoelace_data shoelace_data
WHERE 6 <> shoelace_data.sl_avail
     AND shoelace_data.sl_name = 'sl7';

```

That's it. Since the rule is ALSO, we also output the original query tree. In short, the output from the rule system is a list of two query trees that correspond to these statements:

```

INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, 6,
    current_user, current_timestamp )
FROM shoelace_data
WHERE 6 <> shoelace_data.sl_avail
     AND shoelace_data.sl_name = 'sl7';

```

```

UPDATE shoelace_data SET sl_avail = 6
WHERE sl_name = 'sl7';

```

These are executed in this order, and that is exactly what the rule was meant to do.

The substitutions and the added qualifications ensure that, if the original query would be, say:

```

UPDATE shoelace_data SET sl_color = 'green'
WHERE sl_name = 'sl7';

```

no log entry would get written. In that case, the original query tree does not contain a target list entry for `sl_avail`, so `NEW.sl_avail` will get replaced by `shoelace_data.sl_avail`. Thus, the extra command generated by the rule is:

```

INSERT INTO shoelace_log VALUES (
    shoelace_data.sl_name, shoelace_data.sl_avail,
    current_user, current_timestamp )
FROM shoelace_data
WHERE shoelace_data.sl_avail <> shoelace_data.sl_avail
     AND shoelace_data.sl_name = 'sl7';

```

and that qualification will never be true.

It will also work if the original query modifies multiple rows. So if someone issued the command:

```

UPDATE shoelace_data SET sl_avail = 0
WHERE sl_color = 'black';

```

four rows in fact get updated (`s11`, `s12`, `s13`, and `s14`). But `s13` already has `sl_avail = 0`. In this case, the original query trees qualification is different and that results in the extra query tree:

```
INSERT INTO shoelace_log
SELECT shoelace_data.sl_name, 0,
       current_user, current_timestamp
FROM shoelace_data
WHERE 0 <> shoelace_data.sl_avail
AND shoelace_data.sl_color = 'black';
```

being generated by the rule. This query tree will surely insert three new log entries. And that's absolutely correct.

Here we can see why it is important that the original query tree is executed last. If the UPDATE had been executed first, all the rows would have already been set to zero, so the logging INSERT would not find any row where `0 <> shoelace_data.sl_avail`.

40.4.2. Cooperation with Views

A simple way to protect view relations from the mentioned possibility that someone can try to run INSERT, UPDATE, or DELETE on them is to let those query trees get thrown away. So we could create the rules:

```
CREATE RULE shoe_ins_protect AS ON INSERT TO shoe
DO INSTEAD NOTHING;
CREATE RULE shoe_upd_protect AS ON UPDATE TO shoe
DO INSTEAD NOTHING;
CREATE RULE shoe_del_protect AS ON DELETE TO shoe
DO INSTEAD NOTHING;
```

If someone now tries to do any of these operations on the view relation `shoe`, the rule system will apply these rules. Since the rules have no actions and are `INSTEAD`, the resulting list of query trees will be empty and the whole query will become nothing because there is nothing left to be optimized or executed after the rule system is done with it.

A more sophisticated way to use the rule system is to create rules that rewrite the query tree into one that does the right operation on the real tables. To do that on the `shoelace` view, we create the following rules:

```
CREATE RULE shoelace_ins AS ON INSERT TO shoelace
DO INSTEAD
INSERT INTO shoelace_data VALUES (
    NEW.sl_name,
    NEW.sl_avail,
    NEW.sl_color,
    NEW.sl_len,
    NEW.sl_unit
);

CREATE RULE shoelace_upd AS ON UPDATE TO shoelace
DO INSTEAD
UPDATE shoelace_data
SET sl_name = NEW.sl_name,
    sl_avail = NEW.sl_avail,
    sl_color = NEW.sl_color,
    sl_len = NEW.sl_len,
    sl_unit = NEW.sl_unit
WHERE sl_name = OLD.sl_name;
```

```
CREATE RULE shoelace_del AS ON DELETE TO shoelace
DO INSTEAD
DELETE FROM shoelace_data
WHERE sl_name = OLD.sl_name;
```

If you want to support RETURNING queries on the view, you need to make the rules include RETURNING clauses that compute the view rows. This is usually pretty trivial for views on a single table, but it's a bit tedious for join views such as shoelace. An example for the insert case is:

```
CREATE RULE shoelace_ins AS ON INSERT TO shoelace
DO INSTEAD
INSERT INTO shoelace_data VALUES (
    NEW.sl_name,
    NEW.sl_avail,
    NEW.sl_color,
    NEW.sl_len,
    NEW.sl_unit
)
RETURNING
    shoelace_data.*,
    (SELECT shoelace_data.sl_len * u.un_fact
     FROM unit u WHERE shoelace_data.sl_unit = u.un_name);
```

Note that this one rule supports both INSERT and INSERT RETURNING queries on the view — the RETURNING clause is simply ignored for INSERT.

Now assume that once in a while, a pack of shoelaces arrives at the shop and a big parts list along with it. But you don't want to manually update the shoelace view every time. Instead we set up two little tables: one where you can insert the items from the part list, and one with a special trick. The creation commands for these are:

```
CREATE TABLE shoelace_arrive (
    arr_name    text,
    arr_quant   integer
);

CREATE TABLE shoelace_ok (
    ok_name     text,
    ok_quant    integer
);

CREATE RULE shoelace_ok_ins AS ON INSERT TO shoelace_ok
DO INSTEAD
UPDATE shoelace
    SET sl_avail = sl_avail + NEW.ok_quant
    WHERE sl_name = NEW.ok_name;
```

Now you can fill the table shoelace_arrive with the data from the parts list:

```
SELECT * FROM shoelace_arrive;
```

arr_name	arr_quant
s13	10
s16	20
s18	20

(3 rows)

Take a quick look at the current data:

```
SELECT * FROM shoelace;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl1	5	black	80	cm	80
sl2	6	black	100	cm	100
sl7	6	brown	60	cm	60
sl3	0	black	35	inch	88.9
sl4	8	black	40	inch	101.6
sl8	1	brown	40	inch	101.6
sl5	4	brown	1	m	100
sl6	0	brown	0.9	m	90

(8 rows)

Now move the arrived shoelaces in:

```
INSERT INTO shoelace_ok SELECT * FROM shoelace_arrive;
```

and check the results:

```
SELECT * FROM shoelace ORDER BY sl_name;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl1	5	black	80	cm	80
sl2	6	black	100	cm	100
sl7	6	brown	60	cm	60
sl4	8	black	40	inch	101.6
sl3	10	black	35	inch	88.9
sl8	21	brown	40	inch	101.6
sl5	4	brown	1	m	100
sl6	20	brown	0.9	m	90

(8 rows)

```
SELECT * FROM shoelace_log;
```

sl_name	sl_avail	log_who	log_when
sl7	6	Al	Tue Oct 20 19:14:45 1998 MET DST
sl3	10	Al	Tue Oct 20 19:25:16 1998 MET DST
sl6	20	Al	Tue Oct 20 19:25:16 1998 MET DST
sl8	21	Al	Tue Oct 20 19:25:16 1998 MET DST

(4 rows)

It's a long way from the one `INSERT ... SELECT` to these results. And the description of the query-tree transformation will be the last in this chapter. First, there is the parser's output:

```
INSERT INTO shoelace_ok
SELECT shoelace_arrive.arr_name, shoelace_arrive.arr_quant
FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok;
```

Now the first rule `shoelace_ok_ins` is applied and turns this into:

```

UPDATE shoelace
  SET sl_avail = shoelace.sl_avail + shoelace_arrive.arr_quant
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
        shoelace_ok old, shoelace_ok new,
        shoelace shoelace
  WHERE shoelace.sl_name = shoelace_arrive.arr_name;

```

and throws away the original INSERT on shoelace_ok. This rewritten query is passed to the rule system again, and the second applied rule shoelace_upd produces:

```

UPDATE shoelace_data
  SET sl_name = shoelace.sl_name,
      sl_avail = shoelace.sl_avail + shoelace_arrive.arr_quant,
      sl_color = shoelace.sl_color,
      sl_len = shoelace.sl_len,
      sl_unit = shoelace.sl_unit
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
        shoelace_ok old, shoelace_ok new,
        shoelace shoelace, shoelace old,
        shoelace new, shoelace_data shoelace_data
  WHERE shoelace.sl_name = shoelace_arrive.arr_name
        AND shoelace_data.sl_name = shoelace.sl_name;

```

Again it's an INSTEAD rule and the previous query tree is trashed. Note that this query still uses the view shoelace. But the rule system isn't finished with this step, so it continues and applies the _RETURN rule on it, and we get:

```

UPDATE shoelace_data
  SET sl_name = s.sl_name,
      sl_avail = s.sl_avail + shoelace_arrive.arr_quant,
      sl_color = s.sl_color,
      sl_len = s.sl_len,
      sl_unit = s.sl_unit
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
        shoelace_ok old, shoelace_ok new,
        shoelace shoelace, shoelace old,
        shoelace new, shoelace_data shoelace_data,
        shoelace old, shoelace new,
        shoelace_data s, unit u
  WHERE s.sl_name = shoelace_arrive.arr_name
        AND shoelace_data.sl_name = s.sl_name;

```

Finally, the rule log_shoelace gets applied, producing the extra query tree:

```

INSERT INTO shoelace_log
SELECT s.sl_name,
      s.sl_avail + shoelace_arrive.arr_quant,
      current_user,
      current_timestamp
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
        shoelace_ok old, shoelace_ok new,
        shoelace shoelace, shoelace old,
        shoelace new, shoelace_data shoelace_data,
        shoelace old, shoelace new,
        shoelace_data s, unit u,

```

```

        shoelace_data old, shoelace_data new
        shoelace_log shoelace_log
WHERE s.sl_name = shoelace_arrive.arr_name
      AND shoelace_data.sl_name = s.sl_name
      AND (s.sl_avail + shoelace_arrive.arr_quant) <> s.sl_avail;

```

After that the rule system runs out of rules and returns the generated query trees.

So we end up with two final query trees that are equivalent to the SQL statements:

```

INSERT INTO shoelace_log
SELECT s.sl_name,
       s.sl_avail + shoelace_arrive.arr_quant,
       current_user,
       current_timestamp
FROM shoelace_arrive shoelace_arrive, shoelace_data
shoelace_data,
     shoelace_data s
WHERE s.sl_name = shoelace_arrive.arr_name
      AND shoelace_data.sl_name = s.sl_name
      AND s.sl_avail + shoelace_arrive.arr_quant <> s.sl_avail;

```

```

UPDATE shoelace_data
SET sl_avail = shoelace_data.sl_avail +
shoelace_arrive.arr_quant
FROM shoelace_arrive shoelace_arrive,
     shoelace_data shoelace_data,
     shoelace_data s
WHERE s.sl_name = shoelace_arrive.sl_name
      AND shoelace_data.sl_name = s.sl_name;

```

The result is that data coming from one relation inserted into another, changed into updates on a third, changed into updating a fourth plus logging that final update in a fifth gets reduced into two queries.

There is a little detail that's a bit ugly. Looking at the two queries, it turns out that the shoelace_data relation appears twice in the range table where it could definitely be reduced to one. The planner does not handle it and so the execution plan for the rule systems output of the INSERT will be

```

Nested Loop
-> Merge Join
    -> Merge Join
        -> Seq Scan
            -> Sort
                -> Seq Scan on s
        -> Seq Scan
            -> Sort
                -> Seq Scan on shoelace_arrive
    -> Seq Scan on shoelace_data

```

while omitting the extra range table entry would result in a

```

Merge Join
-> Seq Scan
    -> Sort
        -> Seq Scan on s
-> Seq Scan
    -> Sort
        -> Seq Scan on shoelace_arrive

```

which produces exactly the same entries in the log table. Thus, the rule system caused one extra scan on the table `shoelace_data` that is absolutely not necessary. And the same redundant scan is done once more in the UPDATE. But it was a really hard job to make that all possible at all.

Now we make a final demonstration of the PostgreSQL rule system and its power. Say you add some shoelaces with extraordinary colors to your database:

```
INSERT INTO shoelace VALUES ('sl9', 0, 'pink', 35.0, 'inch', 0.0);
INSERT INTO shoelace VALUES ('sl10', 1000, 'magenta', 40.0, 'inch',
0.0);
```

We would like to make a view to check which shoelace entries do not fit any shoe in color. The view for this is:

```
CREATE VIEW shoelace_mismatch AS
SELECT * FROM shoelace WHERE NOT EXISTS
(SELECT shoename FROM shoe WHERE slcolor = sl_color);
```

Its output is:

```
SELECT * FROM shoelace_mismatch;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl9	0	pink	35	inch	88.9
sl10	1000	magenta	40	inch	101.6

Now we want to set it up so that mismatching shoelaces that are not in stock are deleted from the database. To make it a little harder for PostgreSQL, we don't delete it directly. Instead we create one more view:

```
CREATE VIEW shoelace_can_delete AS
SELECT * FROM shoelace_mismatch WHERE sl_avail = 0;
```

and do it this way:

```
DELETE FROM shoelace WHERE EXISTS
(SELECT * FROM shoelace_can_delete
WHERE sl_name = shoelace.sl_name);
```

Voilà:

```
SELECT * FROM shoelace;
```

sl_name	sl_avail	sl_color	sl_len	sl_unit	sl_len_cm
sl1	5	black	80	cm	80
sl2	6	black	100	cm	100
sl7	6	brown	60	cm	60
sl4	8	black	40	inch	101.6
sl3	10	black	35	inch	88.9
sl8	21	brown	40	inch	101.6
sl10	1000	magenta	40	inch	101.6
sl5	4	brown	1	m	100

```
s16      |      20 | brown   |      0.9 | m      |      90
(9 rows)
```

A DELETE on a view, with a subquery qualification that in total uses 4 nesting/joined views, where one of them itself has a subquery qualification containing a view and where calculated view columns are used, gets rewritten into one single query tree that deletes the requested data from a real table.

There are probably only a few situations out in the real world where such a construct is necessary. But it makes you feel comfortable that it works.

40.5. Rules and Privileges

Due to rewriting of queries by the PostgreSQL rule system, other tables/views than those used in the original query get accessed. When update rules are used, this can include write access to tables.

Rewrite rules don't have a separate owner. The owner of a relation (table or view) is automatically the owner of the rewrite rules that are defined for it. The PostgreSQL rule system changes the behavior of the default access control system. Relations that are used due to rules get checked against the privileges of the rule owner, not the user invoking the rule. This means that users only need the required privileges for the tables/views that are explicitly named in their queries.

For example: A user has a list of phone numbers where some of them are private, the others are of interest for the assistant of the office. The user can construct the following:

```
CREATE TABLE phone_data (person text, phone text, private boolean);
CREATE VIEW phone_number AS
    SELECT person, CASE WHEN NOT private THEN phone END AS phone
    FROM phone_data;
GRANT SELECT ON phone_number TO assistant;
```

Nobody except that user (and the database superusers) can access the `phone_data` table. But because of the GRANT, the assistant can run a SELECT on the `phone_number` view. The rule system will rewrite the SELECT from `phone_number` into a SELECT from `phone_data`. Since the user is the owner of `phone_number` and therefore the owner of the rule, the read access to `phone_data` is now checked against the user's privileges and the query is permitted. The check for accessing `phone_number` is also performed, but this is done against the invoking user, so nobody but the user and the assistant can use it.

The privileges are checked rule by rule. So the assistant is for now the only one who can see the public phone numbers. But the assistant can set up another view and grant access to that to the public. Then, anyone can see the `phone_number` data through the assistant's view. What the assistant cannot do is to create a view that directly accesses `phone_data`. (Actually the assistant can, but it will not work since every access will be denied during the permission checks.) And as soon as the user notices that the assistant opened their `phone_number` view, the user can revoke the assistant's access. Immediately, any access to the assistant's view would fail.

One might think that this rule-by-rule checking is a security hole, but in fact it isn't. But if it did not work this way, the assistant could set up a table with the same columns as `phone_number` and copy the data to there once per day. Then it's the assistant's own data and the assistant can grant access to everyone they want. A GRANT command means, "I trust you". If someone you trust does the thing above, it's time to think it over and then use REVOKE.

Note that while views can be used to hide the contents of certain columns using the technique shown above, they cannot be used to reliably conceal the data in unseen rows unless the `security_barrier` flag has been set. For example, the following view is insecure:

```
CREATE VIEW phone_number AS
```


to possibly-insecure functions. The user may well have other means of making inferences about the unseen data; for example, they can see the query plan using `EXPLAIN`, or measure the run time of queries against the view. A malicious attacker might be able to infer something about the amount of unseen data, or even gain some information about the data distribution or most common values (since these things may affect the run time of the plan; or even, since they are also reflected in the optimizer statistics, the choice of plan). If these types of "covert channel" attacks are of concern, it is probably unwise to grant any access to the data at all.

40.6. Rules and Command Status

The PostgreSQL server returns a command status string, such as `INSERT 149592 1`, for each command it receives. This is simple enough when there are no rules involved, but what happens when the query is rewritten by rules?

Rules affect the command status as follows:

- If there is no unconditional `INSTEAD` rule for the query, then the originally given query will be executed, and its command status will be returned as usual. (But note that if there were any conditional `INSTEAD` rules, the negation of their qualifications will have been added to the original query. This might reduce the number of rows it processes, and if so the reported status will be affected.)
- If there is any unconditional `INSTEAD` rule for the query, then the original query will not be executed at all. In this case, the server will return the command status for the last query that was inserted by an `INSTEAD` rule (conditional or unconditional) and is of the same command type (`INSERT`, `UPDATE`, or `DELETE`) as the original query. If no query meeting those requirements is added by any rule, then the returned command status shows the original query type and zeroes for the row-count and OID fields.

The programmer can ensure that any desired `INSTEAD` rule is the one that sets the command status in the second case, by giving it the alphabetically last rule name among the active rules, so that it gets applied last.

40.7. Rules Versus Triggers

Many things that can be done using triggers can also be implemented using the PostgreSQL rule system. One of the things that cannot be implemented by rules are some kinds of constraints, especially foreign keys. It is possible to place a qualified rule that rewrites a command to `NOTHING` if the value of a column does not appear in another table. But then the data is silently thrown away and that's not a good idea. If checks for valid values are required, and in the case of an invalid value an error message should be generated, it must be done by a trigger.

In this chapter, we focused on using rules to update views. All of the update rule examples in this chapter can also be implemented using `INSTEAD OF` triggers on the views. Writing such triggers is often easier than writing rules, particularly if complex logic is required to perform the update.

For the things that can be implemented by both, which is best depends on the usage of the database. A trigger is fired once for each affected row. A rule modifies the query or generates an additional query. So if many rows are affected in one statement, a rule issuing one extra command is likely to be faster than a trigger that is called for every single row and must re-determine what to do many times. However, the trigger approach is conceptually far simpler than the rule approach, and is easier for novices to get right.

Here we show an example of how the choice of rules versus triggers plays out in one situation. There are two tables:

```
CREATE TABLE computer (  
    hostname      text,      -- indexed
```

```
    manufacturer    text    -- indexed
);

CREATE TABLE software (
    software        text,    -- indexed
    hostname        text    -- indexed
);
```

Both tables have many thousands of rows and the indexes on `hostname` are unique. The rule or trigger should implement a constraint that deletes rows from `software` that reference a deleted computer. The trigger would use this command:

```
DELETE FROM software WHERE hostname = $1;
```

Since the trigger is called for each individual row deleted from `computer`, it can prepare and save the plan for this command and pass the `hostname` value in the parameter. The rule would be written as:

```
CREATE RULE computer_del AS ON DELETE TO computer
DO DELETE FROM software WHERE hostname = OLD.hostname;
```

Now we look at different types of deletes. In the case of a:

```
DELETE FROM computer WHERE hostname = 'mypc.local.net';
```

the table `computer` is scanned by index (fast), and the command issued by the trigger would also use an index scan (also fast). The extra command from the rule would be:

```
DELETE FROM software WHERE computer.hostname = 'mypc.local.net'
AND software.hostname = computer.hostname;
```

Since there are appropriate indexes set up, the planner will create a plan of

Nestloop

```
-> Index Scan using comp_hostidx on computer
-> Index Scan using soft_hostidx on software
```

So there would be not that much difference in speed between the trigger and the rule implementation.

With the next delete we want to get rid of all the 2000 computers where the `hostname` starts with `old`. There are two possible commands to do that. One is:

```
DELETE FROM computer WHERE hostname >= 'old'
AND hostname < 'ole'
```

The command added by the rule will be:

```
DELETE FROM software WHERE computer.hostname >= 'old' AND
computer.hostname < 'ole'
AND software.hostname = computer.hostname;
```

with the plan

Hash Join

```
-> Seq Scan on software
-> Hash
    -> Index Scan using comp_hostidx on computer
```

The other possible command is:

```
DELETE FROM computer WHERE hostname ~ '^old';
```

which results in the following executing plan for the command added by the rule:

```
Nestloop
  -> Index Scan using comp_hostidx on computer
  -> Index Scan using soft_hostidx on software
```

This shows, that the planner does not realize that the qualification for `hostname` in `computer` could also be used for an index scan on `software` when there are multiple qualification expressions combined with `AND`, which is what it does in the regular-expression version of the command. The trigger will get invoked once for each of the 2000 old computers that have to be deleted, and that will result in one index scan over `computer` and 2000 index scans over `software`. The rule implementation will do it with two commands that use indexes. And it depends on the overall size of the table `software` whether the rule will still be faster in the sequential scan situation. 2000 command executions from the trigger over the SPI manager take some time, even if all the index blocks will soon be in the cache.

The last command we look at is:

```
DELETE FROM computer WHERE manufacturer = 'bim';
```

Again this could result in many rows to be deleted from `computer`. So the trigger will again run many commands through the executor. The command generated by the rule will be:

```
DELETE FROM software WHERE computer.manufacturer = 'bim'
                        AND software.hostname = computer.hostname;
```

The plan for that command will again be the nested loop over two index scans, only using a different index on `computer`:

```
Nestloop
  -> Index Scan using comp_manufidx on computer
  -> Index Scan using soft_hostidx on software
```

In any of these cases, the extra commands from the rule system will be more or less independent from the number of affected rows in a command.

The summary is, rules will only be significantly slower than triggers if their actions result in large and badly qualified joins, a situation where the planner fails.

Chapter 41. Procedural Languages

PostgreSQL allows user-defined functions to be written in other languages besides SQL and C. These other languages are generically called *procedural languages* (PLs). For a function written in a procedural language, the database server has no built-in knowledge about how to interpret the function's source text. Instead, the task is passed to a special handler that knows the details of the language. The handler could either do all the work of parsing, syntax analysis, execution, etc. itself, or it could serve as “glue” between PostgreSQL and an existing implementation of a programming language. The handler itself is a C language function compiled into a shared object and loaded on demand, just like any other C function.

There are currently four procedural languages available in the standard PostgreSQL distribution: PL/pgSQL (Chapter 42), PL/Tcl (Chapter 43), PL/Perl (Chapter 44), and PL/Python (Chapter 45). There are additional procedural languages available that are not included in the core distribution. Appendix H has information about finding them. In addition other languages can be defined by users; the basics of developing a new procedural language are covered in Chapter 55.

41.1. Installing Procedural Languages

A procedural language must be “installed” into each database where it is to be used. But procedural languages installed in the database `template1` are automatically available in all subsequently created databases, since their entries in `template1` will be copied by `CREATE DATABASE`. So the database administrator can decide which languages are available in which databases and can make some languages available by default if desired.

For the languages supplied with the standard distribution, it is only necessary to execute `CREATE EXTENSION language_name` to install the language into the current database. The manual procedure described below is only recommended for installing languages that have not been packaged as extensions.

Manual Procedural Language Installation

A procedural language is installed in a database in five steps, which must be carried out by a database superuser. In most cases the required SQL commands should be packaged as the installation script of an “extension”, so that `CREATE EXTENSION` can be used to execute them.

1. The shared object for the language handler must be compiled and installed into an appropriate library directory. This works in the same way as building and installing modules with regular user-defined C functions does; see Section 37.10.5. Often, the language handler will depend on an external library that provides the actual programming language engine; if so, that must be installed as well.
2. The handler must be declared with the command

```
CREATE FUNCTION handler_function_name()
    RETURNS language_handler
    AS 'path-to-shared-object'
    LANGUAGE C;
```

The special return type of `language_handler` tells the database system that this function does not return one of the defined SQL data types and is not directly usable in SQL statements.

3. (Optional) Optionally, the language handler can provide an “inline” handler function that executes anonymous code blocks (DO commands) written in this language. If an inline handler function is provided by the language, declare it with a command like

```
CREATE FUNCTION inline_function_name(internal)
  RETURNS void
  AS 'path-to-shared-object'
  LANGUAGE C;
```

4. (Optional) Optionally, the language handler can provide a “validator” function that checks a function definition for correctness without actually executing it. The validator function is called by `CREATE FUNCTION` if it exists. If a validator function is provided by the language, declare it with a command like

```
CREATE FUNCTION validator_function_name(oid)
  RETURNS void
  AS 'path-to-shared-object'
  LANGUAGE C STRICT;
```

5. Finally, the PL must be declared with the command

```
CREATE [TRUSTED] LANGUAGE language_name
  HANDLER handler_function_name
  [INLINE inline_function_name]
  [VALIDATOR validator_function_name] ;
```

The optional key word `TRUSTED` specifies that the language does not grant access to data that the user would not otherwise have. Trusted languages are designed for ordinary database users (those without superuser privilege) and allows them to safely create functions and procedures. Since PL functions are executed inside the database server, the `TRUSTED` flag should only be given for languages that do not allow access to database server internals or the file system. The languages PL/pgSQL, PL/Tcl, and PL/Perl are considered trusted; the languages PL/TclU, PL/PerlU, and PL/PythonU are designed to provide unlimited functionality and should *not* be marked trusted.

Example 41.1 shows how the manual installation procedure would work with the language PL/Perl.

Example 41.1. Manual Installation of PL/Perl

The following command tells the database server where to find the shared object for the PL/Perl language's call handler function:

```
CREATE FUNCTION plperl_call_handler() RETURNS language_handler AS
  '$libdir/plperl' LANGUAGE C;
```

PL/Perl has an inline handler function and a validator function, so we declare those too:

```
CREATE FUNCTION plperl_inline_handler(internal) RETURNS void AS
  '$libdir/plperl' LANGUAGE C;
```

```
CREATE FUNCTION plperl_validator(oid) RETURNS void AS
  '$libdir/plperl' LANGUAGE C STRICT;
```

The command:

```
CREATE TRUSTED LANGUAGE plperl
  HANDLER plperl_call_handler
  INLINE plperl_inline_handler
  VALIDATOR plperl_validator;
```

then defines that the previously declared functions should be invoked for functions and procedures where the language attribute is `plperl`.

In a default PostgreSQL installation, the handler for the PL/pgSQL language is built and installed into the “library” directory; furthermore, the PL/pgSQL language itself is installed in all databases. If Tcl support is configured in, the handlers for PL/Tcl and PL/TclU are built and installed in the library directory, but the language itself is not installed in any database by default. Likewise, the PL/Perl and PL/PerlU handlers are built and installed if Perl support is configured, and the PL/PythonU handler is installed if Python support is configured, but these languages are not installed by default.

Chapter 42. PL/pgSQL - SQL Procedural Language

42.1. Overview

PL/pgSQL is a loadable procedural language for the PostgreSQL database system. The design goals of PL/pgSQL were to create a loadable procedural language that

- can be used to create functions and triggers,
- adds control structures to the SQL language,
- can perform complex computations,
- inherits all user-defined types, functions, and operators,
- can be defined to be trusted by the server,
- is easy to use.

Functions created with PL/pgSQL can be used anywhere that built-in functions could be used. For example, it is possible to create complex conditional computation functions and later use them to define operators or use them in index expressions.

In PostgreSQL 9.0 and later, PL/pgSQL is installed by default. However it is still a loadable module, so especially security-conscious administrators could choose to remove it.

42.1.1. Advantages of Using PL/pgSQL

SQL is the language PostgreSQL and most other relational databases use as query language. It's portable and easy to learn. But every SQL statement must be executed individually by the database server.

That means that your client application must send each query to the database server, wait for it to be processed, receive and process the results, do some computation, then send further queries to the server. All this incurs interprocess communication and will also incur network overhead if your client is on a different machine than the database server.

With PL/pgSQL you can group a block of computation and a series of queries *inside* the database server, thus having the power of a procedural language and the ease of use of SQL, but with considerable savings of client/server communication overhead.

- Extra round trips between client and server are eliminated
- Intermediate results that the client does not need do not have to be marshaled or transferred between server and client
- Multiple rounds of query parsing can be avoided

This can result in a considerable performance increase as compared to an application that does not use stored functions.

Also, with PL/pgSQL you can use all the data types, operators and functions of SQL.

42.1.2. Supported Argument and Result Data Types

Functions written in PL/pgSQL can accept as arguments any scalar or array data type supported by the server, and they can return a result of any of these types. They can also accept or return any composite

type (row type) specified by name. It is also possible to declare a PL/pgSQL function as accepting `record`, which means that any composite type will do as input, or as returning `record`, which means that the result is a row type whose columns are determined by specification in the calling query, as discussed in Section 7.2.1.4.

PL/pgSQL functions can be declared to accept a variable number of arguments by using the `VARIADIC` marker. This works exactly the same way as for SQL functions, as discussed in Section 37.5.5.

PL/pgSQL functions can also be declared to accept and return the polymorphic types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`. The actual data types handled by a polymorphic function can vary from call to call, as discussed in Section 37.2.5. An example is shown in Section 42.3.1.

PL/pgSQL functions can also be declared to return a “set” (or table) of any data type that can be returned as a single instance. Such a function generates its output by executing `RETURN NEXT` for each desired element of the result set, or by using `RETURN QUERY` to output the result of evaluating a query.

Finally, a PL/pgSQL function can be declared to return `void` if it has no useful return value. (Alternatively, it could be written as a procedure in that case.)

PL/pgSQL functions can also be declared with output parameters in place of an explicit specification of the return type. This does not add any fundamental capability to the language, but it is often convenient, especially for returning multiple values. The `RETURNS TABLE` notation can also be used in place of `RETURNS SETOF`.

Specific examples appear in Section 42.3.1 and Section 42.6.1.

42.2. Structure of PL/pgSQL

Functions written in PL/pgSQL are defined to the server by executing `CREATE FUNCTION` commands. Such a command would normally look like, say,

```
CREATE FUNCTION somefunc(integer, text) RETURNS integer
AS 'function body text'
LANGUAGE plpgsql;
```

The function body is simply a string literal so far as `CREATE FUNCTION` is concerned. It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the function body, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function body must be escaped by doubling them. Almost all the examples in this chapter use dollar-quoted literals for their function bodies.

PL/pgSQL is a block-structured language. The complete text of a function body must be a *block*. A block is defined as:

```
[ <<label>> ]
[ DECLARE
    declarations ]
BEGIN
    statements
END [ label ];
```

Each declaration and each statement within a block is terminated by a semicolon. A block that appears within another block must have a semicolon after `END`, as shown above; however the final `END` that concludes a function body does not require a semicolon.

Tip

A common mistake is to write a semicolon immediately after `BEGIN`. This is incorrect and will result in a syntax error.

A *label* is only needed if you want to identify the block for use in an `EXIT` statement, or to qualify the names of the variables declared in the block. If a label is given after `END`, it must match the label at the block's beginning.

All key words are case-insensitive. Identifiers are implicitly converted to lower case unless double-quoted, just as they are in ordinary SQL commands.

Comments work the same way in PL/pgSQL code as in ordinary SQL. A double dash (`--`) starts a comment that extends to the end of the line. A `/*` starts a block comment that extends to the matching occurrence of `*/`. Block comments nest.

Any statement in the statement section of a block can be a *subblock*. Subblocks can be used for logical grouping or to localize variables to a small group of statements. Variables declared in a subblock mask any similarly-named variables of outer blocks for the duration of the subblock; but you can access the outer variables anyway if you qualify their names with their block's label. For example:

```
CREATE FUNCTION somefunc() RETURNS integer AS $$
<< outerblock >>
DECLARE
    quantity integer := 30;
BEGIN
    RAISE NOTICE 'Quantity here is %', quantity; -- Prints 30
    quantity := 50;
    --
    -- Create a subblock
    --
    DECLARE
        quantity integer := 80;
    BEGIN
        RAISE NOTICE 'Quantity here is %', quantity; -- Prints 80
        RAISE NOTICE 'Outer quantity here is %',
outerblock.quantity; -- Prints 50
    END;

    RAISE NOTICE 'Quantity here is %', quantity; -- Prints 50

    RETURN quantity;
END;
$$ LANGUAGE plpgsql;
```

Note

There is actually a hidden “outer block” surrounding the body of any PL/pgSQL function. This block provides the declarations of the function's parameters (if any), as well as some special variables such as `FOUND` (see Section 42.5.5). The outer block is labeled with the function's name, meaning that parameters and special variables can be qualified with the function's name.

It is important not to confuse the use of `BEGIN/END` for grouping statements in PL/pgSQL with the similarly-named SQL commands for transaction control. PL/pgSQL's `BEGIN/END` are only for group-

ing; they do not start or end a transaction. See Section 42.8 for information on managing transactions in PL/pgSQL. Also, a block containing an `EXCEPTION` clause effectively forms a subtransaction that can be rolled back without affecting the outer transaction. For more about that see Section 42.6.8.

42.3. Declarations

All variables used in a block must be declared in the declarations section of the block. (The only exceptions are that the loop variable of a `FOR` loop iterating over a range of integer values is automatically declared as an integer variable, and likewise the loop variable of a `FOR` loop iterating over a cursor's result is automatically declared as a record variable.)

PL/pgSQL variables can have any SQL data type, such as `integer`, `varchar`, and `char`.

Here are some examples of variable declarations:

```
user_id integer;
quantity numeric(5);
url varchar;
myrow tablename%ROWTYPE;
myfield tablename.columnname%TYPE;
arow RECORD;
```

The general syntax of a variable declaration is:

```
name [ CONSTANT ] type [ COLLATE collation_name ] [ NOT NULL ]
[ { DEFAULT | := | = } expression ];
```

The `DEFAULT` clause, if given, specifies the initial value assigned to the variable when the block is entered. If the `DEFAULT` clause is not given then the variable is initialized to the SQL null value. The `CONSTANT` option prevents the variable from being assigned to after initialization, so that its value will remain constant for the duration of the block. The `COLLATE` option specifies a collation to use for the variable (see Section 42.3.6). If `NOT NULL` is specified, an assignment of a null value results in a run-time error. All variables declared as `NOT NULL` must have a nonnull default value specified. Equal (=) can be used instead of PL/SQL-compliant :=.

A variable's default value is evaluated and assigned to the variable each time the block is entered (not just once per function call). So, for example, assigning `now()` to a variable of type `timestamp` causes the variable to have the time of the current function call, not the time when the function was precompiled.

Examples:

```
quantity integer DEFAULT 32;
url varchar := 'http://mysite.com';
user_id CONSTANT integer := 10;
```

42.3.1. Declaring Function Parameters

Parameters passed to functions are named with the identifiers `$1`, `$2`, etc. Optionally, aliases can be declared for `$n` parameter names for increased readability. Either the alias or the numeric identifier can then be used to refer to the parameter value.

There are two ways to create an alias. The preferred way is to give a name to the parameter in the `CREATE FUNCTION` command, for example:

```
CREATE FUNCTION sales_tax(subtotal real) RETURNS real AS $$
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

The other way is to explicitly declare an alias, using the declaration syntax

```
name ALIAS FOR $n;
```

The same example in this style looks like:

```
CREATE FUNCTION sales_tax(real) RETURNS real AS $$
DECLARE
    subtotal ALIAS FOR $1;
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

Note

These two examples are not perfectly equivalent. In the first case, `subtotal` could be referenced as `sales_tax.subtotal`, but in the second case it could not. (Had we attached a label to the inner block, `subtotal` could be qualified with that label, instead.)

Some more examples:

```
CREATE FUNCTION instr(vvarchar, integer) RETURNS integer AS $$
DECLARE
    v_string ALIAS FOR $1;
    index ALIAS FOR $2;
BEGIN
    -- some computations using v_string and index here
END;
$$ LANGUAGE plpgsql;
```

```
CREATE FUNCTION concat_selected_fields(in_t sometablename) RETURNS
text AS $$
BEGIN
    RETURN in_t.f1 || in_t.f3 || in_t.f5 || in_t.f7;
END;
$$ LANGUAGE plpgsql;
```

When a PL/pgSQL function is declared with output parameters, the output parameters are given `$n` names and optional aliases in just the same way as the normal input parameters. An output parameter is effectively a variable that starts out `NULL`; it should be assigned to during the execution of the function. The final value of the parameter is what is returned. For instance, the sales-tax example could also be done this way:

```
CREATE FUNCTION sales_tax(subtotal real, OUT tax real) AS $$
BEGIN
```

```

    tax := subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;

```

Notice that we omitted `RETURNS real` — we could have included it, but it would be redundant.

Output parameters are most useful when returning multiple values. A trivial example is:

```

CREATE FUNCTION sum_n_product(x int, y int, OUT sum int, OUT prod
    int) AS $$
BEGIN
    sum := x + y;
    prod := x * y;
END;
$$ LANGUAGE plpgsql;

```

As discussed in Section 37.5.4, this effectively creates an anonymous record type for the function's results. If a `RETURNS` clause is given, it must say `RETURNS record`.

Another way to declare a PL/pgSQL function is with `RETURNS TABLE`, for example:

```

CREATE FUNCTION extended_sales(p_itemno int)
RETURNS TABLE(quantity int, total numeric) AS $$
BEGIN
    RETURN QUERY SELECT s.quantity, s.quantity * s.price FROM sales
    AS s
        WHERE s.itemno = p_itemno;
END;
$$ LANGUAGE plpgsql;

```

This is exactly equivalent to declaring one or more `OUT` parameters and specifying `RETURNS SETOF some_type`.

When the return type of a PL/pgSQL function is declared as a polymorphic type (`anyelement`, `anyarray`, `anynonarray`, `anyenum`, or `anyrange`), a special parameter `$0` is created. Its data type is the actual return type of the function, as deduced from the actual input types (see Section 37.2.5). This allows the function to access its actual return type as shown in Section 42.3.3. `$0` is initialized to null and can be modified by the function, so it can be used to hold the return value if desired, though that is not required. `$0` can also be given an alias. For example, this function works on any data type that has a `+` operator:

```

CREATE FUNCTION add_three_values(v1 anyelement, v2 anyelement, v3
    anyelement)
RETURNS anyelement AS $$
DECLARE
    result ALIAS FOR $0;
BEGIN
    result := v1 + v2 + v3;
    RETURN result;
END;
$$ LANGUAGE plpgsql;

```

The same effect can be obtained by declaring one or more output parameters as polymorphic types. In this case the special `$0` parameter is not used; the output parameters themselves serve the same purpose. For example:

```
CREATE FUNCTION add_three_values(v1 anyelement, v2 anyelement, v3
    anyelement,
                                OUT sum anyelement)
AS $$
BEGIN
    sum := v1 + v2 + v3;
END;
$$ LANGUAGE plpgsql;
```

42.3.2. ALIAS

```
newname ALIAS FOR oldname;
```

The ALIAS syntax is more general than is suggested in the previous section: you can declare an alias for any variable, not just function parameters. The main practical use for this is to assign a different name for variables with predetermined names, such as NEW or OLD within a trigger function.

Examples:

```
DECLARE
    prior ALIAS FOR old;
    updated ALIAS FOR new;
```

Since ALIAS creates two different ways to name the same object, unrestricted use can be confusing. It's best to use it only for the purpose of overriding predetermined names.

42.3.3. Copying Types

```
variable%TYPE
```

%TYPE provides the data type of a variable or table column. You can use this to declare variables that will hold database values. For example, let's say you have a column named `user_id` in your `users` table. To declare a variable with the same data type as `users.user_id` you write:

```
user_id users.user_id%TYPE;
```

By using %TYPE you don't need to know the data type of the structure you are referencing, and most importantly, if the data type of the referenced item changes in the future (for instance: you change the type of `user_id` from `integer` to `real`), you might not need to change your function definition.

%TYPE is particularly valuable in polymorphic functions, since the data types needed for internal variables can change from one call to the next. Appropriate variables can be created by applying %TYPE to the function's arguments or result placeholders.

42.3.4. Row Types

```
name table_name%ROWTYPE;
name composite_type_name;
```

A variable of a composite type is called a *row* variable (or *row-type* variable). Such a variable can hold a whole row of a SELECT or FOR query result, so long as that query's column set matches the declared type of the variable. The individual fields of the row value are accessed using the usual dot notation, for example `rowvar.field`.

A row variable can be declared to have the same type as the rows of an existing table or view, by using the *table_name*%ROWTYPE notation; or it can be declared by giving a composite type's name. (Since every table has an associated composite type of the same name, it actually does not matter in PostgreSQL whether you write %ROWTYPE or not. But the form with %ROWTYPE is more portable.)

Parameters to a function can be composite types (complete table rows). In that case, the corresponding identifier *\$n* will be a row variable, and fields can be selected from it, for example *\$1.user_id*.

Here is an example of using composite types. *table1* and *table2* are existing tables having at least the mentioned fields:

```
CREATE FUNCTION merge_fields(t_row table1) RETURNS text AS $$
DECLARE
    t2_row table2%ROWTYPE;
BEGIN
    SELECT * INTO t2_row FROM table2 WHERE ... ;
    RETURN t_row.f1 || t2_row.f3 || t_row.f5 || t2_row.f7;
END;
$$ LANGUAGE plpgsql;

SELECT merge_fields(t.*) FROM table1 t WHERE ... ;
```

42.3.5. Record Types

```
name RECORD;
```

Record variables are similar to row-type variables, but they have no predefined structure. They take on the actual row structure of the row they are assigned during a *SELECT* or *FOR* command. The substructure of a record variable can change each time it is assigned to. A consequence of this is that until a record variable is first assigned to, it has no substructure, and any attempt to access a field in it will draw a run-time error.

Note that *RECORD* is not a true data type, only a placeholder. One should also realize that when a PL/pgSQL function is declared to return type *record*, this is not quite the same concept as a record variable, even though such a function might use a record variable to hold its result. In both cases the actual row structure is unknown when the function is written, but for a function returning *record* the actual structure is determined when the calling query is parsed, whereas a record variable can change its row structure on-the-fly.

42.3.6. Collation of PL/pgSQL Variables

When a PL/pgSQL function has one or more parameters of collatable data types, a collation is identified for each function call depending on the collations assigned to the actual arguments, as described in Section 23.2. If a collation is successfully identified (i.e., there are no conflicts of implicit collations among the arguments) then all the collatable parameters are treated as having that collation implicitly. This will affect the behavior of collation-sensitive operations within the function. For example, consider

```
CREATE FUNCTION less_than(a text, b text) RETURNS boolean AS $$
BEGIN
    RETURN a < b;
END;
$$ LANGUAGE plpgsql;

SELECT less_than(text_field_1, text_field_2) FROM table1;
```

```
SELECT less_than(text_field_1, text_field_2 COLLATE "C") FROM
table1;
```

The first use of `less_than` will use the common collation of `text_field_1` and `text_field_2` for the comparison, while the second use will use C collation.

Furthermore, the identified collation is also assumed as the collation of any local variables that are of collatable types. Thus this function would not work any differently if it were written as

```
CREATE FUNCTION less_than(a text, b text) RETURNS boolean AS $$
DECLARE
    local_a text := a;
    local_b text := b;
BEGIN
    RETURN local_a < local_b;
END;
$$ LANGUAGE plpgsql;
```

If there are no parameters of collatable data types, or no common collation can be identified for them, then parameters and local variables use the default collation of their data type (which is usually the database's default collation, but could be different for variables of domain types).

A local variable of a collatable data type can have a different collation associated with it by including the `COLLATE` option in its declaration, for example

```
DECLARE
    local_a text COLLATE "en_US";
```

This option overrides the collation that would otherwise be given to the variable according to the rules above.

Also, of course explicit `COLLATE` clauses can be written inside a function if it is desired to force a particular collation to be used in a particular operation. For example,

```
CREATE FUNCTION less_than_c(a text, b text) RETURNS boolean AS $$
BEGIN
    RETURN a < b COLLATE "C";
END;
$$ LANGUAGE plpgsql;
```

This overrides the collations associated with the table columns, parameters, or local variables used in the expression, just as would happen in a plain SQL command.

42.4. Expressions

All expressions used in PL/pgSQL statements are processed using the server's main SQL executor. For example, when you write a PL/pgSQL statement like

```
IF expression THEN ...
```

PL/pgSQL will evaluate the expression by feeding a query like

```
SELECT expression
```

to the main SQL engine. While forming the `SELECT` command, any occurrences of PL/pgSQL variable names are replaced by parameters, as discussed in detail in Section 42.11.1. This allows the query

plan for the `SELECT` to be prepared just once and then reused for subsequent evaluations with different values of the variables. Thus, what really happens on first use of an expression is essentially a `PREPARE` command. For example, if we have declared two integer variables `x` and `y`, and we write

```
IF x < y THEN ...
```

what happens behind the scenes is equivalent to

```
PREPARE statement_name(integer, integer) AS SELECT $1 < $2;
```

and then this prepared statement is `EXECUTED` for each execution of the `IF` statement, with the current values of the PL/pgSQL variables supplied as parameter values. Normally these details are not important to a PL/pgSQL user, but they are useful to know when trying to diagnose a problem. More information appears in Section 42.11.2.

42.5. Basic Statements

In this section and the following ones, we describe all the statement types that are explicitly understood by PL/pgSQL. Anything not recognized as one of these statement types is presumed to be an SQL command and is sent to the main database engine to execute, as described in Section 42.5.2 and Section 42.5.3.

42.5.1. Assignment

An assignment of a value to a PL/pgSQL variable is written as:

```
variable { := | = } expression;
```

As explained previously, the expression in such a statement is evaluated by means of an SQL `SELECT` command sent to the main database engine. The expression must yield a single value (possibly a row value, if the variable is a row or record variable). The target variable can be a simple variable (optionally qualified with a block name), a field of a row or record variable, or an element of an array that is a simple variable or field. Equal (=) can be used instead of PL/SQL-compliant :=.

If the expression's result data type doesn't match the variable's data type, the value will be coerced as though by an assignment cast (see Section 10.4). If no assignment cast is known for the pair of data types involved, the PL/pgSQL interpreter will attempt to convert the result value textually, that is by applying the result type's output function followed by the variable type's input function. Note that this could result in run-time errors generated by the input function, if the string form of the result value is not acceptable to the input function.

Examples:

```
tax := subtotal * 0.06;
my_record.user_id := 20;
```

42.5.2. Executing a Command with No Result

For any SQL command that does not return rows, for example `INSERT` without a `RETURNING` clause, you can execute the command within a PL/pgSQL function just by writing the command.

Any PL/pgSQL variable name appearing in the command text is treated as a parameter, and then the current value of the variable is provided as the parameter value at run time. This is exactly like the processing described earlier for expressions; for details see Section 42.11.1.

When executing a SQL command in this way, PL/pgSQL may cache and re-use the execution plan for the command, as discussed in Section 42.11.2.

Sometimes it is useful to evaluate an expression or `SELECT` query but discard the result, for example when calling a function that has side-effects but no useful result value. To do this in PL/pgSQL, use the `PERFORM` statement:

```
PERFORM query;
```

This executes *query* and discards the result. Write the *query* the same way you would write an SQL `SELECT` command, but replace the initial keyword `SELECT` with `PERFORM`. For `WITH` queries, use `PERFORM` and then place the query in parentheses. (In this case, the query can only return one row.) PL/pgSQL variables will be substituted into the query just as for commands that return no result, and the plan is cached in the same way. Also, the special variable `FOUND` is set to true if the query produced at least one row, or false if it produced no rows (see Section 42.5.5).

Note

One might expect that writing `SELECT` directly would accomplish this result, but at present the only accepted way to do it is `PERFORM`. A SQL command that can return rows, such as `SELECT`, will be rejected as an error unless it has an `INTO` clause as discussed in the next section.

An example:

```
PERFORM create_mv('cs_session_page_requests_mv', my_query);
```

42.5.3. Executing a Query with a Single-Row Result

The result of a SQL command yielding a single row (possibly of multiple columns) can be assigned to a record variable, row-type variable, or list of scalar variables. This is done by writing the base SQL command and adding an `INTO` clause. For example,

```
SELECT select_expressions INTO [STRICT] target FROM ...;
INSERT ... RETURNING expressions INTO [STRICT] target;
UPDATE ... RETURNING expressions INTO [STRICT] target;
DELETE ... RETURNING expressions INTO [STRICT] target;
```

where *target* can be a record variable, a row variable, or a comma-separated list of simple variables and record/row fields. PL/pgSQL variables will be substituted into the rest of the query, and the plan is cached, just as described above for commands that do not return rows. This works for `SELECT`, `INSERT/UPDATE/DELETE` with `RETURNING`, and utility commands that return row-set results (such as `EXPLAIN`). Except for the `INTO` clause, the SQL command is the same as it would be written outside PL/pgSQL.

Tip

Note that this interpretation of `SELECT` with `INTO` is quite different from PostgreSQL's regular `SELECT INTO` command, wherein the `INTO` target is a newly created table. If you want to create a table from a `SELECT` result inside a PL/pgSQL function, use the syntax `CREATE TABLE ... AS SELECT`.

If a row or a variable list is used as target, the query's result columns must exactly match the structure of the target as to number and data types, or else a run-time error occurs. When a record variable is the target, it automatically configures itself to the row type of the query result columns.

The INTO clause can appear almost anywhere in the SQL command. Customarily it is written either just before or just after the list of *select_expressions* in a SELECT command, or at the end of the command for other command types. It is recommended that you follow this convention in case the PL/pgSQL parser becomes stricter in future versions.

If STRICT is not specified in the INTO clause, then *target* will be set to the first row returned by the query, or to nulls if the query returned no rows. (Note that “the first row” is not well-defined unless you've used ORDER BY.) Any result rows after the first row are discarded. You can check the special FOUND variable (see Section 42.5.5) to determine whether a row was returned:

```
SELECT * INTO myrec FROM emp WHERE empname = myname;
IF NOT FOUND THEN
    RAISE EXCEPTION 'employee % not found', myname;
END IF;
```

If the STRICT option is specified, the query must return exactly one row or a run-time error will be reported, either NO_DATA_FOUND (no rows) or TOO_MANY_ROWS (more than one row). You can use an exception block if you wish to catch the error, for example:

```
BEGIN
    SELECT * INTO STRICT myrec FROM emp WHERE empname = myname;
EXCEPTION
    WHEN NO_DATA_FOUND THEN
        RAISE EXCEPTION 'employee % not found', myname;
    WHEN TOO_MANY_ROWS THEN
        RAISE EXCEPTION 'employee % not unique', myname;
END;
```

Successful execution of a command with STRICT always sets FOUND to true.

For INSERT/UPDATE/DELETE with RETURNING, PL/pgSQL reports an error for more than one returned row, even when STRICT is not specified. This is because there is no option such as ORDER BY with which to determine which affected row should be returned.

If `print_strict_params` is enabled for the function, then when an error is thrown because the requirements of STRICT are not met, the `DETAIL` part of the error message will include information about the parameters passed to the query. You can change the `print_strict_params` setting for all functions by setting `plpgsql.print_strict_params`, though only subsequent function compilations will be affected. You can also enable it on a per-function basis by using a compiler option, for example:

```
CREATE FUNCTION get_userid(username text) RETURNS int
AS $$
#print_strict_params on
DECLARE
userid int;
BEGIN
    SELECT users.userid INTO STRICT userid
        FROM users WHERE users.username = get_userid.username;
    RETURN userid;
END
$$ LANGUAGE plpgsql;
```

On failure, this function might produce an error message such as

```
ERROR: query returned no rows
DETAIL: parameters: $1 = 'nosuchuser'
CONTEXT: PL/pgSQL function get_userid(text) line 6 at SQL
statement
```

Note

The `STRICT` option matches the behavior of Oracle PL/SQL's `SELECT INTO` and related statements.

To handle cases where you need to process multiple result rows from a SQL query, see Section 42.6.6.

42.5.4. Executing Dynamic Commands

Oftentimes you will want to generate dynamic commands inside your PL/pgSQL functions, that is, commands that will involve different tables or different data types each time they are executed. PL/pgSQL's normal attempts to cache plans for commands (as discussed in Section 42.11.2) will not work in such scenarios. To handle this sort of problem, the `EXECUTE` statement is provided:

```
EXECUTE command-string [ INTO [STRICT] target ] [ USING expression
[ , ... ] ];
```

where *command-string* is an expression yielding a string (of type `text`) containing the command to be executed. The optional *target* is a record variable, a row variable, or a comma-separated list of simple variables and record/row fields, into which the results of the command will be stored. The optional `USING` expressions supply values to be inserted into the command.

No substitution of PL/pgSQL variables is done on the computed command string. Any required variable values must be inserted in the command string as it is constructed; or you can use parameters as described below.

Also, there is no plan caching for commands executed via `EXECUTE`. Instead, the command is always planned each time the statement is run. Thus the command string can be dynamically created within the function to perform actions on different tables and columns.

The `INTO` clause specifies where the results of a SQL command returning rows should be assigned. If a row or variable list is provided, it must exactly match the structure of the query's results (when a record variable is used, it will configure itself to match the result structure automatically). If multiple rows are returned, only the first will be assigned to the `INTO` variable. If no rows are returned, `NULL` is assigned to the `INTO` variable(s). If no `INTO` clause is specified, the query results are discarded.

If the `STRICT` option is given, an error is reported unless the query produces exactly one row.

The command string can use parameter values, which are referenced in the command as `$1`, `$2`, etc. These symbols refer to values supplied in the `USING` clause. This method is often preferable to inserting data values into the command string as text: it avoids run-time overhead of converting the values to text and back, and it is much less prone to SQL-injection attacks since there is no need for quoting or escaping. An example is:

```
EXECUTE 'SELECT count(*) FROM mytable WHERE inserted_by = $1 AND
inserted <= $2'
INTO c
```

```
USING checked_user, checked_date;
```

Note that parameter symbols can only be used for data values — if you want to use dynamically determined table or column names, you must insert them into the command string textually. For example, if the preceding query needed to be done against a dynamically selected table, you could do this:

```
EXECUTE 'SELECT count(*) FROM '
      || quote_ident(tabname)
      || ' WHERE inserted_by = $1 AND inserted <= $2'
INTO c
USING checked_user, checked_date;
```

A cleaner approach is to use `format()`'s `%I` specification for table or column names (strings separated by a newline are concatenated):

```
EXECUTE format('SELECT count(*) FROM %I '
      'WHERE inserted_by = $1 AND inserted <= $2', tabname)
INTO c
USING checked_user, checked_date;
```

Another restriction on parameter symbols is that they only work in `SELECT`, `INSERT`, `UPDATE`, and `DELETE` commands. In other statement types (generically called utility statements), you must insert values textually even if they are just data values.

An `EXECUTE` with a simple constant command string and some `USING` parameters, as in the first example above, is functionally equivalent to just writing the command directly in PL/pgSQL and allowing replacement of PL/pgSQL variables to happen automatically. The important difference is that `EXECUTE` will re-plan the command on each execution, generating a plan that is specific to the current parameter values; whereas PL/pgSQL may otherwise create a generic plan and cache it for reuse. In situations where the best plan depends strongly on the parameter values, it can be helpful to use `EXECUTE` to positively ensure that a generic plan is not selected.

`SELECT INTO` is not currently supported within `EXECUTE`; instead, execute a plain `SELECT` command and specify `INTO` as part of the `EXECUTE` itself.

Note

The PL/pgSQL `EXECUTE` statement is not related to the `EXECUTE SQL` statement supported by the PostgreSQL server. The server's `EXECUTE` statement cannot be used directly within PL/pgSQL functions (and is not needed).

Example 42.1. Quoting Values in Dynamic Queries

When working with dynamic commands you will often have to handle escaping of single quotes. The recommended method for quoting fixed text in your function body is dollar quoting. (If you have legacy code that does not use dollar quoting, please refer to the overview in Section 42.12.1, which can save you some effort when translating said code to a more reasonable scheme.)

Dynamic values require careful handling since they might contain quote characters. An example using `format()` (this assumes that you are dollar quoting the function body so quote marks need not be doubled):

```
EXECUTE format('UPDATE tbl SET %I = $1 '
      'WHERE key = $2', colname) USING newvalue, keyvalue;
```

It is also possible to call the quoting functions directly:

```
EXECUTE 'UPDATE tbl SET '
      || quote_ident(colname)
      || ' = '
      || quote_literal(newvalue)
      || ' WHERE key = '
      || quote_literal(keyvalue);
```

This example demonstrates the use of the `quote_ident` and `quote_literal` functions (see Section 9.4). For safety, expressions containing column or table identifiers should be passed through `quote_ident` before insertion in a dynamic query. Expressions containing values that should be literal strings in the constructed command should be passed through `quote_literal`. These functions take the appropriate steps to return the input text enclosed in double or single quotes respectively, with any embedded special characters properly escaped.

Because `quote_literal` is labeled `STRICT`, it will always return null when called with a null argument. In the above example, if `newvalue` or `keyvalue` were null, the entire dynamic query string would become null, leading to an error from `EXECUTE`. You can avoid this problem by using the `quote_nullable` function, which works the same as `quote_literal` except that when called with a null argument it returns the string `NULL`. For example,

```
EXECUTE 'UPDATE tbl SET '
      || quote_ident(colname)
      || ' = '
      || quote_nullable(newvalue)
      || ' WHERE key = '
      || quote_nullable(keyvalue);
```

If you are dealing with values that might be null, you should usually use `quote_nullable` in place of `quote_literal`.

As always, care must be taken to ensure that null values in a query do not deliver unintended results. For example the `WHERE` clause

```
'WHERE key = ' || quote_nullable(keyvalue)
```

will never succeed if `keyvalue` is null, because the result of using the equality operator `=` with a null operand is always null. If you wish null to work like an ordinary key value, you would need to rewrite the above as

```
'WHERE key IS NOT DISTINCT FROM ' || quote_nullable(keyvalue)
```

(At present, `IS NOT DISTINCT FROM` is handled much less efficiently than `=`, so don't do this unless you must. See Section 9.2 for more information on nulls and `IS DISTINCT`.)

Note that dollar quoting is only useful for quoting fixed text. It would be a very bad idea to try to write this example as:

```
EXECUTE 'UPDATE tbl SET '
      || quote_ident(colname)
      || ' = $$'
      || newvalue
      || '$$ WHERE key = '
      || quote_literal(keyvalue);
```

because it would break if the contents of `newvalue` happened to contain `$$`. The same objection would apply to any other dollar-quoting delimiter you might pick. So, to safely quote text that is not known in advance, you *must* use `quote_literal`, `quote_nullable`, or `quote_ident`, as appropriate.

Dynamic SQL statements can also be safely constructed using the `format` function (see Section 9.4.1). For example:

```
EXECUTE format('UPDATE tbl SET %I = %L '
              'WHERE key = %L', colname, newvalue, keyvalue);
```

`%I` is equivalent to `quote_ident`, and `%L` is equivalent to `quote_nullable`. The `format` function can be used in conjunction with the `USING` clause:

```
EXECUTE format('UPDATE tbl SET %I = $1 WHERE key = $2', colname)
          USING newvalue, keyvalue;
```

This form is better because the variables are handled in their native data type format, rather than unconditionally converting them to text and quoting them via `%L`. It is also more efficient.

A much larger example of a dynamic command and `EXECUTE` can be seen in Example 42.10, which builds and executes a `CREATE FUNCTION` command to define a new function.

42.5.5. Obtaining the Result Status

There are several ways to determine the effect of a command. The first method is to use the `GET DIAGNOSTICS` command, which has the form:

```
GET [ CURRENT ] DIAGNOSTICS variable { = | := } item [ , ... ];
```

This command allows retrieval of system status indicators. `CURRENT` is a noise word (but see also `GET STACKED DIAGNOSTICS` in Section 42.6.8.1). Each *item* is a key word identifying a status value to be assigned to the specified *variable* (which should be of the right data type to receive it). The currently available status items are shown in Table 42.1. Colon-equal (`:=`) can be used instead of the SQL-standard `=` token. An example:

```
GET DIAGNOSTICS integer_var = ROW_COUNT;
```

Table 42.1. Available Diagnostics Items

Name	Type	Description
<code>ROW_COUNT</code>	<code>bigint</code>	the number of rows processed by the most recent SQL command
<code>PG_CONTEXT</code>	<code>text</code>	line(s) of text describing the current call stack (see Section 42.6.9)

The second method to determine the effects of a command is to check the special variable named `FOUND`, which is of type `boolean`. `FOUND` starts out false within each PL/pgSQL function call. It is set by each of the following types of statements:

- A `SELECT INTO` statement sets `FOUND` true if a row is assigned, false if no row is returned.
- A `PERFORM` statement sets `FOUND` true if it produces (and discards) one or more rows, false if no row is produced.

- UPDATE, INSERT, and DELETE statements set FOUND true if at least one row is affected, false if no row is affected.
- A FETCH statement sets FOUND true if it returns a row, false if no row is returned.
- A MOVE statement sets FOUND true if it successfully repositions the cursor, false otherwise.
- A FOR or FOREACH statement sets FOUND true if it iterates one or more times, else false. FOUND is set this way when the loop exits; inside the execution of the loop, FOUND is not modified by the loop statement, although it might be changed by the execution of other statements within the loop body.
- RETURN QUERY and RETURN QUERY EXECUTE statements set FOUND true if the query returns at least one row, false if no row is returned.

Other PL/pgSQL statements do not change the state of FOUND. Note in particular that EXECUTE changes the output of GET DIAGNOSTICS, but does not change FOUND.

FOUND is a local variable within each PL/pgSQL function; any changes to it affect only the current function.

42.5.6. Doing Nothing At All

Sometimes a placeholder statement that does nothing is useful. For example, it can indicate that one arm of an if/then/else chain is deliberately empty. For this purpose, use the NULL statement:

```
NULL;
```

For example, the following two fragments of code are equivalent:

```
BEGIN
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN
        NULL; -- ignore the error
END;
```

```
BEGIN
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN -- ignore the error
END;
```

Which is preferable is a matter of taste.

Note

In Oracle's PL/SQL, empty statement lists are not allowed, and so NULL statements are *required* for situations such as this. PL/pgSQL allows you to just write nothing, instead.

42.6. Control Structures

Control structures are probably the most useful (and important) part of PL/pgSQL. With PL/pgSQL's control structures, you can manipulate PostgreSQL data in a very flexible and powerful way.

42.6.1. Returning From a Function

There are two commands available that allow you to return data from a function: `RETURN` and `RETURN NEXT`.

42.6.1.1. RETURN

```
RETURN expression;
```

`RETURN` with an expression terminates the function and returns the value of *expression* to the caller. This form is used for PL/pgSQL functions that do not return a set.

In a function that returns a scalar type, the expression's result will automatically be cast into the function's return type as described for assignments. But to return a composite (row) value, you must write an expression delivering exactly the requested column set. This may require use of explicit casting.

If you declared the function with output parameters, write just `RETURN` with no expression. The current values of the output parameter variables will be returned.

If you declared the function to return `void`, a `RETURN` statement can be used to exit the function early; but do not write an expression following `RETURN`.

The return value of a function cannot be left undefined. If control reaches the end of the top-level block of the function without hitting a `RETURN` statement, a run-time error will occur. This restriction does not apply to functions with output parameters and functions returning `void`, however. In those cases a `RETURN` statement is automatically executed if the top-level block finishes.

Some examples:

```
-- functions returning a scalar type
RETURN 1 + 2;
RETURN scalar_var;

-- functions returning a composite type
RETURN composite_type_var;
RETURN (1, 2, 'three'::text); -- must cast columns to correct
types
```

42.6.1.2. RETURN NEXT and RETURN QUERY

```
RETURN NEXT expression;
RETURN QUERY query;
RETURN QUERY EXECUTE command-string [ USING expression [, ... ] ];
```

When a PL/pgSQL function is declared to return `SETOF sometype`, the procedure to follow is slightly different. In that case, the individual items to return are specified by a sequence of `RETURN NEXT` or `RETURN QUERY` commands, and then a final `RETURN` command with no argument is used to indicate that the function has finished executing. `RETURN NEXT` can be used with both scalar and composite data types; with a composite result type, an entire “table” of results will be returned. `RETURN QUERY` appends the results of executing a query to the function's result set. `RETURN NEXT` and `RETURN QUERY` can be freely intermixed in a single set-returning function, in which case their results will be concatenated.

`RETURN NEXT` and `RETURN QUERY` do not actually return from the function — they simply append zero or more rows to the function's result set. Execution then continues with the next statement in the PL/pgSQL function. As successive `RETURN NEXT` or `RETURN QUERY` commands are executed,

the result set is built up. A final RETURN, which should have no argument, causes control to exit the function (or you can just let control reach the end of the function).

RETURN QUERY has a variant RETURN QUERY EXECUTE, which specifies the query to be executed dynamically. Parameter expressions can be inserted into the computed query string via USING, in just the same way as in the EXECUTE command.

If you declared the function with output parameters, write just RETURN NEXT with no expression. On each execution, the current values of the output parameter variable(s) will be saved for eventual return as a row of the result. Note that you must declare the function as returning SETOF record when there are multiple output parameters, or SETOF *some type* when there is just one output parameter of type *some type*, in order to create a set-returning function with output parameters.

Here is an example of a function using RETURN NEXT:

```
CREATE TABLE foo (fooid INT, foosubid INT, fooname TEXT);
INSERT INTO foo VALUES (1, 2, 'three');
INSERT INTO foo VALUES (4, 5, 'six');

CREATE OR REPLACE FUNCTION get_all_foo() RETURNS SETOF foo AS
$BODY$
DECLARE
    r foo%rowtype;
BEGIN
    FOR r IN
        SELECT * FROM foo WHERE fooid > 0
    LOOP
        -- can do some processing here
        RETURN NEXT r; -- return current row of SELECT
    END LOOP;
    RETURN;
END
$BODY$
LANGUAGE plpgsql;

SELECT * FROM get_all_foo();
```

Here is an example of a function using RETURN QUERY:

```
CREATE FUNCTION get_available_flightid(date) RETURNS SETOF integer
AS
$BODY$
BEGIN
    RETURN QUERY SELECT flightid
                  FROM flight
                  WHERE flightdate >= $1
                     AND flightdate < ($1 + 1);

    -- Since execution is not finished, we can check whether rows
    were returned
    -- and raise exception if not.
    IF NOT FOUND THEN
        RAISE EXCEPTION 'No flight at %.', $1;
    END IF;

    RETURN;
END
$BODY$
```

```

$BODY$
LANGUAGE plpgsql;

-- Returns available flights or raises exception if there are no
-- available flights.
SELECT * FROM get_available_flightid(CURRENT_DATE);

```

Note

The current implementation of `RETURN NEXT` and `RETURN QUERY` stores the entire result set before returning from the function, as discussed above. That means that if a PL/pgSQL function produces a very large result set, performance might be poor: data will be written to disk to avoid memory exhaustion, but the function itself will not return until the entire result set has been generated. A future version of PL/pgSQL might allow users to define set-returning functions that do not have this limitation. Currently, the point at which data begins being written to disk is controlled by the `work_mem` configuration variable. Administrators who have sufficient memory to store larger result sets in memory should consider increasing this parameter.

42.6.2. Returning from a Procedure

A procedure does not have a return value. A procedure can therefore end without a `RETURN` statement. If you wish to use a `RETURN` statement to exit the code early, write just `RETURN` with no expression.

If the procedure has output parameters, the final values of the output parameter variables will be returned to the caller.

42.6.3. Calling a Procedure

A PL/pgSQL function, procedure, or `DO` block can call a procedure using `CALL`. Output parameters are handled differently from the way that `CALL` works in plain SQL. Each `INOUT` parameter of the procedure must correspond to a variable in the `CALL` statement, and whatever the procedure returns is assigned back to that variable after it returns. For example:

```

CREATE PROCEDURE triple(INOUT x int)
LANGUAGE plpgsql
AS $$
BEGIN
    x := x * 3;
END;
$$;

DO $$
DECLARE myvar int := 5;
BEGIN
    CALL triple(myvar);
    RAISE NOTICE 'myvar = %', myvar; -- prints 15
END
$$;

```

42.6.4. Conditionals

`IF` and `CASE` statements let you execute alternative commands based on certain conditions. PL/pgSQL has three forms of `IF`:

- IF ... THEN ... END IF
- IF ... THEN ... ELSE ... END IF
- IF ... THEN ... ELSIF ... THEN ... ELSE ... END IF

and two forms of CASE:

- CASE ... WHEN ... THEN ... ELSE ... END CASE
- CASE WHEN ... THEN ... ELSE ... END CASE

42.6.4.1. IF-THEN

```
IF boolean-expression THEN
    statements
END IF;
```

IF-THEN statements are the simplest form of IF. The statements between THEN and END IF will be executed if the condition is true. Otherwise, they are skipped.

Example:

```
IF v_user_id <> 0 THEN
    UPDATE users SET email = v_email WHERE user_id = v_user_id;
END IF;
```

42.6.4.2. IF-THEN-ELSE

```
IF boolean-expression THEN
    statements
ELSE
    statements
END IF;
```

IF-THEN-ELSE statements add to IF-THEN by letting you specify an alternative set of statements that should be executed if the condition is not true. (Note this includes the case where the condition evaluates to NULL.)

Examples:

```
IF parentid IS NULL OR parentid = ''
THEN
    RETURN fullname;
ELSE
    RETURN hp_true_filename(parentid) || '/' || fullname;
END IF;
```

```
IF v_count > 0 THEN
    INSERT INTO users_count (count) VALUES (v_count);
    RETURN 't';
ELSE
    RETURN 'f';
END IF;
```

42.6.4.3. IF-THEN-ELSIF

```

IF boolean-expression THEN
    statements
[ ELSIF boolean-expression THEN
    statements
[ ELSIF boolean-expression THEN
    statements
    ...
]
]
[ ELSE
    statements ]
END IF;

```

Sometimes there are more than just two alternatives. IF-THEN-ELSIF provides a convenient method of checking several alternatives in turn. The IF conditions are tested successively until the first one that is true is found. Then the associated statement(s) are executed, after which control passes to the next statement after END IF. (Any subsequent IF conditions are *not* tested.) If none of the IF conditions is true, then the ELSE block (if any) is executed.

Here is an example:

```

IF number = 0 THEN
    result := 'zero';
ELSIF number > 0 THEN
    result := 'positive';
ELSIF number < 0 THEN
    result := 'negative';
ELSE
    -- hmm, the only other possibility is that number is null
    result := 'NULL';
END IF;

```

The key word ELSIF can also be spelled ELSEIF.

An alternative way of accomplishing the same task is to nest IF-THEN-ELSE statements, as in the following example:

```

IF demo_row.sex = 'm' THEN
    pretty_sex := 'man';
ELSE
    IF demo_row.sex = 'f' THEN
        pretty_sex := 'woman';
    END IF;
END IF;

```

However, this method requires writing a matching END IF for each IF, so it is much more cumbersome than using ELSIF when there are many alternatives.

42.6.4.4. Simple CASE

```

CASE search-expression
    WHEN expression [, expression [ ... ]] THEN
        statements
    [ WHEN expression [, expression [ ... ]] THEN

```

```

        statements
    ... ]
[ ELSE
    statements ]
END CASE;
```

The simple form of CASE provides conditional execution based on equality of operands. The *search-expression* is evaluated (once) and successively compared to each *expression* in the WHEN clauses. If a match is found, then the corresponding *statements* are executed, and then control passes to the next statement after END CASE. (Subsequent WHEN expressions are not evaluated.) If no match is found, the ELSE *statements* are executed; but if ELSE is not present, then a CASE_NOT_FOUND exception is raised.

Here is a simple example:

```

CASE x
  WHEN 1, 2 THEN
    msg := 'one or two';
  ELSE
    msg := 'other value than one or two';
END CASE;
```

42.6.4.5. Searched CASE

```

CASE
  WHEN boolean-expression THEN
    statements
  [ WHEN boolean-expression THEN
    statements
    ... ]
  [ ELSE
    statements ]
END CASE;
```

The searched form of CASE provides conditional execution based on truth of Boolean expressions. Each WHEN clause's *boolean-expression* is evaluated in turn, until one is found that yields true. Then the corresponding *statements* are executed, and then control passes to the next statement after END CASE. (Subsequent WHEN expressions are not evaluated.) If no true result is found, the ELSE *statements* are executed; but if ELSE is not present, then a CASE_NOT_FOUND exception is raised.

Here is an example:

```

CASE
  WHEN x BETWEEN 0 AND 10 THEN
    msg := 'value is between zero and ten';
  WHEN x BETWEEN 11 AND 20 THEN
    msg := 'value is between eleven and twenty';
END CASE;
```

This form of CASE is entirely equivalent to IF-THEN-ELSIF, except for the rule that reaching an omitted ELSE clause results in an error rather than doing nothing.

42.6.5. Simple Loops

With the LOOP, EXIT, CONTINUE, WHILE, FOR, and FOREACH statements, you can arrange for your PL/pgSQL function to repeat a series of commands.

42.6.5.1. LOOP

```
[ <<label>> ]
LOOP
    statements
END LOOP [ label ];
```

LOOP defines an unconditional loop that is repeated indefinitely until terminated by an EXIT or RETURN statement. The optional *label* can be used by EXIT and CONTINUE statements within nested loops to specify which loop those statements refer to.

42.6.5.2. EXIT

```
EXIT [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the innermost loop is terminated and the statement following END LOOP is executed next. If *label* is given, it must be the label of the current or some outer level of nested loop or block. Then the named loop or block is terminated and control continues with the statement after the loop's/block's corresponding END.

If WHEN is specified, the loop exit occurs only if *boolean-expression* is true. Otherwise, control passes to the statement after EXIT.

EXIT can be used with all types of loops; it is not limited to use with unconditional loops.

When used with a BEGIN block, EXIT passes control to the next statement after the end of the block. Note that a label must be used for this purpose; an unlabeled EXIT is never considered to match a BEGIN block. (This is a change from pre-8.4 releases of PostgreSQL, which would allow an unlabeled EXIT to match a BEGIN block.)

Examples:

```
LOOP
    -- some computations
    IF count > 0 THEN
        EXIT; -- exit loop
    END IF;
END LOOP;
```

```
LOOP
    -- some computations
    EXIT WHEN count > 0; -- same result as previous example
END LOOP;
```

```
<<ablock>>
BEGIN
    -- some computations
    IF stocks > 100000 THEN
        EXIT ablock; -- causes exit from the BEGIN block
    END IF;
    -- computations here will be skipped when stocks > 100000
END;
```

42.6.5.3. CONTINUE

```
CONTINUE [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the next iteration of the innermost loop is begun. That is, all statements remaining in the loop body are skipped, and control returns to the loop control expression (if any) to determine whether another loop iteration is needed. If *label* is present, it specifies the label of the loop whose execution will be continued.

If *WHEN* is specified, the next iteration of the loop is begun only if *boolean-expression* is true. Otherwise, control passes to the statement after *CONTINUE*.

CONTINUE can be used with all types of loops; it is not limited to use with unconditional loops.

Examples:

```
LOOP
    -- some computations
    EXIT WHEN count > 100;
    CONTINUE WHEN count < 50;
    -- some computations for count IN [50 .. 100]
END LOOP;
```

42.6.5.4. WHILE

```
[ <<label>> ]
WHILE boolean-expression LOOP
    statements
END LOOP [ label ];
```

The *WHILE* statement repeats a sequence of statements so long as the *boolean-expression* evaluates to true. The expression is checked just before each entry to the loop body.

For example:

```
WHILE amount_owed > 0 AND gift_certificate_balance > 0 LOOP
    -- some computations here
END LOOP;

WHILE NOT done LOOP
    -- some computations here
END LOOP;
```

42.6.5.5. FOR (Integer Variant)

```
[ <<label>> ]
FOR name IN [ REVERSE ] expression .. expression [ BY expression ]
LOOP
    statements
END LOOP [ label ];
```

This form of *FOR* creates a loop that iterates over a range of integer values. The variable *name* is automatically defined as type *integer* and exists only inside the loop (any existing definition of the variable name is ignored within the loop). The two expressions giving the lower and upper bound of the range are evaluated once when entering the loop. If the *BY* clause isn't specified the iteration step is 1, otherwise it's the value specified in the *BY* clause, which again is evaluated once on loop entry. If *REVERSE* is specified then the step value is subtracted, rather than added, after each iteration.

Some examples of integer *FOR* loops:

```
FOR i IN 1..10 LOOP
    -- i will take on the values 1,2,3,4,5,6,7,8,9,10 within the
    loop
END LOOP;
```

```
FOR i IN REVERSE 10..1 LOOP
    -- i will take on the values 10,9,8,7,6,5,4,3,2,1 within the
    loop
END LOOP;
```

```
FOR i IN REVERSE 10..1 BY 2 LOOP
    -- i will take on the values 10,8,6,4,2 within the loop
END LOOP;
```

If the lower bound is greater than the upper bound (or less than, in the REVERSE case), the loop body is not executed at all. No error is raised.

If a *label* is attached to the FOR loop then the integer loop variable can be referenced with a qualified name, using that *label*.

42.6.6. Looping through Query Results

Using a different type of FOR loop, you can iterate through the results of a query and manipulate that data accordingly. The syntax is:

```
[ <<label>> ]
FOR target IN query LOOP
    statements
END LOOP [ label ];
```

The *target* is a record variable, row variable, or comma-separated list of scalar variables. The *target* is successively assigned each row resulting from the *query* and the loop body is executed for each row. Here is an example:

```
CREATE FUNCTION refresh_mviews() RETURNS integer AS $$
DECLARE
    mviews RECORD;
BEGIN
    RAISE NOTICE 'Refreshing all materialized views...';

    FOR mviews IN
        SELECT n.nspname AS mv_schema,
               c.relname AS mv_name,
               pg_catalog.pg_get_userbyid(c.relowner) AS owner
        FROM pg_catalog.pg_class c
        LEFT JOIN pg_catalog.pg_namespace n ON (n.oid = c.relnamespace)
        WHERE c.relkind = 'm'
        ORDER BY 1
    LOOP

        -- Now "mviews" has one record with information about the
        materialized view

        RAISE NOTICE 'Refreshing materialized view %.% (owner:
        %)...',
            quote_ident(mviews.mv_schema),
```

```

        quote_ident(mviews.mv_name),
        quote_ident(mviews.owner);
    EXECUTE format('REFRESH MATERIALIZED VIEW %I.%I',
mviews.mv_schema, mviews.mv_name);
    END LOOP;

    RAISE NOTICE 'Done refreshing materialized views.';
    RETURN 1;
END;
$$ LANGUAGE plpgsql;

```

If the loop is terminated by an EXIT statement, the last assigned row value is still accessible after the loop.

The *query* used in this type of FOR statement can be any SQL command that returns rows to the caller: SELECT is the most common case, but you can also use INSERT, UPDATE, or DELETE with a RETURNING clause. Some utility commands such as EXPLAIN will work too.

PL/pgSQL variables are substituted into the query text, and the query plan is cached for possible reuse, as discussed in detail in Section 42.11.1 and Section 42.11.2.

The FOR-IN-EXECUTE statement is another way to iterate over rows:

```

[ <<label>> ]
FOR target IN EXECUTE text_expression [ USING expression [, ... ] ]
LOOP
    statements
END LOOP [ label ];

```

This is like the previous form, except that the source query is specified as a string expression, which is evaluated and replanned on each entry to the FOR loop. This allows the programmer to choose the speed of a preplanned query or the flexibility of a dynamic query, just as with a plain EXECUTE statement. As with EXECUTE, parameter values can be inserted into the dynamic command via USING.

Another way to specify the query whose results should be iterated through is to declare it as a cursor. This is described in Section 42.7.4.

42.6.7. Looping through Arrays

The FOREACH loop is much like a FOR loop, but instead of iterating through the rows returned by a SQL query, it iterates through the elements of an array value. (In general, FOREACH is meant for looping through components of a composite-valued expression; variants for looping through composites besides arrays may be added in future.) The FOREACH statement to loop over an array is:

```

[ <<label>> ]
FOREACH target [ SLICE number ] IN ARRAY expression LOOP
    statements
END LOOP [ label ];

```

Without SLICE, or if SLICE 0 is specified, the loop iterates through individual elements of the array produced by evaluating the *expression*. The *target* variable is assigned each element value in sequence, and the loop body is executed for each element. Here is an example of looping through the elements of an integer array:

```

CREATE FUNCTION sum(int[]) RETURNS int8 AS $$
DECLARE
    s int8 := 0;

```

```

    x int;
BEGIN
    FOREACH x IN ARRAY $1
    LOOP
        s := s + x;
    END LOOP;
    RETURN s;
END;
$$ LANGUAGE plpgsql;

```

The elements are visited in storage order, regardless of the number of array dimensions. Although the *target* is usually just a single variable, it can be a list of variables when looping through an array of composite values (records). In that case, for each array element, the variables are assigned from successive columns of the composite value.

With a positive *SLICE* value, *FOREACH* iterates through slices of the array rather than single elements. The *SLICE* value must be an integer constant not larger than the number of dimensions of the array. The *target* variable must be an array, and it receives successive slices of the array value, where each slice is of the number of dimensions specified by *SLICE*. Here is an example of iterating through one-dimensional slices:

```

CREATE FUNCTION scan_rows(int[]) RETURNS void AS $$
DECLARE
    x int[];
BEGIN
    FOREACH x SLICE 1 IN ARRAY $1
    LOOP
        RAISE NOTICE 'row = %', x;
    END LOOP;
END;
$$ LANGUAGE plpgsql;

SELECT scan_rows(ARRAY[[1,2,3],[4,5,6],[7,8,9],[10,11,12]]);

NOTICE:  row = {1,2,3}
NOTICE:  row = {4,5,6}
NOTICE:  row = {7,8,9}
NOTICE:  row = {10,11,12}

```

42.6.8. Trapping Errors

By default, any error occurring in a PL/pgSQL function aborts execution of the function, and indeed of the surrounding transaction as well. You can trap errors and recover from them by using a *BEGIN* block with an *EXCEPTION* clause. The syntax is an extension of the normal syntax for a *BEGIN* block:

```

[ <<label>> ]
[ DECLARE
    declarations ]
BEGIN
    statements
EXCEPTION
    WHEN condition [ OR condition ... ] THEN
        handler_statements
    [ WHEN condition [ OR condition ... ] THEN
        handler_statements
    ... ]
END;

```

If no error occurs, this form of block simply executes all the *statements*, and then control passes to the next statement after `END`. But if an error occurs within the *statements*, further processing of the *statements* is abandoned, and control passes to the `EXCEPTION` list. The list is searched for the first *condition* matching the error that occurred. If a match is found, the corresponding *handler_statements* are executed, and then control passes to the next statement after `END`. If no match is found, the error propagates out as though the `EXCEPTION` clause were not there at all: the error can be caught by an enclosing block with `EXCEPTION`, or if there is none it aborts processing of the function.

The *condition* names can be any of those shown in Appendix A. A category name matches any error within its category. The special condition name `OTHERS` matches every error type except `QUERY_CANCELED` and `ASSERT_FAILURE`. (It is possible, but often unwise, to trap those two error types by name.) Condition names are not case-sensitive. Also, an error condition can be specified by `SQLSTATE` code; for example these are equivalent:

```
WHEN division_by_zero THEN ...
WHEN SQLSTATE '22012' THEN ...
```

If a new error occurs within the selected *handler_statements*, it cannot be caught by this `EXCEPTION` clause, but is propagated out. A surrounding `EXCEPTION` clause could catch it.

When an error is caught by an `EXCEPTION` clause, the local variables of the PL/pgSQL function remain as they were when the error occurred, but all changes to persistent database state within the block are rolled back. As an example, consider this fragment:

```
INSERT INTO mytab(firstname, lastname) VALUES('Tom', 'Jones');
BEGIN
    UPDATE mytab SET firstname = 'Joe' WHERE lastname = 'Jones';
    x := x + 1;
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN
        RAISE NOTICE 'caught division_by_zero';
        RETURN x;
END;
```

When control reaches the assignment to `y`, it will fail with a `division_by_zero` error. This will be caught by the `EXCEPTION` clause. The value returned in the `RETURN` statement will be the incremented value of `x`, but the effects of the `UPDATE` command will have been rolled back. The `INSERT` command preceding the block is not rolled back, however, so the end result is that the database contains Tom Jones not Joe Jones.

Tip

A block containing an `EXCEPTION` clause is significantly more expensive to enter and exit than a block without one. Therefore, don't use `EXCEPTION` without need.

Example 42.2. Exceptions with `UPDATE/INSERT`

This example uses exception handling to perform either `UPDATE` or `INSERT`, as appropriate. It is recommended that applications use `INSERT` with `ON CONFLICT DO UPDATE` rather than actually using this pattern. This example serves primarily to illustrate use of PL/pgSQL control flow structures:

```
CREATE TABLE db (a INT PRIMARY KEY, b TEXT);
```

```

CREATE FUNCTION merge_db(key INT, data TEXT) RETURNS VOID AS
$$
BEGIN
    LOOP
        -- first try to update the key
        UPDATE db SET b = data WHERE a = key;
        IF found THEN
            RETURN;
        END IF;
        -- not there, so try to insert the key
        -- if someone else inserts the same key concurrently,
        -- we could get a unique-key failure
        BEGIN
            INSERT INTO db(a,b) VALUES (key, data);
            RETURN;
        EXCEPTION WHEN unique_violation THEN
            -- Do nothing, and loop to try the UPDATE again.
        END;
    END LOOP;
END;
$$
LANGUAGE plpgsql;

SELECT merge_db(1, 'david');
SELECT merge_db(1, 'dennis');

```

This coding assumes the `unique_violation` error is caused by the `INSERT`, and not by, say, an `INSERT` in a trigger function on the table. It might also misbehave if there is more than one unique index on the table, since it will retry the operation regardless of which index caused the error. More safety could be had by using the features discussed next to check that the trapped error was the one expected.

42.6.8.1. Obtaining Information about an Error

Exception handlers frequently need to identify the specific error that occurred. There are two ways to get information about the current exception in PL/pgSQL: special variables and the `GET STACKED DIAGNOSTICS` command.

Within an exception handler, the special variable `SQLSTATE` contains the error code that corresponds to the exception that was raised (refer to Table A.1 for a list of possible error codes). The special variable `SQLERRM` contains the error message associated with the exception. These variables are undefined outside exception handlers.

Within an exception handler, one may also retrieve information about the current exception by using the `GET STACKED DIAGNOSTICS` command, which has the form:

```
GET STACKED DIAGNOSTICS variable { = | := } item [ , ... ];
```

Each *item* is a key word identifying a status value to be assigned to the specified *variable* (which should be of the right data type to receive it). The currently available status items are shown in Table 42.2.

Table 42.2. Error Diagnostics Items

Name	Type	Description
RETURNED_SQLSTATE	text	the SQLSTATE error code of the exception

Name	Type	Description
COLUMN_NAME	text	the name of the column related to exception
CONSTRAINT_NAME	text	the name of the constraint related to exception
PG_DATATYPE_NAME	text	the name of the data type related to exception
MESSAGE_TEXT	text	the text of the exception's primary message
TABLE_NAME	text	the name of the table related to exception
SCHEMA_NAME	text	the name of the schema related to exception
PG_EXCEPTION_DETAIL	text	the text of the exception's detail message, if any
PG_EXCEPTION_HINT	text	the text of the exception's hint message, if any
PG_EXCEPTION_CONTEXT	text	line(s) of text describing the call stack at the time of the exception (see Section 42.6.9)

If the exception did not set a value for an item, an empty string will be returned.

Here is an example:

```

DECLARE
    text_var1 text;
    text_var2 text;
    text_var3 text;
BEGIN
    -- some processing which might cause an exception
    ...
EXCEPTION WHEN OTHERS THEN
    GET STACKED DIAGNOSTICS text_var1 = MESSAGE_TEXT,
                           text_var2 = PG_EXCEPTION_DETAIL,
                           text_var3 = PG_EXCEPTION_HINT;
END;
```

42.6.9. Obtaining Execution Location Information

The `GET DIAGNOSTICS` command, previously described in Section 42.5.5, retrieves information about current execution state (whereas the `GET STACKED DIAGNOSTICS` command discussed above reports information about the execution state as of a previous error). Its `PG_CONTEXT` status item is useful for identifying the current execution location. `PG_CONTEXT` returns a text string with line(s) of text describing the call stack. The first line refers to the current function and currently executing `GET DIAGNOSTICS` command. The second and any subsequent lines refer to calling functions further up the call stack. For example:

```

CREATE OR REPLACE FUNCTION outer_func() RETURNS integer AS $$
BEGIN
    RETURN inner_func();
END;
$$ LANGUAGE plpgsql;
```

```
CREATE OR REPLACE FUNCTION inner_func() RETURNS integer AS $$
DECLARE
    stack text;
BEGIN
    GET DIAGNOSTICS stack = PG_CONTEXT;
    RAISE NOTICE E'--- Call Stack ---\n%', stack;
    RETURN 1;
END;
$$ LANGUAGE plpgsql;
```

```
SELECT outer_func();
```

```
NOTICE: --- Call Stack ---
PL/pgSQL function inner_func() line 5 at GET DIAGNOSTICS
PL/pgSQL function outer_func() line 3 at RETURN
CONTEXT: PL/pgSQL function outer_func() line 3 at RETURN
outer_func
-----
          1
(1 row)
```

GET STACKED DIAGNOSTICS ... PG_EXCEPTION_CONTEXT returns the same sort of stack trace, but describing the location at which an error was detected, rather than the current location.

42.7. Cursors

Rather than executing a whole query at once, it is possible to set up a *cursor* that encapsulates the query, and then read the query result a few rows at a time. One reason for doing this is to avoid memory overrun when the result contains a large number of rows. (However, PL/pgSQL users do not normally need to worry about that, since FOR loops automatically use a cursor internally to avoid memory problems.) A more interesting usage is to return a reference to a cursor that a function has created, allowing the caller to read the rows. This provides an efficient way to return large row sets from functions.

42.7.1. Declaring Cursor Variables

All access to cursors in PL/pgSQL goes through cursor variables, which are always of the special data type `refcursor`. One way to create a cursor variable is just to declare it as a variable of type `refcursor`. Another way is to use the cursor declaration syntax, which in general is:

```
name [ [ NO ] SCROLL ] CURSOR [ ( arguments ) ] FOR query;
```

(FOR can be replaced by IS for Oracle compatibility.) If SCROLL is specified, the cursor will be capable of scrolling backward; if NO SCROLL is specified, backward fetches will be rejected; if neither specification appears, it is query-dependent whether backward fetches will be allowed. *arguments*, if specified, is a comma-separated list of pairs *name datatype* that define names to be replaced by parameter values in the given query. The actual values to substitute for these names will be specified later, when the cursor is opened.

Some examples:

```
DECLARE
    curs1 refcursor;
    curs2 CURSOR FOR SELECT * FROM tenk1;
```

```
curs3 CURSOR (key integer) FOR SELECT * FROM tenk1 WHERE
unique1 = key;
```

All three of these variables have the data type `refcursor`, but the first can be used with any query, while the second has a fully specified query already *bound* to it, and the last has a parameterized query bound to it. (`key` will be replaced by an integer parameter value when the cursor is opened.) The variable `curs1` is said to be *unbound* since it is not bound to any particular query.

42.7.2. Opening Cursors

Before a cursor can be used to retrieve rows, it must be *opened*. (This is the equivalent action to the SQL command `DECLARE CURSOR`.) PL/pgSQL has three forms of the `OPEN` statement, two of which use unbound cursor variables while the third uses a bound cursor variable.

Note

Bound cursor variables can also be used without explicitly opening the cursor, via the `FOR` statement described in Section 42.7.4.

42.7.2.1. OPEN FOR query

```
OPEN unbound_cursorvar [ [ NO ] SCROLL ] FOR query;
```

The cursor variable is opened and given the specified query to execute. The cursor cannot be open already, and it must have been declared as an unbound cursor variable (that is, as a simple `refcursor` variable). The query must be a `SELECT`, or something else that returns rows (such as `EXPLAIN`). The query is treated in the same way as other SQL commands in PL/pgSQL: PL/pgSQL variable names are substituted, and the query plan is cached for possible reuse. When a PL/pgSQL variable is substituted into the cursor query, the value that is substituted is the one it has at the time of the `OPEN`; subsequent changes to the variable will not affect the cursor's behavior. The `SCROLL` and `NO SCROLL` options have the same meanings as for a bound cursor.

An example:

```
OPEN curs1 FOR SELECT * FROM foo WHERE key = mykey;
```

42.7.2.2. OPEN FOR EXECUTE

```
OPEN unbound_cursorvar [ [ NO ] SCROLL ] FOR EXECUTE query_string
[ USING expression [, ... ] ];
```

The cursor variable is opened and given the specified query to execute. The cursor cannot be open already, and it must have been declared as an unbound cursor variable (that is, as a simple `refcursor` variable). The query is specified as a string expression, in the same way as in the `EXECUTE` command. As usual, this gives flexibility so the query plan can vary from one run to the next (see Section 42.11.2), and it also means that variable substitution is not done on the command string. As with `EXECUTE`, parameter values can be inserted into the dynamic command via `format()` and `USING`. The `SCROLL` and `NO SCROLL` options have the same meanings as for a bound cursor.

An example:

```
OPEN curs1 FOR EXECUTE format('SELECT * FROM %I WHERE coll =
    $1',tablename) USING keyvalue;
```

In this example, the table name is inserted into the query via `format()`. The comparison value for `coll` is inserted via a `USING` parameter, so it needs no quoting.

42.7.2.3. Opening a Bound Cursor

```
OPEN bound_cursorvar [ ( [ argument_name := ] argument_value
    [, ...] ) ];
```

This form of `OPEN` is used to open a cursor variable whose query was bound to it when it was declared. The cursor cannot be open already. A list of actual argument value expressions must appear if and only if the cursor was declared to take arguments. These values will be substituted in the query.

The query plan for a bound cursor is always considered cacheable; there is no equivalent of `EXECUTE` in this case. Notice that `SCROLL` and `NO SCROLL` cannot be specified in `OPEN`, as the cursor's scrolling behavior was already determined.

Argument values can be passed using either *positional* or *named* notation. In positional notation, all arguments are specified in order. In named notation, each argument's name is specified using `:=` to separate it from the argument expression. Similar to calling functions, described in Section 4.3, it is also allowed to mix positional and named notation.

Examples (these use the cursor declaration examples above):

```
OPEN curs2;
OPEN curs3(42);
OPEN curs3(key := 42);
```

Because variable substitution is done on a bound cursor's query, there are really two ways to pass values into the cursor: either with an explicit argument to `OPEN`, or implicitly by referencing a PL/pgSQL variable in the query. However, only variables declared before the bound cursor was declared will be substituted into it. In either case the value to be passed is determined at the time of the `OPEN`. For example, another way to get the same effect as the `curs3` example above is

```
DECLARE
    key integer;
    curs4 CURSOR FOR SELECT * FROM tenk1 WHERE unique1 = key;
BEGIN
    key := 42;
    OPEN curs4;
```

42.7.3. Using Cursors

Once a cursor has been opened, it can be manipulated with the statements described here.

These manipulations need not occur in the same function that opened the cursor to begin with. You can return a `refcursor` value out of a function and let the caller operate on the cursor. (Internally, a `refcursor` value is simply the string name of a so-called portal containing the active query for the cursor. This name can be passed around, assigned to other `refcursor` variables, and so on, without disturbing the portal.)

All portals are implicitly closed at transaction end. Therefore a `refcursor` value is usable to reference an open cursor only until the end of the transaction.

42.7.3.1. FETCH

```
FETCH [ direction { FROM | IN } ] cursor INTO target;
```

FETCH retrieves the next row from the cursor into a target, which might be a row variable, a record variable, or a comma-separated list of simple variables, just like SELECT INTO. If there is no next row, the target is set to NULL(s). As with SELECT INTO, the special variable FOUND can be checked to see whether a row was obtained or not.

The *direction* clause can be any of the variants allowed in the SQL FETCH command except the ones that can fetch more than one row; namely, it can be NEXT, PRIOR, FIRST, LAST, ABSOLUTE *count*, RELATIVE *count*, FORWARD, or BACKWARD. Omitting *direction* is the same as specifying NEXT. In the forms using a *count*, the *count* can be any integer-valued expression (unlike the SQL FETCH command, which only allows an integer constant). *direction* values that require moving backward are likely to fail unless the cursor was declared or opened with the SCROLL option.

cursor must be the name of a *refcursor* variable that references an open cursor portal.

Examples:

```
FETCH curs1 INTO rowvar;
FETCH curs2 INTO foo, bar, baz;
FETCH LAST FROM curs3 INTO x, y;
FETCH RELATIVE -2 FROM curs4 INTO x;
```

42.7.3.2. MOVE

```
MOVE [ direction { FROM | IN } ] cursor;
```

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only repositions the cursor and does not return the row moved to. As with SELECT INTO, the special variable FOUND can be checked to see whether there was a next row to move to.

Examples:

```
MOVE curs1;
MOVE LAST FROM curs3;
MOVE RELATIVE -2 FROM curs4;
MOVE FORWARD 2 FROM curs4;
```

42.7.3.3. UPDATE/DELETE WHERE CURRENT OF

```
UPDATE table SET ... WHERE CURRENT OF cursor;
DELETE FROM table WHERE CURRENT OF cursor;
```

When a cursor is positioned on a table row, that row can be updated or deleted using the cursor to identify the row. There are restrictions on what the cursor's query can be (in particular, no grouping) and it's best to use FOR UPDATE in the cursor. For more information see the DECLARE reference page.

An example:

```
UPDATE foo SET dataval = myval WHERE CURRENT OF curs1;
```

42.7.3.4. CLOSE

```
CLOSE cursor;
```

CLOSE closes the portal underlying an open cursor. This can be used to release resources earlier than end of transaction, or to free up the cursor variable to be opened again.

An example:

```
CLOSE curs1;
```

42.7.3.5. Returning Cursors

PL/pgSQL functions can return cursors to the caller. This is useful to return multiple rows or columns, especially with very large result sets. To do this, the function opens the cursor and returns the cursor name to the caller (or simply opens the cursor using a portal name specified by or otherwise known to the caller). The caller can then fetch rows from the cursor. The cursor can be closed by the caller, or it will be closed automatically when the transaction closes.

The portal name used for a cursor can be specified by the programmer or automatically generated. To specify a portal name, simply assign a string to the `refcursor` variable before opening it. The string value of the `refcursor` variable will be used by `OPEN` as the name of the underlying portal. However, if the `refcursor` variable is null, `OPEN` automatically generates a name that does not conflict with any existing portal, and assigns it to the `refcursor` variable.

Note

A bound cursor variable is initialized to the string value representing its name, so that the portal name is the same as the cursor variable name, unless the programmer overrides it by assignment before opening the cursor. But an unbound cursor variable defaults to the null value initially, so it will receive an automatically-generated unique name, unless overridden.

The following example shows one way a cursor name can be supplied by the caller:

```
CREATE TABLE test (col text);
INSERT INTO test VALUES ('123');

CREATE FUNCTION reffunc(refcursor) RETURNS refcursor AS '
BEGIN
    OPEN $1 FOR SELECT col FROM test;
    RETURN $1;
END;
' LANGUAGE plpgsql;

BEGIN;
SELECT reffunc('funcursor');
FETCH ALL IN funcursor;
COMMIT;
```

The following example uses automatic cursor name generation:

```

CREATE FUNCTION reffunc2() RETURNS refcursor AS '
DECLARE
    ref refcursor;
BEGIN
    OPEN ref FOR SELECT col FROM test;
    RETURN ref;
END;
' LANGUAGE plpgsql;

-- need to be in a transaction to use cursors.
BEGIN;
SELECT reffunc2();

           reffunc2
-----
<unnamed cursor 1>
(1 row)

FETCH ALL IN "<unnamed cursor 1>";
COMMIT;

```

The following example shows one way to return multiple cursors from a single function:

```

CREATE FUNCTION myfunc(refcursor, refcursor) RETURNS SETOF
    refcursor AS $$
BEGIN
    OPEN $1 FOR SELECT * FROM table_1;
    RETURN NEXT $1;
    OPEN $2 FOR SELECT * FROM table_2;
    RETURN NEXT $2;
END;
$$ LANGUAGE plpgsql;

-- need to be in a transaction to use cursors.
BEGIN;

SELECT * FROM myfunc('a', 'b');

FETCH ALL FROM a;
FETCH ALL FROM b;
COMMIT;

```

42.7.4. Looping through a Cursor's Result

There is a variant of the FOR statement that allows iterating through the rows returned by a cursor. The syntax is:

```

[ <<label>> ]
FOR recordvar IN bound_cursorvar [ ( [ argument_name
    := ] argument_value [, ...] ) ] LOOP
    statements
END LOOP [ label ];

```

The cursor variable must have been bound to some query when it was declared, and it *cannot* be open already. The FOR statement automatically opens the cursor, and it closes the cursor again when the loop exits. A list of actual argument value expressions must appear if and only if the cursor was

declared to take arguments. These values will be substituted in the query, in just the same way as during an OPEN (see Section 42.7.2.3).

The variable *recordvar* is automatically defined as type *record* and exists only inside the loop (any existing definition of the variable name is ignored within the loop). Each row returned by the cursor is successively assigned to this record variable and the loop body is executed.

42.8. Transaction Management

In procedures invoked by the CALL command as well as in anonymous code blocks (DO command), it is possible to end transactions using the commands COMMIT and ROLLBACK. A new transaction is started automatically after a transaction is ended using these commands, so there is no separate START TRANSACTION command. (Note that BEGIN and END have different meanings in PL/pgSQL.)

Here is a simple example:

```
CREATE PROCEDURE transaction_test1()
LANGUAGE plpgsql
AS $$
BEGIN
    FOR i IN 0..9 LOOP
        INSERT INTO test1 (a) VALUES (i);
        IF i % 2 = 0 THEN
            COMMIT;
        ELSE
            ROLLBACK;
        END IF;
    END LOOP;
END
$$;

CALL transaction_test1();
```

A new transaction starts out with default transaction characteristics such as transaction isolation level. In cases where transactions are committed in a loop, it might be desirable to start new transactions automatically with the same characteristics as the previous one. The commands COMMIT AND CHAIN and ROLLBACK AND CHAIN accomplish this.

Transaction control is only possible in CALL or DO invocations from the top level or nested CALL or DO invocations without any other intervening command. For example, if the call stack is CALL proc1() → CALL proc2() → CALL proc3(), then the second and third procedures can perform transaction control actions. But if the call stack is CALL proc1() → SELECT func2() → CALL proc3(), then the last procedure cannot do transaction control, because of the SELECT in between.

Special considerations apply to cursor loops. Consider this example:

```
CREATE PROCEDURE transaction_test2()
LANGUAGE plpgsql
AS $$
DECLARE
    r RECORD;
BEGIN
    FOR r IN SELECT * FROM test2 ORDER BY x LOOP
        INSERT INTO test1 (a) VALUES (r.x);
        COMMIT;
    END LOOP;
END
$$;
```

```

        END LOOP;
    END;
    $$;

CALL transaction_test2();

```

Normally, cursors are automatically closed at transaction commit. However, a cursor created as part of a loop like this is automatically converted to a holdable cursor by the first COMMIT or ROLLBACK. That means that the cursor is fully evaluated at the first COMMIT or ROLLBACK rather than row by row. The cursor is still removed automatically after the loop, so this is mostly invisible to the user.

Transaction commands are not allowed in cursor loops driven by commands that are not read-only (for example UPDATE ... RETURNING).

A transaction cannot be ended inside a block with exception handlers.

42.9. Errors and Messages

42.9.1. Reporting Errors and Messages

Use the RAISE statement to report messages and raise errors.

```

RAISE [ level ] 'format' [, expression [, ... ] ] [ USING option
    = expression [, ... ] ];
RAISE [ level ] condition_name [ USING option = expression
    [, ... ] ];
RAISE [ level ] SQLSTATE 'sqlstate' [ USING option = expression
    [, ... ] ];
RAISE [ level ] USING option = expression [, ... ] ;
RAISE ;

```

The *level* option specifies the error severity. Allowed levels are DEBUG, LOG, INFO, NOTICE, WARNING, and EXCEPTION, with EXCEPTION being the default. EXCEPTION raises an error (which normally aborts the current transaction); the other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the log_min_messages and client_min_messages configuration variables. See Chapter 19 for more information.

After *level* if any, you can write a *format* (which must be a simple string literal, not an expression). The format string specifies the error message text to be reported. The format string can be followed by optional argument expressions to be inserted into the message. Inside the format string, % is replaced by the string representation of the next optional argument's value. Write %% to emit a literal %. The number of arguments must match the number of % placeholders in the format string, or an error is raised during the compilation of the function.

In this example, the value of v_job_id will replace the % in the string:

```
RAISE NOTICE 'Calling cs_create_job(%)', v_job_id;
```

You can attach additional information to the error report by writing USING followed by *option = expression* items. Each *expression* can be any string-valued expression. The allowed *option* key words are:

MESSAGE

Sets the error message text. This option can't be used in the form of RAISE that includes a format string before USING.

DETAIL

Supplies an error detail message.

HINT

Supplies a hint message.

ERRCODE

Specifies the error code (SQLSTATE) to report, either by condition name, as shown in Appendix A, or directly as a five-character SQLSTATE code.

COLUMN

CONSTRAINT

DATATYPE

TABLE

SCHEMA

Supplies the name of a related object.

This example will abort the transaction with the given error message and hint:

```
RAISE EXCEPTION 'Nonexistent ID --> %', user_id
    USING HINT = 'Please check your user ID';
```

These two examples show equivalent ways of setting the SQLSTATE:

```
RAISE 'Duplicate user ID: %', user_id USING ERRCODE =
    'unique_violation';
RAISE 'Duplicate user ID: %', user_id USING ERRCODE = '23505';
```

There is a second RAISE syntax in which the main argument is the condition name or SQLSTATE to be reported, for example:

```
RAISE division_by_zero;
RAISE SQLSTATE '22012';
```

In this syntax, USING can be used to supply a custom error message, detail, or hint. Another way to do the earlier example is

```
RAISE unique_violation USING MESSAGE = 'Duplicate user ID: ' ||
    user_id;
```

Still another variant is to write RAISE USING or RAISE *level* USING and put everything else into the USING list.

The last variant of RAISE has no parameters at all. This form can only be used inside a BEGIN block's EXCEPTION clause; it causes the error currently being handled to be re-thrown.

Note

Before PostgreSQL 9.1, RAISE without parameters was interpreted as re-throwing the error from the block containing the active exception handler. Thus an EXCEPTION clause nested within that handler could not catch it, even if the RAISE was within

the nested `EXCEPTION` clause's block. This was deemed surprising as well as being incompatible with Oracle's PL/SQL.

If no condition name nor `SQLSTATE` is specified in a `RAISE EXCEPTION` command, the default is to use `ERRCODE_RAISE_EXCEPTION` (P0001). If no message text is specified, the default is to use the condition name or `SQLSTATE` as message text.

Note

When specifying an error code by `SQLSTATE` code, you are not limited to the pre-defined error codes, but can select any error code consisting of five digits and/or upper-case ASCII letters, other than 00000. It is recommended that you avoid throwing error codes that end in three zeroes, because these are category codes and can only be trapped by trapping the whole category.

42.9.2. Checking Assertions

The `ASSERT` statement is a convenient shorthand for inserting debugging checks into PL/pgSQL functions.

```
ASSERT condition [ , message ];
```

The *condition* is a Boolean expression that is expected to always evaluate to true; if it does, the `ASSERT` statement does nothing further. If the result is false or null, then an `ASSERT_FAILURE` exception is raised. (If an error occurs while evaluating the *condition*, it is reported as a normal error.)

If the optional *message* is provided, it is an expression whose result (if not null) replaces the default error message text “assertion failed”, should the *condition* fail. The *message* expression is not evaluated in the normal case where the assertion succeeds.

Testing of assertions can be enabled or disabled via the configuration parameter `plpgsql.check_asserts`, which takes a Boolean value; the default is `on`. If this parameter is `off` then `ASSERT` statements do nothing.

Note that `ASSERT` is meant for detecting program bugs, not for reporting ordinary error conditions. Use the `RAISE` statement, described above, for that.

42.10. Trigger Functions

PL/pgSQL can be used to define trigger functions on data changes or database events. A trigger function is created with the `CREATE FUNCTION` command, declaring it as a function with no arguments and a return type of `trigger` (for data change triggers) or `event_trigger` (for database event triggers). Special local variables named `TG_something` are automatically defined to describe the condition that triggered the call.

42.10.1. Triggers on Data Changes

A data change trigger is declared as a function with no arguments and a return type of `trigger`. Note that the function must be declared with no arguments even if it expects to receive some arguments specified in `CREATE TRIGGER` — such arguments are passed via `TG_ARGV`, as described below.

When a PL/pgSQL function is called as a trigger, several special variables are created automatically in the top-level block. They are:

NEW

Data type `RECORD`; variable holding the new database row for `INSERT/UPDATE` operations in row-level triggers. This variable is null in statement-level triggers and for `DELETE` operations.

OLD

Data type `RECORD`; variable holding the old database row for `UPDATE/DELETE` operations in row-level triggers. This variable is null in statement-level triggers and for `INSERT` operations.

TG_NAME

Data type name; variable that contains the name of the trigger actually fired.

TG_WHEN

Data type `text`; a string of `BEFORE`, `AFTER`, or `INSTEAD OF`, depending on the trigger's definition.

TG_LEVEL

Data type `text`; a string of either `ROW` or `STATEMENT` depending on the trigger's definition.

TG_OP

Data type `text`; a string of `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` telling for which operation the trigger was fired.

TG_RELID

Data type `oid`; the object ID of the table that caused the trigger invocation.

TG_RELNAME

Data type name; the name of the table that caused the trigger invocation. This is now deprecated, and could disappear in a future release. Use `TG_TABLE_NAME` instead.

TG_TABLE_NAME

Data type name; the name of the table that caused the trigger invocation.

TG_TABLE_SCHEMA

Data type name; the name of the schema of the table that caused the trigger invocation.

TG_NARGS

Data type `integer`; the number of arguments given to the trigger function in the `CREATE TRIGGER` statement.

TG_ARGV[]

Data type array of `text`; the arguments from the `CREATE TRIGGER` statement. The index counts from 0. Invalid indexes (less than 0 or greater than or equal to `tg_nargs`) result in a null value.

A trigger function must return either `NULL` or a record/row value having exactly the structure of the table the trigger was fired for.

Row-level triggers fired `BEFORE` can return null to signal the trigger manager to skip the rest of the operation for this row (i.e., subsequent triggers are not fired, and the `INSERT/UPDATE/DELETE` does not occur for this row). If a nonnull value is returned then the operation proceeds with that row value. Returning a row value different from the original value of `NEW` alters the row that will be inserted or

updated. Thus, if the trigger function wants the triggering action to succeed normally without altering the row value, `NEW` (or a value equal thereto) has to be returned. To alter the row to be stored, it is possible to replace single values directly in `NEW` and return the modified `NEW`, or to build a complete new record/row to return. In the case of a before-trigger on `DELETE`, the returned value has no direct effect, but it has to be nonnull to allow the trigger action to proceed. Note that `NEW` is null in `DELETE` triggers, so returning that is usually not sensible. The usual idiom in `DELETE` triggers is to return `OLD`.

`INSTEAD OF` triggers (which are always row-level triggers, and may only be used on views) can return null to signal that they did not perform any updates, and that the rest of the operation for this row should be skipped (i.e., subsequent triggers are not fired, and the row is not counted in the rows-affected status for the surrounding `INSERT/UPDATE/DELETE`). Otherwise a nonnull value should be returned, to signal that the trigger performed the requested operation. For `INSERT` and `UPDATE` operations, the return value should be `NEW`, which the trigger function may modify to support `INSERT RETURNING` and `UPDATE RETURNING` (this will also affect the row value passed to any subsequent triggers, or passed to a special `EXCLUDED` alias reference within an `INSERT` statement with an `ON CONFLICT DO UPDATE` clause). For `DELETE` operations, the return value should be `OLD`.

The return value of a row-level trigger fired `AFTER` or a statement-level trigger fired `BEFORE` or `AFTER` is always ignored; it might as well be null. However, any of these types of triggers might still abort the entire operation by raising an error.

Example 42.3 shows an example of a trigger function in PL/pgSQL.

Example 42.3. A PL/pgSQL Trigger Function

This example trigger ensures that any time a row is inserted or updated in the table, the current user name and time are stamped into the row. And it checks that an employee's name is given and that the salary is a positive value.

```
CREATE TABLE emp (
    empname text,
    salary integer,
    last_date timestamp,
    last_user text
);

CREATE FUNCTION emp_stamp() RETURNS trigger AS $emp_stamp$
BEGIN
    -- Check that empname and salary are given
    IF NEW.empname IS NULL THEN
        RAISE EXCEPTION 'empname cannot be null';
    END IF;
    IF NEW.salary IS NULL THEN
        RAISE EXCEPTION '% cannot have null salary',
NEW.empname;
    END IF;

    -- Who works for us when they must pay for it?
    IF NEW.salary < 0 THEN
        RAISE EXCEPTION '% cannot have a negative salary',
NEW.empname;
    END IF;

    -- Remember who changed the payroll when
    NEW.last_date := current_timestamp;
    NEW.last_user := current_user;
    RETURN NEW;
END;
```

```
$emp_stamp$ LANGUAGE plpgsql;
```

```
CREATE TRIGGER emp_stamp BEFORE INSERT OR UPDATE ON emp
    FOR EACH ROW EXECUTE FUNCTION emp_stamp();
```

Another way to log changes to a table involves creating a new table that holds a row for each insert, update, or delete that occurs. This approach can be thought of as auditing changes to a table. Example 42.4 shows an example of an audit trigger function in PL/pgSQL.

Example 42.4. A PL/pgSQL Trigger Function for Auditing

This example trigger ensures that any insert, update or delete of a row in the `emp` table is recorded (i.e., audited) in the `emp_audit` table. The current time and user name are stamped into the row, together with the type of operation performed on it.

```
CREATE TABLE emp (
    empname      text NOT NULL,
    salary       integer
);
```

```
CREATE TABLE emp_audit(
    operation     char(1)  NOT NULL,
    stamp         timestamp NOT NULL,
    userid       text     NOT NULL,
    empname      text     NOT NULL,
    salary       integer
);
```

```
CREATE OR REPLACE FUNCTION process_emp_audit() RETURNS TRIGGER AS
    $emp_audit$
    BEGIN
        --
        -- Create a row in emp_audit to reflect the operation
        -- performed on emp,
        -- making use of the special variable TG_OP to work out the
        -- operation.
        --
        IF (TG_OP = 'DELETE') THEN
            INSERT INTO emp_audit SELECT 'D', now(), user, OLD.*;
        ELSIF (TG_OP = 'UPDATE') THEN
            INSERT INTO emp_audit SELECT 'U', now(), user, NEW.*;
        ELSIF (TG_OP = 'INSERT') THEN
            INSERT INTO emp_audit SELECT 'I', now(), user, NEW.*;
        END IF;
        RETURN NULL; -- result is ignored since this is an AFTER
        trigger
    END;
$emp_audit$ LANGUAGE plpgsql;
```

```
CREATE TRIGGER emp_audit
AFTER INSERT OR UPDATE OR DELETE ON emp
    FOR EACH ROW EXECUTE FUNCTION process_emp_audit();
```

A variation of the previous example uses a view joining the main table to the audit table, to show when each entry was last modified. This approach still records the full audit trail of changes to the table, but also presents a simplified view of the audit trail, showing just the last modified timestamp derived from the audit trail for each entry. Example 42.5 shows an example of an audit trigger on a view in PL/pgSQL.

Example 42.5. A PL/pgSQL View Trigger Function for Auditing

This example uses a trigger on the view to make it updatable, and ensure that any insert, update or delete of a row in the view is recorded (i.e., audited) in the `emp_audit` table. The current time and user name are recorded, together with the type of operation performed, and the view displays the last modified time of each row.

```

CREATE TABLE emp (
    empname          text PRIMARY KEY,
    salary           integer
);

CREATE TABLE emp_audit(
    operation        char(1) NOT NULL,
    userid           text NOT NULL,
    empname          text NOT NULL,
    salary           integer,
    stamp            timestamp NOT NULL
);

CREATE VIEW emp_view AS
    SELECT e.empname,
           e.salary,
           max(ea.stamp) AS last_updated
    FROM emp e
    LEFT JOIN emp_audit ea ON ea.empname = e.empname
    GROUP BY 1, 2;

CREATE OR REPLACE FUNCTION update_emp_view() RETURNS TRIGGER AS $$
BEGIN
    --
    -- Perform the required operation on emp, and create a row
in emp_audit
    -- to reflect the change made to emp.
    --
    IF (TG_OP = 'DELETE') THEN
        DELETE FROM emp WHERE empname = OLD.empname;
        IF NOT FOUND THEN RETURN NULL; END IF;

        OLD.last_updated = now();
        INSERT INTO emp_audit VALUES('D', user, OLD.*);
        RETURN OLD;
    ELSIF (TG_OP = 'UPDATE') THEN
        UPDATE emp SET salary = NEW.salary WHERE empname =
OLD.empname;
        IF NOT FOUND THEN RETURN NULL; END IF;

        NEW.last_updated = now();
        INSERT INTO emp_audit VALUES('U', user, NEW.*);
        RETURN NEW;
    ELSIF (TG_OP = 'INSERT') THEN
        INSERT INTO emp VALUES(NEW.empname, NEW.salary);

        NEW.last_updated = now();
        INSERT INTO emp_audit VALUES('I', user, NEW.*);
        RETURN NEW;
    END IF;
END IF;

```

```

END;
$$ LANGUAGE plpgsql;

CREATE TRIGGER emp_audit
INSTEAD OF INSERT OR UPDATE OR DELETE ON emp_view
FOR EACH ROW EXECUTE FUNCTION update_emp_view();

```

One use of triggers is to maintain a summary table of another table. The resulting summary can be used in place of the original table for certain queries — often with vastly reduced run times. This technique is commonly used in Data Warehousing, where the tables of measured or observed data (called fact tables) might be extremely large. Example 42.6 shows an example of a trigger function in PL/pgSQL that maintains a summary table for a fact table in a data warehouse.

Example 42.6. A PL/pgSQL Trigger Function for Maintaining a Summary Table

The schema detailed here is partly based on the *Grocery Store* example from *The Data Warehouse Toolkit* by Ralph Kimball.

```

--
-- Main tables - time dimension and sales fact.
--
CREATE TABLE time_dimension (
    time_key          integer NOT NULL,
    day_of_week       integer NOT NULL,
    day_of_month      integer NOT NULL,
    month             integer NOT NULL,
    quarter           integer NOT NULL,
    year              integer NOT NULL
);
CREATE UNIQUE INDEX time_dimension_key ON time_dimension(time_key);

CREATE TABLE sales_fact (
    time_key          integer NOT NULL,
    product_key       integer NOT NULL,
    store_key         integer NOT NULL,
    amount_sold       numeric(12,2) NOT NULL,
    units_sold        integer NOT NULL,
    amount_cost       numeric(12,2) NOT NULL
);
CREATE INDEX sales_fact_time ON sales_fact(time_key);

--
-- Summary table - sales by time.
--
CREATE TABLE sales_summary_bytime (
    time_key          integer NOT NULL,
    amount_sold       numeric(15,2) NOT NULL,
    units_sold        numeric(12) NOT NULL,
    amount_cost       numeric(15,2) NOT NULL
);
CREATE UNIQUE INDEX sales_summary_bytime_key ON
    sales_summary_bytime(time_key);

--
-- Function and trigger to amend summarized column(s) on UPDATE,
-- INSERT, DELETE.

```

```
--
CREATE OR REPLACE FUNCTION maint_sales_summary_bytime() RETURNS
TRIGGER
AS $maint_sales_summary_bytime$
    DECLARE
        delta_time_key          integer;
        delta_amount_sold       numeric(15,2);
        delta_units_sold        numeric(12);
        delta_amount_cost       numeric(15,2);
    BEGIN

        -- Work out the increment/decrement amount(s).
        IF (TG_OP = 'DELETE') THEN

            delta_time_key = OLD.time_key;
            delta_amount_sold = -1 * OLD.amount_sold;
            delta_units_sold = -1 * OLD.units_sold;
            delta_amount_cost = -1 * OLD.amount_cost;

        ELSIF (TG_OP = 'UPDATE') THEN

            -- forbid updates that change the time_key -
            -- (probably not too onerous, as DELETE + INSERT is how
most
            -- changes will be made).
            IF ( OLD.time_key != NEW.time_key) THEN
                RAISE EXCEPTION 'Update of time_key : % -> % not
allowed',
                                                                OLD.time_key,
NEW.time_key;
            END IF;

            delta_time_key = OLD.time_key;
            delta_amount_sold = NEW.amount_sold - OLD.amount_sold;
            delta_units_sold = NEW.units_sold - OLD.units_sold;
            delta_amount_cost = NEW.amount_cost - OLD.amount_cost;

        ELSIF (TG_OP = 'INSERT') THEN

            delta_time_key = NEW.time_key;
            delta_amount_sold = NEW.amount_sold;
            delta_units_sold = NEW.units_sold;
            delta_amount_cost = NEW.amount_cost;

        END IF;

        -- Insert or update the summary row with the new values.
        <<insert_update>>
        LOOP
            UPDATE sales_summary_bytime
                SET amount_sold = amount_sold + delta_amount_sold,
                    units_sold = units_sold + delta_units_sold,
                    amount_cost = amount_cost + delta_amount_cost
                WHERE time_key = delta_time_key;

            EXIT insert_update WHEN found;
        END LOOP;
    END;
$maint_sales_summary_bytime$
```

```

BEGIN
    INSERT INTO sales_summary_bytime (
        time_key,
        amount_sold,
        units_sold,
        amount_cost)
        VALUES (
            delta_time_key,
            delta_amount_sold,
            delta_units_sold,
            delta_amount_cost
        );

    EXIT insert_update;

EXCEPTION
    WHEN UNIQUE_VIOLATION THEN
        -- do nothing
    END;
END LOOP insert_update;

RETURN NULL;

END;
$maint_sales_summary_bytime$ LANGUAGE plpgsql;

CREATE TRIGGER maint_sales_summary_bytime
AFTER INSERT OR UPDATE OR DELETE ON sales_fact
    FOR EACH ROW EXECUTE FUNCTION maint_sales_summary_bytime();

INSERT INTO sales_fact VALUES(1,1,1,10,3,15);
INSERT INTO sales_fact VALUES(1,2,1,20,5,35);
INSERT INTO sales_fact VALUES(2,2,1,40,15,135);
INSERT INTO sales_fact VALUES(2,3,1,10,1,13);
SELECT * FROM sales_summary_bytime;
DELETE FROM sales_fact WHERE product_key = 1;
SELECT * FROM sales_summary_bytime;
UPDATE sales_fact SET units_sold = units_sold * 2;
SELECT * FROM sales_summary_bytime;

```

AFTER triggers can also make use of *transition tables* to inspect the entire set of rows changed by the triggering statement. The CREATE TRIGGER command assigns names to one or both transition tables, and then the function can refer to those names as though they were read-only temporary tables. Example 42.7 shows an example.

Example 42.7. Auditing with Transition Tables

This example produces the same results as Example 42.4, but instead of using a trigger that fires for every row, it uses a trigger that fires once per statement, after collecting the relevant information in a transition table. This can be significantly faster than the row-trigger approach when the invoking statement has modified many rows. Notice that we must make a separate trigger declaration for each kind of event, since the REFERENCING clauses must be different for each case. But this does not stop us from using a single trigger function if we choose. (In practice, it might be better to use three separate functions and avoid the run-time tests on TG_OP.)

```

CREATE TABLE emp (
    empname      text NOT NULL,
    salary       integer

```

```

);

CREATE TABLE emp_audit(
    operation      char(1)    NOT NULL,
    stamp          timestamp NOT NULL,
    userid         text       NOT NULL,
    empname        text       NOT NULL,
    salary integer
);

CREATE OR REPLACE FUNCTION process_emp_audit() RETURNS TRIGGER AS
$emp_audit$
BEGIN
    --
    -- Create rows in emp_audit to reflect the operations
    performed on emp,
    -- making use of the special variable TG_OP to work out the
    operation.
    --
    IF (TG_OP = 'DELETE') THEN
        INSERT INTO emp_audit
            SELECT 'D', now(), user, o.* FROM old_table o;
    ELSIF (TG_OP = 'UPDATE') THEN
        INSERT INTO emp_audit
            SELECT 'U', now(), user, n.* FROM new_table n;
    ELSIF (TG_OP = 'INSERT') THEN
        INSERT INTO emp_audit
            SELECT 'I', now(), user, n.* FROM new_table n;
    END IF;
    RETURN NULL; -- result is ignored since this is an AFTER
trigger
END;
$emp_audit$ LANGUAGE plpgsql;

CREATE TRIGGER emp_audit_ins
AFTER INSERT ON emp
REFERENCING NEW TABLE AS new_table
FOR EACH STATEMENT EXECUTE FUNCTION process_emp_audit();
CREATE TRIGGER emp_audit_upd
AFTER UPDATE ON emp
REFERENCING OLD TABLE AS old_table NEW TABLE AS new_table
FOR EACH STATEMENT EXECUTE FUNCTION process_emp_audit();
CREATE TRIGGER emp_audit_del
AFTER DELETE ON emp
REFERENCING OLD TABLE AS old_table
FOR EACH STATEMENT EXECUTE FUNCTION process_emp_audit();

```

42.10.2. Triggers on Events

PL/pgSQL can be used to define event triggers. PostgreSQL requires that a function that is to be called as an event trigger must be declared as a function with no arguments and a return type of `event_trigger`.

When a PL/pgSQL function is called as an event trigger, several special variables are created automatically in the top-level block. They are:

`TG_EVENT`

Data type `text`; a string representing the event the trigger is fired for.

TG_TAG

Data type text; variable that contains the command tag for which the trigger is fired.

Example 42.8 shows an example of an event trigger function in PL/pgSQL.

Example 42.8. A PL/pgSQL Event Trigger Function

This example trigger simply raises a NOTICE message each time a supported command is executed.

```
CREATE OR REPLACE FUNCTION snitch() RETURNS event_trigger AS $$
BEGIN
    RAISE NOTICE 'snitch: % %', tg_event, tg_tag;
END;
$$ LANGUAGE plpgsql;

CREATE EVENT TRIGGER snitch ON ddl_command_start EXECUTE FUNCTION
snitch();
```

42.11. PL/pgSQL under the Hood

This section discusses some implementation details that are frequently important for PL/pgSQL users to know.

42.11.1. Variable Substitution

SQL statements and expressions within a PL/pgSQL function can refer to variables and parameters of the function. Behind the scenes, PL/pgSQL substitutes query parameters for such references. Parameters will only be substituted in places where a parameter or column reference is syntactically allowed. As an extreme case, consider this example of poor programming style:

```
INSERT INTO foo (foo) VALUES (foo);
```

The first occurrence of `foo` must syntactically be a table name, so it will not be substituted, even if the function has a variable named `foo`. The second occurrence must be the name of a column of the table, so it will not be substituted either. Only the third occurrence is a candidate to be a reference to the function's variable.

Note

PostgreSQL versions before 9.0 would try to substitute the variable in all three cases, leading to syntax errors.

Since the names of variables are syntactically no different from the names of table columns, there can be ambiguity in statements that also refer to tables: is a given name meant to refer to a table column, or a variable? Let's change the previous example to

```
INSERT INTO dest (col) SELECT foo + bar FROM src;
```

Here, `dest` and `src` must be table names, and `col` must be a column of `dest`, but `foo` and `bar` might reasonably be either variables of the function or columns of `src`.

By default, PL/pgSQL will report an error if a name in a SQL statement could refer to either a variable or a table column. You can fix such a problem by renaming the variable or column, or by qualifying the ambiguous reference, or by telling PL/pgSQL which interpretation to prefer.

The simplest solution is to rename the variable or column. A common coding rule is to use a different naming convention for PL/pgSQL variables than you use for column names. For example, if you consistently name function variables *v_something* while none of your column names start with *v_*, no conflicts will occur.

Alternatively you can qualify ambiguous references to make them clear. In the above example, *src.foo* would be an unambiguous reference to the table column. To create an unambiguous reference to a variable, declare it in a labeled block and use the block's label (see Section 42.2). For example,

```
<<block>>
DECLARE
    foo int;
BEGIN
    foo := ...;
    INSERT INTO dest (col) SELECT block.foo + bar FROM src;
```

Here *block.foo* means the variable even if there is a column *foo* in *src*. Function parameters, as well as special variables such as *FOUND*, can be qualified by the function's name, because they are implicitly declared in an outer block labeled with the function's name.

Sometimes it is impractical to fix all the ambiguous references in a large body of PL/pgSQL code. In such cases you can specify that PL/pgSQL should resolve ambiguous references as the variable (which is compatible with PL/pgSQL's behavior before PostgreSQL 9.0), or as the table column (which is compatible with some other systems such as Oracle).

To change this behavior on a system-wide basis, set the configuration parameter *plpgsql.variable_conflict* to one of *error*, *use_variable*, or *use_column* (where *error* is the factory default). This parameter affects subsequent compilations of statements in PL/pgSQL functions, but not statements already compiled in the current session. Because changing this setting can cause unexpected changes in the behavior of PL/pgSQL functions, it can only be changed by a superuser.

You can also set the behavior on a function-by-function basis, by inserting one of these special commands at the start of the function text:

```
#variable_conflict error
#variable_conflict use_variable
#variable_conflict use_column
```

These commands affect only the function they are written in, and override the setting of *plpgsql.variable_conflict*. An example is

```
CREATE FUNCTION stamp_user(id int, comment text) RETURNS void AS $$
    #variable_conflict use_variable
    DECLARE
        curtime timestamp := now();
    BEGIN
        UPDATE users SET last_modified = curtime, comment = comment
            WHERE users.id = id;
    END;
$$ LANGUAGE plpgsql;
```

In the *UPDATE* command, *curtime*, *comment*, and *id* will refer to the function's variable and parameters whether or not *users* has columns of those names. Notice that we had to qualify the reference to *users.id* in the *WHERE* clause to make it refer to the table column. But we did not have to qualify the reference to *comment* as a target in the *UPDATE* list, because syntactically that must be

a column of `users`. We could write the same function without depending on the `variable_conflict` setting in this way:

```
CREATE FUNCTION stamp_user(id int, comment text) RETURNS void AS $$
    <<fn>>
    DECLARE
        curtime timestamp := now();
    BEGIN
        UPDATE users SET last_modified = fn.curtime, comment =
            stamp_user.comment
            WHERE users.id = stamp_user.id;
    END;
$$ LANGUAGE plpgsql;
```

Variable substitution does not happen in the command string given to `EXECUTE` or one of its variants. If you need to insert a varying value into such a command, do so as part of constructing the string value, or use `USING`, as illustrated in Section 42.5.4.

Variable substitution currently works only in `SELECT`, `INSERT`, `UPDATE`, and `DELETE` commands, because the main SQL engine allows query parameters only in these commands. To use a non-constant name or value in other statement types (generically called utility statements), you must construct the utility statement as a string and `EXECUTE` it.

42.11.2. Plan Caching

The PL/pgSQL interpreter parses the function's source text and produces an internal binary instruction tree the first time the function is called (within each session). The instruction tree fully translates the PL/pgSQL statement structure, but individual SQL expressions and SQL commands used in the function are not translated immediately.

As each expression and SQL command is first executed in the function, the PL/pgSQL interpreter parses and analyzes the command to create a prepared statement, using the SPI manager's `SPI_prepare` function. Subsequent visits to that expression or command reuse the prepared statement. Thus, a function with conditional code paths that are seldom visited will never incur the overhead of analyzing those commands that are never executed within the current session. A disadvantage is that errors in a specific expression or command cannot be detected until that part of the function is reached in execution. (Trivial syntax errors will be detected during the initial parsing pass, but anything deeper will not be detected until execution.)

PL/pgSQL (or more precisely, the SPI manager) can furthermore attempt to cache the execution plan associated with any particular prepared statement. If a cached plan is not used, then a fresh execution plan is generated on each visit to the statement, and the current parameter values (that is, PL/pgSQL variable values) can be used to optimize the selected plan. If the statement has no parameters, or is executed many times, the SPI manager will consider creating a *generic* plan that is not dependent on specific parameter values, and caching that for re-use. Typically this will happen only if the execution plan is not very sensitive to the values of the PL/pgSQL variables referenced in it. If it is, generating a plan each time is a net win. See `PREPARE` for more information about the behavior of prepared statements.

Because PL/pgSQL saves prepared statements and sometimes execution plans in this way, SQL commands that appear directly in a PL/pgSQL function must refer to the same tables and columns on every execution; that is, you cannot use a parameter as the name of a table or column in an SQL command. To get around this restriction, you can construct dynamic commands using the PL/pgSQL `EXECUTE` statement — at the price of performing new parse analysis and constructing a new execution plan on every execution.

The mutable nature of record variables presents another problem in this connection. When fields of a record variable are used in expressions or statements, the data types of the fields must not change

from one call of the function to the next, since each expression will be analyzed using the data type that is present when the expression is first reached. `EXECUTE` can be used to get around this problem when necessary.

If the same function is used as a trigger for more than one table, PL/pgSQL prepares and caches statements independently for each such table — that is, there is a cache for each trigger function and table combination, not just for each function. This alleviates some of the problems with varying data types; for instance, a trigger function will be able to work successfully with a column named `key` even if it happens to have different types in different tables.

Likewise, functions having polymorphic argument types have a separate statement cache for each combination of actual argument types they have been invoked for, so that data type differences do not cause unexpected failures.

Statement caching can sometimes have surprising effects on the interpretation of time-sensitive values. For example there is a difference between what these two functions do:

```
CREATE FUNCTION logfunc1(logtxt text) RETURNS void AS $$
BEGIN
    INSERT INTO logtable VALUES (logtxt, 'now');
END;
$$ LANGUAGE plpgsql;
```

and:

```
CREATE FUNCTION logfunc2(logtxt text) RETURNS void AS $$
DECLARE
    curtime timestamp;
BEGIN
    curtime := 'now';
    INSERT INTO logtable VALUES (logtxt, curtime);
END;
$$ LANGUAGE plpgsql;
```

In the case of `logfunc1`, the PostgreSQL main parser knows when analyzing the `INSERT` that the string `'now'` should be interpreted as `timestamp`, because the target column of `logtable` is of that type. Thus, `'now'` will be converted to a `timestamp` constant when the `INSERT` is analyzed, and then used in all invocations of `logfunc1` during the lifetime of the session. Needless to say, this isn't what the programmer wanted. A better idea is to use the `now()` or `current_timestamp` function.

In the case of `logfunc2`, the PostgreSQL main parser does not know what type `'now'` should become and therefore it returns a data value of type `text` containing the string `now`. During the ensuing assignment to the local variable `curtime`, the PL/pgSQL interpreter casts this string to the `timestamp` type by calling the `text_out` and `timestamp_in` functions for the conversion. So, the computed time stamp is updated on each execution as the programmer expects. Even though this happens to work as expected, it's not terribly efficient, so use of the `now()` function would still be a better idea.

42.12. Tips for Developing in PL/pgSQL

One good way to develop in PL/pgSQL is to use the text editor of your choice to create your functions, and in another window, use `psql` to load and test those functions. If you are doing it this way, it is a good idea to write the function using `CREATE OR REPLACE FUNCTION`. That way you can just reload the file to update the function definition. For example:

```
CREATE OR REPLACE FUNCTION testfunc(integer) RETURNS integer AS $$
    ....
$$ LANGUAGE plpgsql;
```

While running psql, you can load or reload such a function definition file with:

```
\i filename.sql
```

and then immediately issue SQL commands to test the function.

Another good way to develop in PL/pgSQL is with a GUI database access tool that facilitates development in a procedural language. One example of such a tool is pgAdmin, although others exist. These tools often provide convenient features such as escaping single quotes and making it easier to recreate and debug functions.

42.12.1. Handling of Quotation Marks

The code of a PL/pgSQL function is specified in `CREATE FUNCTION` as a string literal. If you write the string literal in the ordinary way with surrounding single quotes, then any single quotes inside the function body must be doubled; likewise any backslashes must be doubled (assuming escape string syntax is used). Doubling quotes is at best tedious, and in more complicated cases the code can become downright incomprehensible, because you can easily find yourself needing half a dozen or more adjacent quote marks. It's recommended that you instead write the function body as a “dollar-quoted” string literal (see Section 4.1.2.4). In the dollar-quoting approach, you never double any quote marks, but instead take care to choose a different dollar-quoting delimiter for each level of nesting you need. For example, you might write the `CREATE FUNCTION` command as:

```
CREATE OR REPLACE FUNCTION testfunc(integer) RETURNS integer AS
    $PROC$
    ....
$PROC$ LANGUAGE plpgsql;
```

Within this, you might use quote marks for simple literal strings in SQL commands and `$$` to delimit fragments of SQL commands that you are assembling as strings. If you need to quote text that includes `$$`, you could use `$$Q$`, and so on.

The following chart shows what you have to do when writing quote marks without dollar quoting. It might be useful when translating pre-dollar quoting code into something more comprehensible.

1 quotation mark

To begin and end the function body, for example:

```
CREATE FUNCTION foo() RETURNS integer AS '
    ....
' LANGUAGE plpgsql;
```

Anywhere within a single-quoted function body, quote marks *must* appear in pairs.

2 quotation marks

For string literals inside the function body, for example:

```
a_output := 'Blah';
```

```
SELECT * FROM users WHERE f_name='foobar';
```

In the dollar-quoting approach, you'd just write:

```
a_output := 'Blah';
SELECT * FROM users WHERE f_name='foobar';
```

which is exactly what the PL/pgSQL parser would see in either case.

4 quotation marks

When you need a single quotation mark in a string constant inside the function body, for example:

```
a_output := a_output || ' AND name LIKE '''foobar''' AND
xyz'
```

The value actually appended to `a_output` would be: `AND name LIKE 'foobar' AND xyz`.

In the dollar-quoting approach, you'd write:

```
a_output := a_output || $$ AND name LIKE 'foobar' AND xyz$$
```

being careful that any dollar-quote delimiters around this are not just `$$`.

6 quotation marks

When a single quotation mark in a string inside the function body is adjacent to the end of that string constant, for example:

```
a_output := a_output || ' AND name LIKE '''foobar''''
```

The value appended to `a_output` would then be: `AND name LIKE 'foobar'`.

In the dollar-quoting approach, this becomes:

```
a_output := a_output || $$ AND name LIKE 'foobar'$$
```

10 quotation marks

When you want two single quotation marks in a string constant (which accounts for 8 quotation marks) and this is adjacent to the end of that string constant (2 more). You will probably only need that if you are writing a function that generates other functions, as in Example 42.10. For example:

```
a_output := a_output || ' if v_' ||
referrer_keys.kind || ' like '''
|| referrer_keys.key_string || '''
then return ''' || referrer_keys.referrer_type
|| '''; end if;'';
```

The value of `a_output` would then be:

```
if v_... like '...' then return '...'; end if;
```

In the dollar-quoting approach, this becomes:

```
a_output := a_output || $$ if v_$$ || referrer_keys.kind || $$
like '$$
|| referrer_keys.key_string || $$'
then return '$$ || referrer_keys.referrer_type
|| $$'; end if;$$;
```

where we assume we only need to put single quote marks into `a_output`, because it will be re-quoted before use.

42.12.2. Additional Compile-Time and Run-Time Checks

To aid the user in finding instances of simple but common problems before they cause harm, PL/pgSQL provides additional *checks*. When enabled, depending on the configuration, they can be used to emit either a `WARNING` or an `ERROR` during the compilation of a function. A function which has received a `WARNING` can be executed without producing further messages, so you are advised to test in a separate development environment.

Setting `plpgsql.extra_warnings`, or `plpgsql.extra_errors`, as appropriate, to "all" is encouraged in development and/or testing environments.

These additional checks are enabled through the configuration variables `plpgsql.extra_warnings` for warnings and `plpgsql.extra_errors` for errors. Both can be set either to a comma-separated list of checks, "none" or "all". The default is "none". Currently the list of available checks includes:

`shadowed_variables`

Checks if a declaration shadows a previously defined variable.

`strict_multi_assignment`

Some PL/PgSQL commands allow assigning values to more than one variable at a time, such as `SELECT INTO`. Typically, the number of target variables and the number of source variables should match, though PL/PgSQL will use `NULL` for missing values and extra variables are ignored. Enabling this check will cause PL/PgSQL to throw a `WARNING` or `ERROR` whenever the number of target variables and the number of source variables are different.

`too_many_rows`

Enabling this check will cause PL/PgSQL to check if a given query returns more than one row when an `INTO` clause is used. As an `INTO` statement will only ever use one row, having a query return multiple rows is generally either inefficient and/or nondeterministic and therefore is likely an error.

The following example shows the effect of `plpgsql.extra_warnings` set to `shadowed_variables`:

```
SET plpgsql.extra_warnings TO 'shadowed_variables';

CREATE FUNCTION foo(f1 int) RETURNS int AS $$
```

```

DECLARE
f1 int;
BEGIN
RETURN f1;
END
$$ LANGUAGE plpgsql;
WARNING: variable "f1" shadows a previously defined variable
LINE 3: f1 int;
      ^
CREATE FUNCTION

```

The below example shows the effects of setting `plpgsql.extra_warnings` to `strict_multi_assignment`:

```

SET plpgsql.extra_warnings TO 'strict_multi_assignment';

CREATE OR REPLACE FUNCTION public.foo()
  RETURNS void
  LANGUAGE plpgsql
AS $$
DECLARE
  x int;
  y int;
BEGIN
  SELECT 1 INTO x, y;
  SELECT 1, 2 INTO x, y;
  SELECT 1, 2, 3 INTO x, y;
END;
$$;

SELECT foo();
WARNING: number of source and target fields in assignment does not
match
DETAIL: strict_multi_assignment check of extra_warnings is active.
HINT: Make sure the query returns the exact list of columns.
WARNING: number of source and target fields in assignment does not
match
DETAIL: strict_multi_assignment check of extra_warnings is active.
HINT: Make sure the query returns the exact list of columns.

foo
----

(1 row)

```

42.13. Porting from Oracle PL/SQL

This section explains differences between PostgreSQL's PL/pgSQL language and Oracle's PL/SQL language, to help developers who port applications from Oracle® to PostgreSQL.

PL/pgSQL is similar to PL/SQL in many aspects. It is a block-structured, imperative language, and all variables have to be declared. Assignments, loops, and conditionals are similar. The main differences you should keep in mind when porting from PL/SQL to PL/pgSQL are:

- If a name used in a SQL command could be either a column name of a table or a reference to a variable of the function, PL/SQL treats it as a column name. This corresponds to PL/pgSQL's `plpgsql.variable_conflict = use_column` behavior, which is not the default, as ex-

plained in Section 42.11.1. It's often best to avoid such ambiguities in the first place, but if you have to port a large amount of code that depends on this behavior, setting `variable_conflict` may be the best solution.

- In PostgreSQL the function body must be written as a string literal. Therefore you need to use dollar quoting or escape single quotes in the function body. (See Section 42.12.1.)
- Data type names often need translation. For example, in Oracle string values are commonly declared as being of type `varchar2`, which is a non-SQL-standard type. In PostgreSQL, use type `varchar` or `text` instead. Similarly, replace type `number` with `numeric`, or use some other numeric data type if there's a more appropriate one.
- Instead of packages, use schemas to organize your functions into groups.
- Since there are no packages, there are no package-level variables either. This is somewhat annoying. You can keep per-session state in temporary tables instead.
- Integer FOR loops with REVERSE work differently: PL/SQL counts down from the second number to the first, while PL/pgSQL counts down from the first number to the second, requiring the loop bounds to be swapped when porting. This incompatibility is unfortunate but is unlikely to be changed. (See Section 42.6.5.5.)
- FOR loops over queries (other than cursors) also work differently: the target variable(s) must have been declared, whereas PL/SQL always declares them implicitly. An advantage of this is that the variable values are still accessible after the loop exits.
- There are various notational differences for the use of cursor variables.

42.13.1. Porting Examples

Example 42.9 shows how to port a simple function from PL/SQL to PL/pgSQL.

Example 42.9. Porting a Simple Function from PL/SQL to PL/pgSQL

Here is an Oracle PL/SQL function:

```
CREATE OR REPLACE FUNCTION cs_fmt_browser_version(v_name varchar2,
                                                v_version
                                                varchar2)
RETURN varchar2 IS
BEGIN
    IF v_version IS NULL THEN
        RETURN v_name;
    END IF;
    RETURN v_name || '/' || v_version;
END;
/
show errors;
```

Let's go through this function and see the differences compared to PL/pgSQL:

- The type name `varchar2` has to be changed to `varchar` or `text`. In the examples in this section, we'll use `varchar`, but `text` is often a better choice if you do not need specific string length limits.
- The RETURN key word in the function prototype (not the function body) becomes RETURNS in PostgreSQL. Also, IS becomes AS, and you need to add a LANGUAGE clause because PL/pgSQL is not the only possible function language.

- In PostgreSQL, the function body is considered to be a string literal, so you need to use quote marks or dollar quotes around it. This substitutes for the terminating / in the Oracle approach.
- The show errors command does not exist in PostgreSQL, and is not needed since errors are reported automatically.

This is how this function would look when ported to PostgreSQL:

```
CREATE OR REPLACE FUNCTION cs_fmt_browser_version(v_name varchar,
                                                v_version
                                                varchar)
RETURNS varchar AS $$
BEGIN
    IF v_version IS NULL THEN
        RETURN v_name;
    END IF;
    RETURN v_name || '/' || v_version;
END;
$$ LANGUAGE plpgsql;
```

Example 42.10 shows how to port a function that creates another function and how to handle the ensuing quoting problems.

Example 42.10. Porting a Function that Creates Another Function from PL/SQL to PL/pgSQL

The following procedure grabs rows from a SELECT statement and builds a large function with the results in IF statements, for the sake of efficiency.

This is the Oracle version:

```
CREATE OR REPLACE PROCEDURE cs_update_referrer_type_proc IS
    CURSOR referrer_keys IS
        SELECT * FROM cs_referrer_keys
        ORDER BY try_order;
    func_cmd VARCHAR(4000);
BEGIN
    func_cmd := 'CREATE OR REPLACE FUNCTION
cs_find_referrer_type(v_host IN VARCHAR2,
                    v_domain IN VARCHAR2, v_url IN VARCHAR2) RETURN
VARCHAR2 IS BEGIN';

    FOR referrer_key IN referrer_keys LOOP
        func_cmd := func_cmd ||
            ' IF v_' || referrer_key.kind
            || ' LIKE ''' || referrer_key.key_string
            || ''' THEN RETURN ''' || referrer_key.referrer_type
            || '''; END IF;';
    END LOOP;

    func_cmd := func_cmd || ' RETURN NULL; END;';

    EXECUTE IMMEDIATE func_cmd;
END;
/
show errors;
```

Here is how this function would end up in PostgreSQL:

```
CREATE OR REPLACE PROCEDURE cs_update_referrer_type_proc() AS $func
$
DECLARE
    referrer_keys CURSOR IS
        SELECT * FROM cs_referrer_keys
        ORDER BY try_order;
    func_body text;
    func_cmd text;
BEGIN
    func_body := 'BEGIN';

    FOR referrer_key IN referrer_keys LOOP
        func_body := func_body ||
            ' IF v_' || referrer_key.kind
            || ' LIKE ' || quote_literal(referrer_key.key_string)
            || ' THEN RETURN ' ||
quote_literal(referrer_key.referrer_type)
            || '; END IF;' ;
    END LOOP;

    func_body := func_body || ' RETURN NULL; END;';

    func_cmd :=
        'CREATE OR REPLACE FUNCTION cs_find_referrer_type(v_host
varchar,
                                                    v_domain
varchar,
                                                    v_url
varchar)
        RETURNS varchar AS '
        || quote_literal(func_body)
        || ' LANGUAGE plpgsql;' ;

    EXECUTE func_cmd;
END;
$func$ LANGUAGE plpgsql;
```

Notice how the body of the function is built separately and passed through `quote_literal` to double any quote marks in it. This technique is needed because we cannot safely use dollar quoting for defining the new function: we do not know for sure what strings will be interpolated from the `referrer_key.key_string` field. (We are assuming here that `referrer_key.kind` can be trusted to always be `host`, `domain`, or `url`, but `referrer_key.key_string` might be anything, in particular it might contain dollar signs.) This function is actually an improvement on the Oracle original, because it will not generate broken code when `referrer_key.key_string` or `referrer_key.referrer_type` contain quote marks.

Example 42.11 shows how to port a function with `OUT` parameters and string manipulation. PostgreSQL does not have a built-in `instr` function, but you can create one using a combination of other functions. In Section 42.13.3 there is a PL/pgSQL implementation of `instr` that you can use to make your porting easier.

Example 42.11. Porting a Procedure With String Manipulation and `OUT` Parameters from PL/SQL to PL/pgSQL

The following Oracle PL/SQL procedure is used to parse a URL and return several elements (`host`, `path`, and `query`).

This is the Oracle version:

```
CREATE OR REPLACE PROCEDURE cs_parse_url(  
    v_url IN VARCHAR2,  
    v_host OUT VARCHAR2, -- This will be passed back  
    v_path OUT VARCHAR2, -- This one too  
    v_query OUT VARCHAR2) -- And this one  
IS  
    a_pos1 INTEGER;  
    a_pos2 INTEGER;  
BEGIN  
    v_host := NULL;  
    v_path := NULL;  
    v_query := NULL;  
    a_pos1 := instr(v_url, '//');  
  
    IF a_pos1 = 0 THEN  
        RETURN;  
    END IF;  
    a_pos2 := instr(v_url, '/', a_pos1 + 2);  
    IF a_pos2 = 0 THEN  
        v_host := substr(v_url, a_pos1 + 2);  
        v_path := '/';  
        RETURN;  
    END IF;  
  
    v_host := substr(v_url, a_pos1 + 2, a_pos2 - a_pos1 - 2);  
    a_pos1 := instr(v_url, '?', a_pos2 + 1);  
  
    IF a_pos1 = 0 THEN  
        v_path := substr(v_url, a_pos2);  
        RETURN;  
    END IF;  
  
    v_path := substr(v_url, a_pos2, a_pos1 - a_pos2);  
    v_query := substr(v_url, a_pos1 + 1);  
END;  
/  
show errors;
```

Here is a possible translation into PL/pgSQL:

```
CREATE OR REPLACE FUNCTION cs_parse_url(  
    v_url IN VARCHAR,  
    v_host OUT VARCHAR, -- This will be passed back  
    v_path OUT VARCHAR, -- This one too  
    v_query OUT VARCHAR) -- And this one  
AS $$  
DECLARE  
    a_pos1 INTEGER;  
    a_pos2 INTEGER;  
BEGIN  
    v_host := NULL;  
    v_path := NULL;  
    v_query := NULL;  
    a_pos1 := instr(v_url, '//');
```

```

IF a_pos1 = 0 THEN
    RETURN;
END IF;
a_pos2 := instr(v_url, '/', a_pos1 + 2);
IF a_pos2 = 0 THEN
    v_host := substr(v_url, a_pos1 + 2);
    v_path := '/';
    RETURN;
END IF;

v_host := substr(v_url, a_pos1 + 2, a_pos2 - a_pos1 - 2);
a_pos1 := instr(v_url, '?', a_pos2 + 1);

IF a_pos1 = 0 THEN
    v_path := substr(v_url, a_pos2);
    RETURN;
END IF;

v_path := substr(v_url, a_pos2, a_pos1 - a_pos2);
v_query := substr(v_url, a_pos1 + 1);
END;
$$ LANGUAGE plpgsql;

```

This function could be used like this:

```
SELECT * FROM cs_parse_url('http://foobar.com/query.cgi?baz');
```

Example 42.12 shows how to port a procedure that uses numerous features that are specific to Oracle.

Example 42.12. Porting a Procedure from PL/SQL to PL/pgSQL

The Oracle version:

```

CREATE OR REPLACE PROCEDURE cs_create_job(v_job_id IN INTEGER) IS
    a_running_job_count INTEGER;
BEGIN
    LOCK TABLE cs_jobs IN EXCLUSIVE MODE;

    SELECT count(*) INTO a_running_job_count FROM cs_jobs WHERE
end_stamp IS NULL;

    IF a_running_job_count > 0 THEN
        COMMIT; -- free lock
        raise_application_error(-20000,
            'Unable to create a new job: a job is currently
running.');
```

```

    END IF;

    DELETE FROM cs_active_job;
    INSERT INTO cs_active_job(job_id) VALUES (v_job_id);

    BEGIN
        INSERT INTO cs_jobs (job_id, start_stamp) VALUES (v_job_id,
now());
    EXCEPTION
        WHEN dup_val_on_index THEN NULL; -- don't worry if it
already exists

```

```

        END;
    COMMIT;
END;
/
show errors

```

This is how we could port this procedure to PL/pgSQL:

```

CREATE OR REPLACE PROCEDURE cs_create_job(v_job_id integer) AS $$
DECLARE
    a_running_job_count integer;
BEGIN
    LOCK TABLE cs_jobs IN EXCLUSIVE MODE;

    SELECT count(*) INTO a_running_job_count FROM cs_jobs WHERE
end_stamp IS NULL;

    IF a_running_job_count > 0 THEN
        COMMIT; -- free lock
        RAISE EXCEPTION 'Unable to create a new job: a job is
currently running'; -- ❶
    END IF;

    DELETE FROM cs_active_job;
    INSERT INTO cs_active_job(job_id) VALUES (v_job_id);

    BEGIN
        INSERT INTO cs_jobs (job_id, start_stamp) VALUES (v_job_id,
now());
    EXCEPTION
        WHEN unique_violation THEN -- ❷
            -- don't worry if it already exists
    END;
    COMMIT;
END;
$$ LANGUAGE plpgsql;

```

- ❶ The syntax of RAISE is considerably different from Oracle's statement, although the basic case RAISE *exception_name* works similarly.
- ❷ The exception names supported by PL/pgSQL are different from Oracle's. The set of built-in exception names is much larger (see Appendix A). There is not currently a way to declare user-defined exception names, although you can throw user-chosen SQLSTATE values instead.

42.13.2. Other Things to Watch For

This section explains a few other things to watch for when porting Oracle PL/SQL functions to PostgreSQL.

42.13.2.1. Implicit Rollback after Exceptions

In PL/pgSQL, when an exception is caught by an EXCEPTION clause, all database changes since the block's BEGIN are automatically rolled back. That is, the behavior is equivalent to what you'd get in Oracle with:

```

BEGIN
    SAVEPOINT s1;
    ... code here ...

```

```
EXCEPTION
    WHEN ... THEN
        ROLLBACK TO s1;
        ... code here ...
    WHEN ... THEN
        ROLLBACK TO s1;
        ... code here ...
END;
```

If you are translating an Oracle procedure that uses `SAVEPOINT` and `ROLLBACK TO` in this style, your task is easy: just omit the `SAVEPOINT` and `ROLLBACK TO`. If you have a procedure that uses `SAVEPOINT` and `ROLLBACK TO` in a different way then some actual thought will be required.

42.13.2.2. EXECUTE

The PL/pgSQL version of `EXECUTE` works similarly to the PL/SQL version, but you have to remember to use `quote_literal` and `quote_ident` as described in Section 42.5.4. Constructs of the type `EXECUTE 'SELECT * FROM $1';` will not work reliably unless you use these functions.

42.13.2.3. Optimizing PL/pgSQL Functions

PostgreSQL gives you two function creation modifiers to optimize execution: “volatility” (whether the function always returns the same result when given the same arguments) and “strictness” (whether the function returns null if any argument is null). Consult the `CREATE FUNCTION` reference page for details.

When making use of these optimization attributes, your `CREATE FUNCTION` statement might look something like this:

```
CREATE FUNCTION foo(...) RETURNS integer AS $$
...
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

42.13.3. Appendix

This section contains the code for a set of Oracle-compatible `instr` functions that you can use to simplify your porting efforts.

```
--
-- instr functions that mimic Oracle's counterpart
-- Syntax: instr(string1, string2 [, n [, m]])
-- where [] denotes optional parameters.
--
-- Search string1, beginning at the nth character, for the mth
-- occurrence
-- of string2. If n is negative, search backwards, starting at the
-- abs(n)'th
-- character from the end of string1.
-- If n is not passed, assume 1 (search starts at first character).
-- If m is not passed, assume 1 (find first occurrence).
-- Returns starting index of string2 in string1, or 0 if string2 is
-- not found.
--
CREATE FUNCTION instr(varchar, varchar) RETURNS integer AS $$
BEGIN
    RETURN instr($1, $2, 1);
```

```
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE FUNCTION instr(string varchar, string_to_search_for varchar,
                     beg_index integer)
RETURNS integer AS $$
DECLARE
    pos integer NOT NULL DEFAULT 0;
    temp_str varchar;
    beg integer;
    length integer;
    ss_length integer;
BEGIN
    IF beg_index > 0 THEN
        temp_str := substring(string FROM beg_index);
        pos := position(string_to_search_for IN temp_str);

        IF pos = 0 THEN
            RETURN 0;
        ELSE
            RETURN pos + beg_index - 1;
        END IF;
    ELSIF beg_index < 0 THEN
        ss_length := char_length(string_to_search_for);
        length := char_length(string);
        beg := length + 1 + beg_index;

        WHILE beg > 0 LOOP
            temp_str := substring(string FROM beg FOR ss_length);
            IF string_to_search_for = temp_str THEN
                RETURN beg;
            END IF;

            beg := beg - 1;
        END LOOP;

        RETURN 0;
    ELSE
        RETURN 0;
    END IF;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

```
CREATE FUNCTION instr(string varchar, string_to_search_for varchar,
                     beg_index integer, occur_index integer)
RETURNS integer AS $$
DECLARE
    pos integer NOT NULL DEFAULT 0;
    occur_number integer NOT NULL DEFAULT 0;
    temp_str varchar;
    beg integer;
    i integer;
    length integer;
    ss_length integer;
BEGIN
    IF occur_index <= 0 THEN
```

```
        RAISE 'argument '%' is out of range', occur_index
        USING ERRCODE = '22003';
    END IF;

    IF beg_index > 0 THEN
        beg := beg_index - 1;
        FOR i IN 1..occur_index LOOP
            temp_str := substring(string FROM beg + 1);
            pos := position(string_to_search_for IN temp_str);
            IF pos = 0 THEN
                RETURN 0;
            END IF;
            beg := beg + pos;
        END LOOP;

        RETURN beg;
    ELSIF beg_index < 0 THEN
        ss_length := char_length(string_to_search_for);
        length := char_length(string);
        beg := length + 1 + beg_index;

        WHILE beg > 0 LOOP
            temp_str := substring(string FROM beg FOR ss_length);
            IF string_to_search_for = temp_str THEN
                occur_number := occur_number + 1;
                IF occur_number = occur_index THEN
                    RETURN beg;
                END IF;
            END IF;

            beg := beg - 1;
        END LOOP;

        RETURN 0;
    ELSE
        RETURN 0;
    END IF;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

Chapter 43. PL/Tcl - Tcl Procedural Language

PL/Tcl is a loadable procedural language for the PostgreSQL database system that enables the Tcl language¹ to be used to write PostgreSQL functions.

43.1. Overview

PL/Tcl offers most of the capabilities a function writer has in the C language, with a few restrictions, and with the addition of the powerful string processing libraries that are available for Tcl.

One compelling *good* restriction is that everything is executed from within the safety of the context of a Tcl interpreter. In addition to the limited command set of safe Tcl, only a few commands are available to access the database via SPI and to raise messages via `elog()`. PL/Tcl provides no way to access internals of the database server or to gain OS-level access under the permissions of the PostgreSQL server process, as a C function can do. Thus, unprivileged database users can be trusted to use this language; it does not give them unlimited authority.

The other notable implementation restriction is that Tcl functions cannot be used to create input/output functions for new data types.

Sometimes it is desirable to write Tcl functions that are not restricted to safe Tcl. For example, one might want a Tcl function that sends email. To handle these cases, there is a variant of PL/Tcl called `PL/TclU` (for untrusted Tcl). This is exactly the same language except that a full Tcl interpreter is used. *If PL/TclU is used, it must be installed as an untrusted procedural language* so that only database superusers can create functions in it. The writer of a PL/TclU function must take care that the function cannot be used to do anything unwanted, since it will be able to do anything that could be done by a user logged in as the database administrator.

The shared object code for the PL/Tcl and PL/TclU call handlers is automatically built and installed in the PostgreSQL library directory if Tcl support is specified in the configuration step of the installation procedure. To install PL/Tcl and/or PL/TclU in a particular database, use the `CREATE EXTENSION` command, for example `CREATE EXTENSION pltcl` or `CREATE EXTENSION pltclu`.

43.2. PL/Tcl Functions and Arguments

To create a function in the PL/Tcl language, use the standard `CREATE FUNCTION` syntax:

```
CREATE FUNCTION funcname (argument-types) RETURNS return-type AS $$
    # PL/Tcl function body
$$ LANGUAGE pltcl;
```

PL/TclU is the same, except that the language has to be specified as `pltclu`.

The body of the function is simply a piece of Tcl script. When the function is called, the argument values are passed to the Tcl script as variables named `1 ... n`. The result is returned from the Tcl code in the usual way, with a `return` statement. In a procedure, the return value from the Tcl code is ignored.

For example, a function returning the greater of two integer values could be defined as:

```
CREATE FUNCTION tcl_max(integer, integer) RETURNS integer AS $$
    if {$1 > $2} {return $1}
```

¹ <http://www.tcl.tk/>

```
    return $2
$$ LANGUAGE pltcl STRICT;
```

Note the clause `STRICT`, which saves us from having to think about null input values: if a null value is passed, the function will not be called at all, but will just return a null result automatically.

In a nonstrict function, if the actual value of an argument is null, the corresponding `$n` variable will be set to an empty string. To detect whether a particular argument is null, use the function `argisnull`. For example, suppose that we wanted `tcl_max` with one null and one nonnull argument to return the nonnull argument, rather than null:

```
CREATE FUNCTION tcl_max(integer, integer) RETURNS integer AS $$
    if {[argisnull 1]} {
        if {[argisnull 2]} { return_null }
        return $2
    }
    if {[argisnull 2]} { return $1 }
    if {$1 > $2} {return $1}
    return $2
$$ LANGUAGE pltcl;
```

As shown above, to return a null value from a PL/Tcl function, execute `return_null`. This can be done whether the function is strict or not.

Composite-type arguments are passed to the function as Tcl arrays. The element names of the array are the attribute names of the composite type. If an attribute in the passed row has the null value, it will not appear in the array. Here is an example:

```
CREATE TABLE employee (
    name text,
    salary integer,
    age integer
);

CREATE FUNCTION overpaid(employee) RETURNS boolean AS $$
    if {200000.0 < $1(salary)} {
        return "t"
    }
    if {$1(age) < 30 && 100000.0 < $1(salary)} {
        return "t"
    }
    return "f"
$$ LANGUAGE pltcl;
```

PL/Tcl functions can return composite-type results, too. To do this, the Tcl code must return a list of column name/value pairs matching the expected result type. Any column names omitted from the list are returned as nulls, and an error is raised if there are unexpected column names. Here is an example:

```
CREATE FUNCTION square_cube(in int, out squared int, out cubed int)
AS $$
    return [list squared [expr {$1 * $1}] cubed [expr {$1 * $1 *
$1}]]
$$ LANGUAGE pltcl;
```

Output arguments of procedures are returned in the same way, for example:

```
CREATE PROCEDURE tcl_triple(INOUT a integer, INOUT b integer) AS $$
    return [list a [expr {$1 * 3}] b [expr {$2 * 3}]]
$$ LANGUAGE pltcl;

CALL tcl_triple(5, 10);
```

Tip

The result list can be made from an array representation of the desired tuple with the `array get` Tcl command. For example:

```
CREATE FUNCTION raise_pay(employee, delta int) RETURNS
    employee AS $$
    set l(salary) [expr {$1(salary) + $2}]
    return [array get l]
$$ LANGUAGE pltcl;
```

PL/Tcl functions can return sets. To do this, the Tcl code should call `return_next` once per row to be returned, passing either the appropriate value when returning a scalar type, or a list of column name/value pairs when returning a composite type. Here is an example returning a scalar type:

```
CREATE FUNCTION sequence(int, int) RETURNS SETOF int AS $$
    for {set i $1} {$i < $2} {incr i} {
        return_next $i
    }
$$ LANGUAGE pltcl;
```

and here is one returning a composite type:

```
CREATE FUNCTION table_of_squares(int, int) RETURNS TABLE (x int, x2
    int) AS $$
    for {set i $1} {$i < $2} {incr i} {
        return_next [list x $i x2 [expr {$i * $i}]]
    }
$$ LANGUAGE pltcl;
```

43.3. Data Values in PL/Tcl

The argument values supplied to a PL/Tcl function's code are simply the input arguments converted to text form (just as if they had been displayed by a `SELECT` statement). Conversely, the `return` and `return_next` commands will accept any string that is acceptable input format for the function's declared result type, or for the specified column of a composite result type.

43.4. Global Data in PL/Tcl

Sometimes it is useful to have some global data that is held between two calls to a function or is shared between different functions. This is easily done in PL/Tcl, but there are some restrictions that must be understood.

For security reasons, PL/Tcl executes functions called by any one SQL role in a separate Tcl interpreter for that role. This prevents accidental or malicious interference by one user with the behavior of another user's PL/Tcl functions. Each such interpreter will have its own values for any "global" Tcl variables. Thus, two PL/Tcl functions will share the same global variables if and only if they are executed by the

same SQL role. In an application wherein a single session executes code under multiple SQL roles (via `SECURITY DEFINER` functions, use of `SET ROLE`, etc) you may need to take explicit steps to ensure that PL/Tcl functions can share data. To do that, make sure that functions that should communicate are owned by the same user, and mark them `SECURITY DEFINER`. You must of course take care that such functions can't be used to do anything unintended.

All PL/TclU functions used in a session execute in the same Tcl interpreter, which of course is distinct from the interpreter(s) used for PL/Tcl functions. So global data is automatically shared between PL/TclU functions. This is not considered a security risk because all PL/TclU functions execute at the same trust level, namely that of a database superuser.

To help protect PL/Tcl functions from unintentionally interfering with each other, a global array is made available to each function via the `upvar` command. The global name of this variable is the function's internal name, and the local name is `GD`. It is recommended that `GD` be used for persistent private data of a function. Use regular Tcl global variables only for values that you specifically intend to be shared among multiple functions. (Note that the `GD` arrays are only global within a particular interpreter, so they do not bypass the security restrictions mentioned above.)

An example of using `GD` appears in the `spi_execp` example below.

43.5. Database Access from PL/Tcl

The following commands are available to access the database from the body of a PL/Tcl function:

```
spi_exec ?-count n? ?-array name? command ?loop-body?
```

Executes an SQL command given as a string. An error in the command causes an error to be raised. Otherwise, the return value of `spi_exec` is the number of rows processed (selected, inserted, updated, or deleted) by the command, or zero if the command is a utility statement. In addition, if the command is a `SELECT` statement, the values of the selected columns are placed in Tcl variables as described below.

The optional `-count` value tells `spi_exec` the maximum number of rows to process in the command. The effect of this is comparable to setting up a query as a cursor and then saying `FETCH n`.

If the command is a `SELECT` statement, the values of the result columns are placed into Tcl variables named after the columns. If the `-array` option is given, the column values are instead stored into elements of the named associative array, with the column names used as array indexes. In addition, the current row number within the result (counting from zero) is stored into the array element named `". tupno"`, unless that name is in use as a column name in the result.

If the command is a `SELECT` statement and no `loop-body` script is given, then only the first row of results are stored into Tcl variables or array elements; remaining rows, if any, are ignored. No storing occurs if the query returns no rows. (This case can be detected by checking the result of `spi_exec`.) For example:

```
spi_exec "SELECT count(*) AS cnt FROM pg_proc"
```

will set the Tcl variable `$cnt` to the number of rows in the `pg_proc` system catalog.

If the optional `loop-body` argument is given, it is a piece of Tcl script that is executed once for each row in the query result. (`loop-body` is ignored if the given command is not a `SELECT`.) The values of the current row's columns are stored into Tcl variables or array elements before each iteration. For example:

```
spi_exec -array C "SELECT * FROM pg_class" {
```

```

        elog DEBUG "have table $C(relname)"
    }

```

will print a log message for every row of `pg_class`. This feature works similarly to other Tcl looping constructs; in particular `continue` and `break` work in the usual way inside the loop body.

If a column of a query result is null, the target variable for it is “unset” rather than being set.

spi_prepare query typelist

Prepares and saves a query plan for later execution. The saved plan will be retained for the life of the current session.

The query can use parameters, that is, placeholders for values to be supplied whenever the plan is actually executed. In the query string, refer to parameters by the symbols `$1 ... $n`. If the query uses parameters, the names of the parameter types must be given as a Tcl list. (Write an empty list for *typelist* if no parameters are used.)

The return value from `spi_prepare` is a query ID to be used in subsequent calls to `spi_execp`. See `spi_execp` for an example.

spi_execp ?-count n? ?-array name? ?-nulls string? queryid ?value-list? ?loop-body?

Executes a query previously prepared with `spi_prepare`. *queryid* is the ID returned by `spi_prepare`. If the query references parameters, a *value-list* must be supplied. This is a Tcl list of actual values for the parameters. The list must be the same length as the parameter type list previously given to `spi_prepare`. Omit *value-list* if the query has no parameters.

The optional value for `-nulls` is a string of spaces and 'n' characters telling `spi_execp` which of the parameters are null values. If given, it must have exactly the same length as the *value-list*. If it is not given, all the parameter values are nonnull.

Except for the way in which the query and its parameters are specified, `spi_execp` works just like `spi_exec`. The `-count`, `-array`, and `loop-body` options are the same, and so is the result value.

Here's an example of a PL/Tcl function using a prepared plan:

```

CREATE FUNCTION t1_count(integer, integer) RETURNS integer AS $$
    if {[ info exists GD(plan) ]} {
        # prepare the saved plan on the first call
        set GD(plan) [ spi_prepare \
            "SELECT count(*) AS cnt FROM t1 WHERE num >= \$1
            AND num <= \$2" \
                [ list int4 int4 ] ]
    }
    spi_execp -count 1 $GD(plan) [ list $1 $2 ]
    return $cnt
$$ LANGUAGE pltcl;

```

We need backslashes inside the query string given to `spi_prepare` to ensure that the `$n` markers will be passed through to `spi_prepare` as-is, and not replaced by Tcl variable substitution.

subtransaction command

The Tcl script contained in *command* is executed within a SQL subtransaction. If the script returns an error, that entire subtransaction is rolled back before returning the error out to the surrounding Tcl code. See Section 43.9 for more details and an example.

`quote string`

Doubles all occurrences of single quote and backslash characters in the given string. This can be used to safely quote strings that are to be inserted into SQL commands given to `spi_exec` or `spi_prepare`. For example, think about an SQL command string like:

```
"SELECT '$val' AS ret"
```

where the Tcl variable `val` actually contains `doesn't`. This would result in the final command string:

```
SELECT 'doesn't' AS ret
```

which would cause a parse error during `spi_exec` or `spi_prepare`. To work properly, the submitted command should contain:

```
SELECT 'doesn''t' AS ret
```

which can be formed in PL/Tcl using:

```
"SELECT '[ quote $val ]' AS ret"
```

One advantage of `spi_execp` is that you don't have to quote parameter values like this, since the parameters are never parsed as part of an SQL command string.

`elog level msg`

Emits a log or error message. Possible levels are `DEBUG`, `LOG`, `INFO`, `NOTICE`, `WARNING`, `ERROR`, and `FATAL`. `ERROR` raises an error condition; if this is not trapped by the surrounding Tcl code, the error propagates out to the calling query, causing the current transaction or subtransaction to be aborted. This is effectively the same as the Tcl `error` command. `FATAL` aborts the transaction and causes the current session to shut down. (There is probably no good reason to use this error level in PL/Tcl functions, but it's provided for completeness.) The other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the `log_min_messages` and `client_min_messages` configuration variables. See Chapter 19 and Section 43.8 for more information.

43.6. Trigger Functions in PL/Tcl

Trigger functions can be written in PL/Tcl. PostgreSQL requires that a function that is to be called as a trigger must be declared as a function with no arguments and a return type of `trigger`.

The information from the trigger manager is passed to the function body in the following variables:

`$TG_name`

The name of the trigger from the `CREATE TRIGGER` statement.

`$TG_relid`

The object ID of the table that caused the trigger function to be invoked.

`$TG_table_name`

The name of the table that caused the trigger function to be invoked.

`$TG_table_schema`

The schema of the table that caused the trigger function to be invoked.

`$TG_relatts`

A Tcl list of the table column names, prefixed with an empty list element. So looking up a column name in the list with Tcl's `lsearch` command returns the element's number starting with 1 for the first column, the same way the columns are customarily numbered in PostgreSQL. (Empty list elements also appear in the positions of columns that have been dropped, so that the attribute numbering is correct for columns to their right.)

`$TG_when`

The string `BEFORE`, `AFTER`, or `INSTEAD OF`, depending on the type of trigger event.

`$TG_level`

The string `ROW` or `STATEMENT` depending on the type of trigger event.

`$TG_op`

The string `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` depending on the type of trigger event.

`$NEW`

An associative array containing the values of the new table row for `INSERT` or `UPDATE` actions, or empty for `DELETE`. The array is indexed by column name. Columns that are null will not appear in the array. This is not set for statement-level triggers.

`$OLD`

An associative array containing the values of the old table row for `UPDATE` or `DELETE` actions, or empty for `INSERT`. The array is indexed by column name. Columns that are null will not appear in the array. This is not set for statement-level triggers.

`$args`

A Tcl list of the arguments to the function as given in the `CREATE TRIGGER` statement. These arguments are also accessible as `$1 ... $n` in the function body.

The return value from a trigger function can be one of the strings `OK` or `SKIP`, or a list of column name/value pairs. If the return value is `OK`, the operation (`INSERT/UPDATE/DELETE`) that fired the trigger will proceed normally. `SKIP` tells the trigger manager to silently suppress the operation for this row. If a list is returned, it tells PL/Tcl to return a modified row to the trigger manager; the contents of the modified row are specified by the column names and values in the list. Any columns not mentioned in the list are set to null. Returning a modified row is only meaningful for row-level `BEFORE INSERT` or `UPDATE` triggers, for which the modified row will be inserted instead of the one given in `$NEW`; or for row-level `INSTEAD OF INSERT` or `UPDATE` triggers where the returned row is used as the source data for `INSERT RETURNING` or `UPDATE RETURNING` clauses. In row-level `BEFORE DELETE` or `INSTEAD OF DELETE` triggers, returning a modified row has the same effect as returning `OK`, that is the operation proceeds. The trigger return value is ignored for all other types of triggers.

Tip

The result list can be made from an array representation of the modified tuple with the `array get` Tcl command.

Here's a little example trigger function that forces an integer value in a table to keep track of the number of updates that are performed on the row. For new rows inserted, the value is initialized to 0 and then incremented on every update operation.

```
CREATE FUNCTION trigfunc_modcount() RETURNS trigger AS $$
    switch $TG_op {
        INSERT {
            set NEW($1) 0
        }
        UPDATE {
            set NEW($1) $OLD($1)
            incr NEW($1)
        }
        default {
            return OK
        }
    }
    return [array get NEW]
$$ LANGUAGE pltcl;

CREATE TABLE mytab (num integer, description text, modcnt integer);

CREATE TRIGGER trig_mytab_modcount BEFORE INSERT OR UPDATE ON mytab
    FOR EACH ROW EXECUTE FUNCTION trigfunc_modcount('modcnt');
```

Notice that the trigger function itself does not know the column name; that's supplied from the trigger arguments. This lets the trigger function be reused with different tables.

43.7. Event Trigger Functions in PL/Tcl

Event trigger functions can be written in PL/Tcl. PostgreSQL requires that a function that is to be called as an event trigger must be declared as a function with no arguments and a return type of `event_trigger`.

The information from the trigger manager is passed to the function body in the following variables:

`$TG_event`

The name of the event the trigger is fired for.

`$TG_tag`

The command tag for which the trigger is fired.

The return value of the trigger function is ignored.

Here's a little example event trigger function that simply raises a `NOTICE` message each time a supported command is executed:

```
CREATE OR REPLACE FUNCTION tclsnitch() RETURNS event_trigger AS $$
    elog NOTICE "tclsnitch: $TG_event $TG_tag"
$$ LANGUAGE pltcl;

CREATE EVENT TRIGGER tcl_a_snitch ON ddl_command_start EXECUTE
    FUNCTION tclsnitch();
```

43.8. Error Handling in PL/Tcl

Tcl code within or called from a PL/Tcl function can raise an error, either by executing some invalid operation or by generating an error using the Tcl `error` command or PL/Tcl's `elog` command. Such errors can be caught within Tcl using the Tcl `catch` command. If an error is not caught but is allowed to propagate out to the top level of execution of the PL/Tcl function, it is reported as a SQL error in the function's calling query.

Conversely, SQL errors that occur within PL/Tcl's `spi_exec`, `spi_prepare`, and `spi_execp` commands are reported as Tcl errors, so they are catchable by Tcl's `catch` command. (Each of these PL/Tcl commands runs its SQL operation in a subtransaction, which is rolled back on error, so that any partially-completed operation is automatically cleaned up.) Again, if an error propagates out to the top level without being caught, it turns back into a SQL error.

Tcl provides an `errorCode` variable that can represent additional information about an error in a form that is easy for Tcl programs to interpret. The contents are in Tcl list format, and the first word identifies the subsystem or library reporting the error; beyond that the contents are left to the individual subsystem or library. For database errors reported by PL/Tcl commands, the first word is `POSTGRES`, the second word is the PostgreSQL version number, and additional words are field name/value pairs providing detailed information about the error. Fields `SQLSTATE`, `condition`, and `message` are always supplied (the first two represent the error code and condition name as shown in Appendix A). Fields that may be present include `detail`, `hint`, `context`, `schema`, `table`, `column`, `datatype`, `constraint`, `statement`, `cursor_position`, `filename`, `lineno`, and `funcname`.

A convenient way to work with PL/Tcl's `errorCode` information is to load it into an array, so that the field names become array subscripts. Code for doing that might look like

```
if {[catch { spi_exec $sql_command }]} {
    if {[lindex $::errorCode 0] == "POSTGRES"} {
        array set errorArray $::errorCode
        if {$errorArray(condition) == "undefined_table"} {
            # deal with missing table
        } else {
            # deal with some other type of SQL error
        }
    }
}
```

(The double colons explicitly specify that `errorCode` is a global variable.)

43.9. Explicit Subtransactions in PL/Tcl

Recovering from errors caused by database access as described in Section 43.8 can lead to an undesirable situation where some operations succeed before one of them fails, and after recovering from that error the data is left in an inconsistent state. PL/Tcl offers a solution to this problem in the form of explicit subtransactions.

Consider a function that implements a transfer between two accounts:

```
CREATE FUNCTION transfer_funds() RETURNS void AS $$
    if [catch {
        spi_exec "UPDATE accounts SET balance = balance - 100 WHERE
account_name = 'joe'"
        spi_exec "UPDATE accounts SET balance = balance + 100 WHERE
account_name = 'mary'"
    } errmsg] {
        set result [format "error transferring funds: %s"
$errorrmsg]
    }
```

```
    } else {
        set result "funds transferred successfully"
    }
    spi_exec "INSERT INTO operations (result) VALUES ('[quote
$result]')"
$$ LANGUAGE pltcl;
```

If the second UPDATE statement results in an exception being raised, this function will log the failure, but the result of the first UPDATE will nevertheless be committed. In other words, the funds will be withdrawn from Joe's account, but will not be transferred to Mary's account. This happens because each `spi_exec` is a separate subtransaction, and only one of those subtransactions got rolled back.

To handle such cases, you can wrap multiple database operations in an explicit subtransaction, which will succeed or roll back as a whole. PL/Tcl provides a subtransaction command to manage this. We can rewrite our function as:

```
CREATE FUNCTION transfer_funds2() RETURNS void AS $$
    if [catch {
        subtransaction {
            spi_exec "UPDATE accounts SET balance = balance - 100
WHERE account_name = 'joe'"
            spi_exec "UPDATE accounts SET balance = balance + 100
WHERE account_name = 'mary'"
        }
    } errmsg] {
        set result [format "error transferring funds: %s"
$errmsg]
    } else {
        set result "funds transferred successfully"
    }
    spi_exec "INSERT INTO operations (result) VALUES ('[quote
$result]')"
$$ LANGUAGE pltcl;
```

Note that use of `catch` is still required for this purpose. Otherwise the error would propagate to the top level of the function, preventing the desired insertion into the `operations` table. The subtransaction command does not trap errors, it only assures that all database operations executed inside its scope will be rolled back together when an error is reported.

A rollback of an explicit subtransaction occurs on any error reported by the contained Tcl code, not only errors originating from database access. Thus a regular Tcl exception raised inside a subtransaction command will also cause the subtransaction to be rolled back. However, non-error exits out of the contained Tcl code (for instance, due to `return`) do not cause a rollback.

43.10. Transaction Management

In a procedure called from the top level or an anonymous code block (`DO` command) called from the top level it is possible to control transactions. To commit the current transaction, call the `commit` command. To roll back the current transaction, call the `rollback` command. (Note that it is not possible to run the SQL commands `COMMIT` or `ROLLBACK` via `spi_exec` or similar. It has to be done using these functions.) After a transaction is ended, a new transaction is automatically started, so there is no separate command for that.

Here is an example:

```
CREATE PROCEDURE transaction_test1()
LANGUAGE pltcl
```

```
AS $$
for {set i 0} {$i < 10} {incr i} {
    spi_exec "INSERT INTO test1 (a) VALUES ($i)"
    if {$i % 2 == 0} {
        commit
    } else {
        rollback
    }
}
}
$$;

CALL transaction_test1();
```

Transactions cannot be ended when an explicit subtransaction is active.

43.11. PL/Tcl Configuration

This section lists configuration parameters that affect PL/Tcl.

`pltcl.start_proc(string)`

This parameter, if set to a nonempty string, specifies the name (possibly schema-qualified) of a parameterless PL/Tcl function that is to be executed whenever a new Tcl interpreter is created for PL/Tcl. Such a function can perform per-session initialization, such as loading additional Tcl code. A new Tcl interpreter is created when a PL/Tcl function is first executed in a database session, or when an additional interpreter has to be created because a PL/Tcl function is called by a new SQL role.

The referenced function must be written in the `pltcl` language, and must not be marked `SECURITY DEFINER`. (These restrictions ensure that it runs in the interpreter it's supposed to initialize.) The current user must have permission to call it, too.

If the function fails with an error it will abort the function call that caused the new interpreter to be created and propagate out to the calling query, causing the current transaction or subtransaction to be aborted. Any actions already done within Tcl won't be undone; however, that interpreter won't be used again. If the language is used again the initialization will be attempted again within a fresh Tcl interpreter.

Only superusers can change this setting. Although this setting can be changed within a session, such changes will not affect Tcl interpreters that have already been created.

`pltclu.start_proc(string)`

This parameter is exactly like `pltcl.start_proc`, except that it applies to PL/TclU. The referenced function must be written in the `pltclu` language.

43.12. Tcl Procedure Names

In PostgreSQL, the same function name can be used for different function definitions as long as the number of arguments or their types differ. Tcl, however, requires all procedure names to be distinct. PL/Tcl deals with this by making the internal Tcl procedure names contain the object ID of the function from the system table `pg_proc` as part of their name. Thus, PostgreSQL functions with the same name and different argument types will be different Tcl procedures, too. This is not normally a concern for a PL/Tcl programmer, but it might be visible when debugging.

Chapter 44. PL/Perl - Perl Procedural Language

PL/Perl is a loadable procedural language that enables you to write PostgreSQL functions in the Perl programming language¹.

The main advantage to using PL/Perl is that this allows use, within stored functions, of the manyfold “string munging” operators and functions available for Perl. Parsing complex strings might be easier using Perl than it is with the string functions and control structures provided in PL/pgSQL.

To install PL/Perl in a particular database, use `CREATE EXTENSION plperl`.

Tip

If a language is installed into `template1`, all subsequently created databases will have the language installed automatically.

Note

Users of source packages must specially enable the build of PL/Perl during the installation process. (Refer to Chapter 16 for more information.) Users of binary packages might find PL/Perl in a separate subpackage.

44.1. PL/Perl Functions and Arguments

To create a function in the PL/Perl language, use the standard `CREATE FUNCTION` syntax:

```
CREATE FUNCTION funcname (argument-types) RETURNS return-type AS $$  
    # PL/Perl function body  
$$ LANGUAGE plperl;
```

The body of the function is ordinary Perl code. In fact, the PL/Perl glue code wraps it inside a Perl subroutine. A PL/Perl function is called in a scalar context, so it can't return a list. You can return non-scalar values (arrays, records, and sets) by returning a reference, as discussed below.

In a PL/Perl procedure, any return value from the Perl code is ignored.

PL/Perl also supports anonymous code blocks called with the `DO` statement:

```
DO $$  
    # PL/Perl code  
$$ LANGUAGE plperl;
```

An anonymous code block receives no arguments, and whatever value it might return is discarded. Otherwise it behaves just like a function.

Note

The use of named nested subroutines is dangerous in Perl, especially if they refer to lexical variables in the enclosing scope. Because a PL/Perl function is wrapped in a

¹ <http://www.perl.org>

subroutine, any named subroutine you place inside one will be nested. In general, it is far safer to create anonymous subroutines which you call via a coderef. For more information, see the entries for Variable "%s" will not stay shared and Variable "%s" is not available in the perldiag man page, or search the Internet for “perl nested named subroutine”.

The syntax of the `CREATE FUNCTION` command requires the function body to be written as a string constant. It is usually most convenient to use dollar quoting (see Section 4.1.2.4) for the string constant. If you choose to use escape string syntax `E' '`, you must double any single quote marks (`'`) and backslashes (`\`) used in the body of the function (see Section 4.1.2.1).

Arguments and results are handled as in any other Perl subroutine: arguments are passed in `@_`, and a result value is returned with `return` or as the last expression evaluated in the function.

For example, a function returning the greater of two integer values could be defined as:

```
CREATE FUNCTION perl_max (integer, integer) RETURNS integer AS $$
    if ($_[0] > $_[1]) { return $_[0]; }
    return $_[1];
$$ LANGUAGE plperl;
```

Note

Arguments will be converted from the database's encoding to UTF-8 for use inside PL/Perl, and then converted from UTF-8 back to the database encoding upon return.

If an SQL null value is passed to a function, the argument value will appear as “undefined” in Perl. The above function definition will not behave very nicely with null inputs (in fact, it will act as though they are zeroes). We could add `STRICT` to the function definition to make PostgreSQL do something more reasonable: if a null value is passed, the function will not be called at all, but will just return a null result automatically. Alternatively, we could check for undefined inputs in the function body. For example, suppose that we wanted `perl_max` with one null and one nonnull argument to return the nonnull argument, rather than a null value:

```
CREATE FUNCTION perl_max (integer, integer) RETURNS integer AS $$
    my ($x, $y) = @_;
    if (not defined $x) {
        return undef if not defined $y;
        return $y;
    }
    return $x if not defined $y;
    return $x if $x > $y;
    return $y;
$$ LANGUAGE plperl;
```

As shown above, to return an SQL null value from a PL/Perl function, return an undefined value. This can be done whether the function is strict or not.

Anything in a function argument that is not a reference is a string, which is in the standard PostgreSQL external text representation for the relevant data type. In the case of ordinary numeric or text types, Perl will just do the right thing and the programmer will normally not have to worry about it. However, in other cases the argument will need to be converted into a form that is more usable in Perl. For example, the `decode_bytea` function can be used to convert an argument of type `bytea` into unescaped binary.

Similarly, values passed back to PostgreSQL must be in the external text representation format. For example, the `encode_bytea` function can be used to escape binary data for a return value of type `bytea`.

Perl can return PostgreSQL arrays as references to Perl arrays. Here is an example:

```
CREATE OR REPLACE function returns_array()
RETURNS text[][] AS $$
    return [['a"b', 'c,d'], ['e\\f', 'g']];
$$ LANGUAGE plperl;

select returns_array();
```

Perl passes PostgreSQL arrays as a blessed `PostgreSQL::InServer::ARRAY` object. This object may be treated as an array reference or a string, allowing for backward compatibility with Perl code written for PostgreSQL versions below 9.1 to run. For example:

```
CREATE OR REPLACE FUNCTION concat_array_elements(text[]) RETURNS
TEXT AS $$
    my $arg = shift;
    my $result = "";
    return undef if (!defined $arg);

    # as an array reference
    for (@$arg) {
        $result .= $_;
    }

    # also works as a string
    $result .= $arg;

    return $result;
$$ LANGUAGE plperl;

SELECT concat_array_elements(ARRAY['PL', '/', 'Perl']);
```

Note

Multidimensional arrays are represented as references to lower-dimensional arrays of references in a way common to every Perl programmer.

Composite-type arguments are passed to the function as references to hashes. The keys of the hash are the attribute names of the composite type. Here is an example:

```
CREATE TABLE employee (
    name text,
    basesalary integer,
    bonus integer
);

CREATE FUNCTION empcomp(employee) RETURNS integer AS $$
    my ($emp) = @_;
    return $emp->{basesalary} + $emp->{bonus};
$$ LANGUAGE plperl;
```

```
SELECT name, empcomp(employee.*) FROM employee;
```

A PL/Perl function can return a composite-type result using the same approach: return a reference to a hash that has the required attributes. For example:

```
CREATE TYPE testrowperl AS (f1 integer, f2 text, f3 text);

CREATE OR REPLACE FUNCTION perl_row() RETURNS testrowperl AS $$
    return {f2 => 'hello', f1 => 1, f3 => 'world'};
$$ LANGUAGE plperl;

SELECT * FROM perl_row();
```

Any columns in the declared result data type that are not present in the hash will be returned as null values.

Similarly, output arguments of procedures can be returned as a hash reference:

```
CREATE PROCEDURE perl_triple(INOUT a integer, INOUT b integer) AS $
$
    my ($a, $b) = @_;
    return {a => $a * 3, b => $b * 3};
$$ LANGUAGE plperl;

CALL perl_triple(5, 10);
```

PL/Perl functions can also return sets of either scalar or composite types. Usually you'll want to return rows one at a time, both to speed up startup time and to keep from queuing up the entire result set in memory. You can do this with `return_next` as illustrated below. Note that after the last `return_next`, you must put either `return` or (better) `return undef`.

```
CREATE OR REPLACE FUNCTION perl_set_int(int)
RETURNS SETOF INTEGER AS $$
    foreach (0..$_[0]) {
        return_next($_);
    }
    return undef;
$$ LANGUAGE plperl;

SELECT * FROM perl_set_int(5);

CREATE OR REPLACE FUNCTION perl_set()
RETURNS SETOF testrowperl AS $$
    return_next({ f1 => 1, f2 => 'Hello', f3 => 'World' });
    return_next({ f1 => 2, f2 => 'Hello', f3 => 'PostgreSQL' });
    return_next({ f1 => 3, f2 => 'Hello', f3 => 'PL/Perl' });
    return undef;
$$ LANGUAGE plperl;
```

For small result sets, you can return a reference to an array that contains either scalars, references to arrays, or references to hashes for simple types, array types, and composite types, respectively. Here are some simple examples of returning the entire result set as an array reference:

```
CREATE OR REPLACE FUNCTION perl_set_int(int) RETURNS SETOF INTEGER
AS $$
```

```
    return [0..$_[0]];
$$ LANGUAGE plperl;

SELECT * FROM perl_set_int(5);

CREATE OR REPLACE FUNCTION perl_set() RETURNS SETOF testrowperl AS
$$
    return [
        { f1 => 1, f2 => 'Hello', f3 => 'World' },
        { f1 => 2, f2 => 'Hello', f3 => 'PostgreSQL' },
        { f1 => 3, f2 => 'Hello', f3 => 'PL/Perl' }
    ];
$$ LANGUAGE plperl;

SELECT * FROM perl_set();
```

If you wish to use the `strict` pragma with your code you have a few options. For temporary global use you can `SET plperl.use_strict` to true. This will affect subsequent compilations of PL/Perl functions, but not functions already compiled in the current session. For permanent global use you can set `plperl.use_strict` to true in the `postgresql.conf` file.

For permanent use in specific functions you can simply put:

```
use strict;
```

at the top of the function body.

The feature pragma is also available to use if your Perl is version 5.10.0 or higher.

44.2. Data Values in PL/Perl

The argument values supplied to a PL/Perl function's code are simply the input arguments converted to text form (just as if they had been displayed by a `SELECT` statement). Conversely, the `return` and `return_next` commands will accept any string that is acceptable input format for the function's declared return type.

44.3. Built-in Functions

44.3.1. Database Access from PL/Perl

Access to the database itself from your Perl function can be done via the following functions:

```
spi_exec_query(query [, max-rows])
```

`spi_exec_query` executes an SQL command and returns the entire row set as a reference to an array of hash references. *You should only use this command when you know that the result set will be relatively small.* Here is an example of a query (`SELECT` command) with the optional maximum number of rows:

```
$rv = spi_exec_query('SELECT * FROM my_table', 5);
```

This returns up to 5 rows from the table `my_table`. If `my_table` has a column `my_column`, you can get that value from row `$i` of the result like this:

```
$foo = $rv->{rows}[$i]->{my_column};
```

The total number of rows returned from a `SELECT` query can be accessed like this:

```
$nrows = $rv->{processed}
```

Here is an example using a different command type:

```
$query = "INSERT INTO my_table VALUES (1, 'test')";  
$rv = spi_exec_query($query);
```

You can then access the command status (e.g., `SPI_OK_INSERT`) like this:

```
$res = $rv->{status};
```

To get the number of rows affected, do:

```
$nrows = $rv->{processed};
```

Here is a complete example:

```
CREATE TABLE test (  
    i int,  
    v varchar  
);  
  
INSERT INTO test (i, v) VALUES (1, 'first line');  
INSERT INTO test (i, v) VALUES (2, 'second line');  
INSERT INTO test (i, v) VALUES (3, 'third line');  
INSERT INTO test (i, v) VALUES (4, 'immortal');  
  
CREATE OR REPLACE FUNCTION test_munge() RETURNS SETOF test AS $$  
    my $rv = spi_exec_query('select i, v from test;');  
    my $status = $rv->{status};  
    my $nrows = $rv->{processed};  
    foreach my $rn (0 .. $nrows - 1) {  
        my $row = $rv->{rows}[$rn];  
        $row->{i} += 200 if defined($row->{i});  
        $row->{v} =~ tr/A-Za-z/a-zA-Z/ if (defined($row->{v}));  
        return_next($row);  
    }  
    return undef;  
$$ LANGUAGE plperl;  
  
SELECT * FROM test_munge();  
  
spi_query(command)  
spi_fetchrow(cursor)  
spi_cursor_close(cursor)
```

`spi_query` and `spi_fetchrow` work together as a pair for row sets which might be large, or for cases where you wish to return rows as they arrive. `spi_fetchrow` works *only* with `spi_query`. The following example illustrates how you use them together:

```
CREATE TYPE foo_type AS (the_num INTEGER, the_text TEXT);
```

```

CREATE OR REPLACE FUNCTION lotsa_md5 (INTEGER) RETURNS SETOF
foo_type AS $$
    use Digest::MD5 qw(md5_hex);
    my $file = '/usr/share/dict/words';
    my $t = localtime;
    elog(NOTICE, "opening file $file at $t" );
    open my $fh, '<', $file # ooh, it's a file access!
        or elog(ERROR, "cannot open $file for reading: $!");
    my @words = <$fh>;
    close $fh;
    $t = localtime;
    elog(NOTICE, "closed file $file at $t");
    chomp(@words);
    my $row;
    my $sth = spi_query("SELECT * FROM generate_series(1,$_[0])
AS b(a)");
    while (defined ($row = spi_fetchrow($sth))) {
        return_next({
            the_num => $row->{a},
            the_text => md5_hex($words[rand @words])
        });
    }
    return;
$$ LANGUAGE plperl;

SELECT * from lotsa_md5(500);

```

Normally, `spi_fetchrow` should be repeated until it returns `undef`, indicating that there are no more rows to read. The cursor returned by `spi_query` is automatically freed when `spi_fetchrow` returns `undef`. If you do not wish to read all the rows, instead call `spi_cursor_close` to free the cursor. Failure to do so will result in memory leaks.

```

spi_prepare(command, argument types)
spi_query_prepared(plan, arguments)
spi_exec_prepared(plan [, attributes], arguments)
spi_freeplan(plan)

```

`spi_prepare`, `spi_query_prepared`, `spi_exec_prepared`, and `spi_freeplan` implement the same functionality but for prepared queries. `spi_prepare` accepts a query string with numbered argument placeholders (`$1`, `$2`, etc) and a string list of argument types:

```

$plan = spi_prepare('SELECT * FROM test WHERE id > $1 AND name =
    $2',
                                                            'INTEGER',
    'TEXT');

```

Once a query plan is prepared by a call to `spi_prepare`, the plan can be used instead of the string query, either in `spi_exec_prepared`, where the result is the same as returned by `spi_exec_query`, or in `spi_query_prepared` which returns a cursor exactly as `spi_query` does, which can be later passed to `spi_fetchrow`. The optional second parameter to `spi_exec_prepared` is a hash reference of attributes; the only attribute currently supported is `limit`, which sets the maximum number of rows returned by a query.

The advantage of prepared queries is that it is possible to use one prepared plan for more than one query execution. After the plan is not needed anymore, it can be freed with `spi_freeplan`:

```

CREATE OR REPLACE FUNCTION init() RETURNS VOID AS $$

```

```

        $_SHARED{my_plan} = spi_prepare('SELECT (now() +
    $1)::date AS now',
                                        'INTERVAL');
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION add_time( INTERVAL ) RETURNS TEXT AS
$$
    return spi_exec_prepared(
        $_SHARED{my_plan},
        $_[0]
    )->{rows}->[0]->{now};
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION done() RETURNS VOID AS $$
    spi_freeplan( $_SHARED{my_plan} );
    undef $_SHARED{my_plan};
$$ LANGUAGE plperl;

SELECT init();
SELECT add_time('1 day'), add_time('2 days'), add_time('3
    days');
SELECT done();

```

add_time	add_time	add_time
2005-12-10	2005-12-11	2005-12-12

Note that the parameter subscript in `spi_prepare` is defined via `$1`, `$2`, `$3`, etc, so avoid declaring query strings in double quotes that might easily lead to hard-to-catch bugs.

Another example illustrates usage of an optional parameter in `spi_exec_prepared`:

```

CREATE TABLE hosts AS SELECT id, ('192.168.1.' || id)::inet AS
    address
                                FROM generate_series(1,3) AS id;

CREATE OR REPLACE FUNCTION init_hosts_query() RETURNS VOID AS $$
    $_SHARED{plan} = spi_prepare('SELECT * FROM hosts
                                WHERE address << $1',
    'inet');
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION query_hosts(inet) RETURNS SETOF hosts
    AS $$
    return spi_exec_prepared(
        $_SHARED{plan},
        {limit => 2},
        $_[0]
    )->{rows};
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION release_hosts_query() RETURNS VOID AS
    $$
    spi_freeplan($_SHARED{plan});
    undef $_SHARED{plan};
$$ LANGUAGE plperl;

SELECT init_hosts_query();

```

```
SELECT query_hosts('192.168.1.0/30');
SELECT release_hosts_query();
```

```
      query_hosts
-----
(1,192.168.1.1)
(2,192.168.1.2)
(2 rows)
```

```
spi_commit()
spi_rollback()
```

Commit or roll back the current transaction. This can only be called in a procedure or anonymous code block (DO command) called from the top level. (Note that it is not possible to run the SQL commands COMMIT or ROLLBACK via `spi_exec_query` or similar. It has to be done using these functions.) After a transaction is ended, a new transaction is automatically started, so there is no separate function for that.

Here is an example:

```
CREATE PROCEDURE transaction_test1()
LANGUAGE plperl
AS $$
foreach my $i (0..9) {
    spi_exec_query("INSERT INTO test1 (a) VALUES ($i)");
    if ($i % 2 == 0) {
        spi_commit();
    } else {
        spi_rollback();
    }
}
$$;

CALL transaction_test1();
```

44.3.2. Utility Functions in PL/Perl

`elog(level, msg)`

Emit a log or error message. Possible levels are DEBUG, LOG, INFO, NOTICE, WARNING, and ERROR. ERROR raises an error condition; if this is not trapped by the surrounding Perl code, the error propagates out to the calling query, causing the current transaction or subtransaction to be aborted. This is effectively the same as the Perl `die` command. The other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the `log_min_messages` and `client_min_messages` configuration variables. See Chapter 19 for more information.

`quote_literal(string)`

Return the given string suitably quoted to be used as a string literal in an SQL statement string. Embedded single-quotes and backslashes are properly doubled. Note that `quote_literal` returns undef on undef input; if the argument might be undef, `quote_nullable` is often more suitable.

`quote_nullable(string)`

Return the given string suitably quoted to be used as a string literal in an SQL statement string; or, if the argument is undef, return the unquoted string "NULL". Embedded single-quotes and backslashes are properly doubled.

`quote_ident(string)`

Return the given string suitably quoted to be used as an identifier in an SQL statement string. Quotes are added only if necessary (i.e., if the string contains non-identifier characters or would be case-folded). Embedded quotes are properly doubled.

`decode_bytea(string)`

Return the unescaped binary data represented by the contents of the given string, which should be `bytea` encoded.

`encode_bytea(string)`

Return the `bytea` encoded form of the binary data contents of the given string.

`encode_array_literal(array)`

`encode_array_literal(array, delimiter)`

Returns the contents of the referenced array as a string in array literal format (see Section 8.15.2). Returns the argument value unaltered if it's not a reference to an array. The delimiter used between elements of the array literal defaults to `,` if a delimiter is not specified or is `undef`.

`encode_typed_literal(value, typename)`

Converts a Perl variable to the value of the data type passed as a second argument and returns a string representation of this value. Correctly handles nested arrays and values of composite types.

`encode_array_constructor(array)`

Returns the contents of the referenced array as a string in array constructor format (see Section 4.2.12). Individual values are quoted using `quote_nullable`. Returns the argument value, quoted using `quote_nullable`, if it's not a reference to an array.

`looks_like_number(string)`

Returns a true value if the content of the given string looks like a number, according to Perl, returns false otherwise. Returns `undef` if the argument is `undef`. Leading and trailing space is ignored. `Inf` and `Infinity` are regarded as numbers.

`is_array_ref(argument)`

Returns a true value if the given argument may be treated as an array reference, that is, if `ref` of the argument is `ARRAY` or `PostgreSQL::InServer::ARRAY`. Returns false otherwise.

44.4. Global Values in PL/Perl

You can use the global hash `$_SHARED` to store data, including code references, between function calls for the lifetime of the current session.

Here is a simple example for shared data:

```
CREATE OR REPLACE FUNCTION set_var(name text, val text) RETURNS
text AS $$
    if ($_SHARED{$_[0]} = $_[1]) {
        return 'ok';
    } else {
        return "cannot set shared variable $_[0] to $_[1]";
    }
}
$$ LANGUAGE plperl;
```

```
CREATE OR REPLACE FUNCTION get_var(name text) RETURNS text AS $$
    return $_SHARED{$_[0]};
$$ LANGUAGE plperl;

SELECT set_var('sample', 'Hello, PL/Perl! How's tricks?');
SELECT get_var('sample');
```

Here is a slightly more complicated example using a code reference:

```
CREATE OR REPLACE FUNCTION myfuncs() RETURNS void AS $$
    $_SHARED{myquote} = sub {
        my $arg = shift;
        $arg =~ s/(['\\])/\\$1/g;
        return "'$arg'";
    };
$$ LANGUAGE plperl;

SELECT myfuncs(); /* initializes the function */

/* Set up a function that uses the quote function */

CREATE OR REPLACE FUNCTION use_quote(TEXT) RETURNS text AS $$
    my $text_to_quote = shift;
    my $qfunc = $_SHARED{myquote};
    return &$qfunc($text_to_quote);
$$ LANGUAGE plperl;
```

(You could have replaced the above with the one-liner `return $_SHARED{myquote}->($_[0]);` at the expense of readability.)

For security reasons, PL/Perl executes functions called by any one SQL role in a separate Perl interpreter for that role. This prevents accidental or malicious interference by one user with the behavior of another user's PL/Perl functions. Each such interpreter has its own value of the `$_SHARED` variable and other global state. Thus, two PL/Perl functions will share the same value of `$_SHARED` if and only if they are executed by the same SQL role. In an application wherein a single session executes code under multiple SQL roles (via `SECURITY DEFINER` functions, use of `SET ROLE`, etc) you may need to take explicit steps to ensure that PL/Perl functions can share data via `$_SHARED`. To do that, make sure that functions that should communicate are owned by the same user, and mark them `SECURITY DEFINER`. You must of course take care that such functions can't be used to do anything unintended.

44.5. Trusted and Untrusted PL/Perl

Normally, PL/Perl is installed as a “trusted” programming language named `plperl`. In this setup, certain Perl operations are disabled to preserve security. In general, the operations that are restricted are those that interact with the environment. This includes file handle operations, `require`, and `use` (for external modules). There is no way to access internals of the database server process or to gain OS-level access with the permissions of the server process, as a C function can do. Thus, any unprivileged database user can be permitted to use this language.

Here is an example of a function that will not work because file system operations are not allowed for security reasons:

```
CREATE FUNCTION badfunc() RETURNS integer AS $$
    my $tmpfile = "/tmp/badfile";
    open my $fh, '>', $tmpfile
```

```

        or elog(ERROR, qq{could not open the file "$tmpfile": $!});
    print $fh "Testing writing to a file\n";
    close $fh or elog(ERROR, qq{could not close the file
"$tmpfile": $!});
    return 1;
$$ LANGUAGE plperl;

```

The creation of this function will fail as its use of a forbidden operation will be caught by the validator.

Sometimes it is desirable to write Perl functions that are not restricted. For example, one might want a Perl function that sends mail. To handle these cases, PL/Perl can also be installed as an “untrusted” language (usually called PL/PerlU). In this case the full Perl language is available. When installing the language, the language name `plperlU` will select the untrusted PL/Perl variant.

The writer of a PL/PerlU function must take care that the function cannot be used to do anything unwanted, since it will be able to do anything that could be done by a user logged in as the database administrator. Note that the database system allows only database superusers to create functions in untrusted languages.

If the above function was created by a superuser using the language `plperlU`, execution would succeed.

In the same way, anonymous code blocks written in Perl can use restricted operations if the language is specified as `plperlU` rather than `plperl`, but the caller must be a superuser.

Note

While PL/Perl functions run in a separate Perl interpreter for each SQL role, all PL/PerlU functions executed in a given session run in a single Perl interpreter (which is not any of the ones used for PL/Perl functions). This allows PL/PerlU functions to share data freely, but no communication can occur between PL/Perl and PL/PerlU functions.

Note

Perl cannot support multiple interpreters within one process unless it was built with the appropriate flags, namely either `usemultiplicity` or `useithreads`. (`usemultiplicity` is preferred unless you actually need to use threads. For more details, see the `perlembed` man page.) If PL/Perl is used with a copy of Perl that was not built this way, then it is only possible to have one Perl interpreter per session, and so any one session can only execute either PL/PerlU functions, or PL/Perl functions that are all called by the same SQL role.

44.6. PL/Perl Triggers

PL/Perl can be used to write trigger functions. In a trigger function, the hash reference `$_TD` contains information about the current trigger event. `$_TD` is a global variable, which gets a separate local value for each invocation of the trigger. The fields of the `$_TD` hash reference are:

```
$_TD->{new} {foo}
```

NEW value of column `foo`

```
$_TD->{old} {foo}
```

OLD value of column `foo`

`$_TD->{name}`

Name of the trigger being called

`$_TD->{event}`

Trigger event: INSERT, UPDATE, DELETE, TRUNCATE, or UNKNOWN

`$_TD->{when}`

When the trigger was called: BEFORE, AFTER, INSTEAD OF, or UNKNOWN

`$_TD->{level}`

The trigger level: ROW, STATEMENT, or UNKNOWN

`$_TD->{relid}`

OID of the table on which the trigger fired

`$_TD->{table_name}`

Name of the table on which the trigger fired

`$_TD->{relname}`

Name of the table on which the trigger fired. This has been deprecated, and could be removed in a future release. Please use `$_TD->{table_name}` instead.

`$_TD->{table_schema}`

Name of the schema in which the table on which the trigger fired, is

`$_TD->{argc}`

Number of arguments of the trigger function

`@{$_TD->{args}}`

Arguments of the trigger function. Does not exist if `$_TD->{argc}` is 0.

Row-level triggers can return one of the following:

`return;`

Execute the operation

`"SKIP"`

Don't execute the operation

`"MODIFY"`

Indicates that the NEW row was modified by the trigger function

Here is an example of a trigger function, illustrating some of the above:

```
CREATE TABLE test (
  i int,
  v varchar
);
```

```
CREATE OR REPLACE FUNCTION valid_id() RETURNS trigger AS $$
```

```
if (($_TD->{new}{i} >= 100) || ($_TD->{new}{i} <= 0)) {
    return "SKIP";    # skip INSERT/UPDATE command
} elsif ($_TD->{new}{v} ne "immortal") {
    $_TD->{new}{v} .= "(modified by trigger)";
    return "MODIFY"; # modify row and execute INSERT/UPDATE
command
} else {
    return;          # execute INSERT/UPDATE command
}
}
$$ LANGUAGE plperl;

CREATE TRIGGER test_valid_id_trig
BEFORE INSERT OR UPDATE ON test
FOR EACH ROW EXECUTE FUNCTION valid_id();
```

44.7. PL/Perl Event Triggers

PL/Perl can be used to write event trigger functions. In an event trigger function, the hash reference `$_TD` contains information about the current trigger event. `$_TD` is a global variable, which gets a separate local value for each invocation of the trigger. The fields of the `$_TD` hash reference are:

`$_TD->{event}`

The name of the event the trigger is fired for.

`$_TD->{tag}`

The command tag for which the trigger is fired.

The return value of the trigger function is ignored.

Here is an example of an event trigger function, illustrating some of the above:

```
CREATE OR REPLACE FUNCTION perlsnitch() RETURNS event_trigger AS $$
    elog(NOTICE, "perlsnitch: " . $_TD->{event} . " " . $_TD->{tag} .
    " ");
$$ LANGUAGE plperl;

CREATE EVENT TRIGGER perl_a_snitch
ON ddl_command_start
EXECUTE FUNCTION perlsnitch();
```

44.8. PL/Perl Under the Hood

44.8.1. Configuration

This section lists configuration parameters that affect PL/Perl.

`plperl.on_init(string)`

Specifies Perl code to be executed when a Perl interpreter is first initialized, before it is specialized for use by `plperl` or `plperlu`. The SPI functions are not available when this code is executed. If the code fails with an error it will abort the initialization of the interpreter and propagate out to the calling query, causing the current transaction or subtransaction to be aborted.

The Perl code is limited to a single string. Longer code can be placed into a module and loaded by the `on_init` string. Examples:

```
plperl.on_init = 'require "plperlinit.pl" '
plperl.on_init = 'use lib "/my/app"; use MyApp::PgInit;'
```

Any modules loaded by `plperl.on_init`, either directly or indirectly, will be available for use by `plperl`. This may create a security risk. To see what modules have been loaded you can use:

```
DO 'elog(WARNING, join ", ", sort keys %INC)' LANGUAGE plperl;
```

Initialization will happen in the postmaster if the `plperl` library is included in `shared_preload_libraries`, in which case extra consideration should be given to the risk of destabilizing the postmaster. The principal reason for making use of this feature is that Perl modules loaded by `plperl.on_init` need be loaded only at postmaster start, and will be instantly available without loading overhead in individual database sessions. However, keep in mind that the overhead is avoided only for the first Perl interpreter used by a database session — either PL/PerlU, or PL/Perl for the first SQL role that calls a PL/Perl function. Any additional Perl interpreters created in a database session will have to execute `plperl.on_init` afresh. Also, on Windows there will be no savings whatsoever from preloading, since the Perl interpreter created in the postmaster process does not propagate to child processes.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

```
plperl.on_plperl_init (string)
plperl.on_plperlu_init (string)
```

These parameters specify Perl code to be executed when a Perl interpreter is specialized for `plperl` or `plperlu` respectively. This will happen when a PL/Perl or PL/PerlU function is first executed in a database session, or when an additional interpreter has to be created because the other language is called or a PL/Perl function is called by a new SQL role. This follows any initialization done by `plperl.on_init`. The SPI functions are not available when this code is executed. The Perl code in `plperl.on_plperl_init` is executed after “locking down” the interpreter, and thus it can only perform trusted operations.

If the code fails with an error it will abort the initialization and propagate out to the calling query, causing the current transaction or subtransaction to be aborted. Any actions already done within Perl won't be undone; however, that interpreter won't be used again. If the language is used again the initialization will be attempted again within a fresh Perl interpreter.

Only superusers can change these settings. Although these settings can be changed within a session, such changes will not affect Perl interpreters that have already been used to execute functions.

```
plperl.use_strict (boolean)
```

When set true subsequent compilations of PL/Perl functions will have the `strict` pragma enabled. This parameter does not affect functions already compiled in the current session.

44.8.2. Limitations and Missing Features

The following features are currently missing from PL/Perl, but they would make welcome contributions.

- PL/Perl functions cannot call each other directly.
- SPI is not yet fully implemented.
- If you are fetching very large data sets using `spi_exec_query`, you should be aware that these will all go into memory. You can avoid this by using `spi_query/spi_fetchrow` as illustrated earlier.

A similar problem occurs if a set-returning function passes a large set of rows back to PostgreSQL via `return`. You can avoid this problem too by instead using `return_next` for each row returned, as shown previously.

- When a session ends normally, not due to a fatal error, any `END` blocks that have been defined are executed. Currently no other actions are performed. Specifically, file handles are not automatically flushed and objects are not automatically destroyed.

Chapter 45. PL/Python - Python Procedural Language

The PL/Python procedural language allows PostgreSQL functions to be written in the Python language¹.

To install PL/Python in a particular database, use `CREATE EXTENSION plpythonu` (but see also Section 45.1).

Tip

If a language is installed into `template1`, all subsequently created databases will have the language installed automatically.

PL/Python is only available as an “untrusted” language, meaning it does not offer any way of restricting what users can do in it and is therefore named `plpythonu`. A trusted variant `plpython` might become available in the future if a secure execution mechanism is developed in Python. The writer of a function in untrusted PL/Python must take care that the function cannot be used to do anything unwanted, since it will be able to do anything that could be done by a user logged in as the database administrator. Only superusers can create functions in untrusted languages such as `plpythonu`.

Note

Users of source packages must specially enable the build of PL/Python during the installation process. (Refer to the installation instructions for more information.) Users of binary packages might find PL/Python in a separate subpackage.

45.1. Python 2 vs. Python 3

PL/Python supports both the Python 2 and Python 3 language variants. (The PostgreSQL installation instructions might contain more precise information about the exact supported minor versions of Python.) Because the Python 2 and Python 3 language variants are incompatible in some important aspects, the following naming and transitioning scheme is used by PL/Python to avoid mixing them:

- The PostgreSQL language named `plpython2u` implements PL/Python based on the Python 2 language variant.
- The PostgreSQL language named `plpython3u` implements PL/Python based on the Python 3 language variant.
- The language named `plpythonu` implements PL/Python based on the default Python language variant, which is currently Python 2. (This default is independent of what any local Python installations might consider to be their “default”, for example, what `/usr/bin/python` might be.) The default will probably be changed to Python 3 in a distant future release of PostgreSQL, depending on the progress of the migration to Python 3 in the Python community.

This scheme is analogous to the recommendations in PEP 394² regarding the naming and transitioning of the `python` command.

¹ <https://www.python.org>

² <https://www.python.org/dev/peps/pep-0394/>

It depends on the build configuration or the installed packages whether PL/Python for Python 2 or Python 3 or both are available.

Tip

The built variant depends on which Python version was found during the installation or which version was explicitly set using the `PYTHON` environment variable; see Section 16.4. To make both variants of PL/Python available in one installation, the source tree has to be configured and built twice.

This results in the following usage and migration strategy:

- Existing users and users who are currently not interested in Python 3 use the language name `plpythonu` and don't have to change anything for the foreseeable future. It is recommended to gradually “future-proof” the code via migration to Python 2.6/2.7 to simplify the eventual migration to Python 3.

In practice, many PL/Python functions will migrate to Python 3 with few or no changes.

- Users who know that they have heavily Python 2 dependent code and don't plan to ever change it can make use of the `plpython2u` language name. This will continue to work into the very distant future, until Python 2 support might be completely dropped by PostgreSQL.
- Users who want to dive into Python 3 can use the `plpython3u` language name, which will keep working forever by today's standards. In the distant future, when Python 3 might become the default, they might like to remove the “3” for aesthetic reasons.
- Daredevils, who want to build a Python-3-only operating system environment, can change the contents of `pg_pltemplate` to make `plpythonu` be equivalent to `plpython3u`, keeping in mind that this would make their installation incompatible with most of the rest of the world.

See also the document [What's New In Python 3.0³](#) for more information about porting to Python 3.

It is not allowed to use PL/Python based on Python 2 and PL/Python based on Python 3 in the same session, because the symbols in the dynamic modules would clash, which could result in crashes of the PostgreSQL server process. There is a check that prevents mixing Python major versions in a session, which will abort the session if a mismatch is detected. It is possible, however, to use both PL/Python variants in the same database, from separate sessions.

45.2. PL/Python Functions

Functions in PL/Python are declared via the standard `CREATE FUNCTION` syntax:

```
CREATE FUNCTION funcname (argument-list)
  RETURNS return-type
AS $$
  # PL/Python function body
$$ LANGUAGE plpythonu;
```

The body of a function is simply a Python script. When the function is called, its arguments are passed as elements of the list `args`; named arguments are also passed as ordinary variables to the Python script. Use of named arguments is usually more readable. The result is returned from the Python code in the usual way, with `return` or `yield` (in case of a result-set statement). If you do not provide a return value, Python returns the default `None`. PL/Python translates Python's `None` into the SQL null

³ <https://docs.python.org/3/whatsnew/3.0.html>

value. In a procedure, the result from the Python code must be `None` (typically achieved by ending the procedure without a `return` statement or by using a `return` statement without argument); otherwise, an error will be raised.

For example, a function to return the greater of two integers can be defined as:

```
CREATE FUNCTION pymax (a integer, b integer)
  RETURNS integer
AS $$
  if a > b:
    return a
  return b
$$ LANGUAGE plpythonu;
```

The Python code that is given as the body of the function definition is transformed into a Python function. For example, the above results in:

```
def __plpython_procedure_pymax_23456():
    if a > b:
        return a
    return b
```

assuming that 23456 is the OID assigned to the function by PostgreSQL.

The arguments are set as global variables. Because of the scoping rules of Python, this has the subtle consequence that an argument variable cannot be reassigned inside the function to the value of an expression that involves the variable name itself, unless the variable is redeclared as global in the block. For example, the following won't work:

```
CREATE FUNCTION pystrip(x text)
  RETURNS text
AS $$
  x = x.strip() # error
  return x
$$ LANGUAGE plpythonu;
```

because assigning to `x` makes `x` a local variable for the entire block, and so the `x` on the right-hand side of the assignment refers to a not-yet-assigned local variable `x`, not the PL/Python function parameter. Using the `global` statement, this can be made to work:

```
CREATE FUNCTION pystrip(x text)
  RETURNS text
AS $$
  global x
  x = x.strip() # ok now
  return x
$$ LANGUAGE plpythonu;
```

But it is advisable not to rely on this implementation detail of PL/Python. It is better to treat the function parameters as read-only.

45.3. Data Values

Generally speaking, the aim of PL/Python is to provide a “natural” mapping between the PostgreSQL and the Python worlds. This informs the data mapping rules described below.

45.3.1. Data Type Mapping

When a PL/Python function is called, its arguments are converted from their PostgreSQL data type to a corresponding Python type:

- PostgreSQL `boolean` is converted to Python `bool`.
- PostgreSQL `smallint` and `int` are converted to Python `int`. PostgreSQL `bigint` and `oid` are converted to `long` in Python 2 and to `int` in Python 3.
- PostgreSQL `real` and `double` are converted to Python `float`.
- PostgreSQL `numeric` is converted to Python `Decimal`. This type is imported from the `cdecimal` package if that is available. Otherwise, `decimal.Decimal` from the standard library will be used. `cdecimal` is significantly faster than `decimal`. In Python 3.3 and up, however, `cdecimal` has been integrated into the standard library under the name `decimal`, so there is no longer any difference.
- PostgreSQL `bytea` is converted to Python `str` in Python 2 and to `bytes` in Python 3. In Python 2, the string should be treated as a byte sequence without any character encoding.
- All other data types, including the PostgreSQL character string types, are converted to a Python `str`. In Python 2, this string will be in the PostgreSQL server encoding; in Python 3, it will be a Unicode string like all strings.
- For nonscalar data types, see below.

When a PL/Python function returns, its return value is converted to the function's declared PostgreSQL return data type as follows:

- When the PostgreSQL return type is `boolean`, the return value will be evaluated for truth according to the *Python* rules. That is, 0 and empty string are false, but notably 'f' is true.
- When the PostgreSQL return type is `bytea`, the return value will be converted to a string (Python 2) or bytes (Python 3) using the respective Python built-ins, with the result being converted to `bytea`.
- For all other PostgreSQL return types, the return value is converted to a string using the Python built-in `str`, and the result is passed to the input function of the PostgreSQL data type. (If the Python value is a `float`, it is converted using the `repr` built-in instead of `str`, to avoid loss of precision.)

Strings in Python 2 are required to be in the PostgreSQL server encoding when they are passed to PostgreSQL. Strings that are not valid in the current server encoding will raise an error, but not all encoding mismatches can be detected, so garbage data can still result when this is not done correctly. Unicode strings are converted to the correct encoding automatically, so it can be safer and more convenient to use those. In Python 3, all strings are Unicode strings.

- For nonscalar data types, see below.

Note that logical mismatches between the declared PostgreSQL return type and the Python data type of the actual return object are not flagged; the value will be converted in any case.

45.3.2. Null, None

If an SQL null value is passed to a function, the argument value will appear as `None` in Python. For example, the function definition of `pymax` shown in Section 45.2 will return the wrong answer for null inputs. We could add `STRICT` to the function definition to make PostgreSQL do something more reasonable: if a null value is passed, the function will not be called at all, but will just return a null result automatically. Alternatively, we could check for null inputs in the function body:

```
CREATE FUNCTION pymax (a integer, b integer)
  RETURNS integer
AS $$
  if (a is None) or (b is None):
    return None
  if a > b:
    return a
  return b
$$ LANGUAGE plpythonu;
```

As shown above, to return an SQL null value from a PL/Python function, return the value None. This can be done whether the function is strict or not.

45.3.3. Arrays, Lists

SQL array values are passed into PL/Python as a Python list. To return an SQL array value out of a PL/Python function, return a Python list:

```
CREATE FUNCTION return_arr()
  RETURNS int[]
AS $$
return [1, 2, 3, 4, 5]
$$ LANGUAGE plpythonu;
```

```
SELECT return_arr();
   return_arr
-----
  {1,2,3,4,5}
(1 row)
```

Multidimensional arrays are passed into PL/Python as nested Python lists. A 2-dimensional array is a list of lists, for example. When returning a multi-dimensional SQL array out of a PL/Python function, the inner lists at each level must all be of the same size. For example:

```
CREATE FUNCTION test_type_conversion_array_int4(x int4[]) RETURNS
  int4[] AS $$
plpy.info(x, type(x))
return x
$$ LANGUAGE plpythonu;
```

```
SELECT * FROM test_type_conversion_array_int4(ARRAY[[1,2,3],
[4,5,6]]);
INFO:  ([[1, 2, 3], [4, 5, 6]], <type 'list'>)
 test_type_conversion_array_int4
-----
  {{1,2,3},{4,5,6}}
(1 row)
```

Other Python sequences, like tuples, are also accepted for backwards-compatibility with PostgreSQL versions 9.6 and below, when multi-dimensional arrays were not supported. However, they are always treated as one-dimensional arrays, because they are ambiguous with composite types. For the same reason, when a composite type is used in a multi-dimensional array, it must be represented by a tuple, rather than a list.

Note that in Python, strings are sequences, which can have undesirable effects that might be familiar to Python programmers:

```
CREATE FUNCTION return_str_arr()  
  RETURNS varchar[]  
AS $$  
return "hello"  
$$ LANGUAGE plpythonu;  
  
SELECT return_str_arr();  
   return_str_arr  
-----  
   {h,e,l,l,o}  
(1 row)
```

45.3.4. Composite Types

Composite-type arguments are passed to the function as Python mappings. The element names of the mapping are the attribute names of the composite type. If an attribute in the passed row has the null value, it has the value None in the mapping. Here is an example:

```
CREATE TABLE employee (  
  name text,  
  salary integer,  
  age integer  
);  
  
CREATE FUNCTION overpaid (e employee)  
  RETURNS boolean  
AS $$  
  if e["salary"] > 200000:  
    return True  
  if (e["age"] < 30) and (e["salary"] > 100000):  
    return True  
  return False  
$$ LANGUAGE plpythonu;
```

There are multiple ways to return row or composite types from a Python function. The following examples assume we have:

```
CREATE TYPE named_value AS (  
  name text,  
  value integer  
);
```

A composite result can be returned as a:

Sequence type (a tuple or list, but not a set because it is not indexable)

Returned sequence objects must have the same number of items as the composite result type has fields. The item with index 0 is assigned to the first field of the composite type, 1 to the second and so on. For example:

```
CREATE FUNCTION make_pair (name text, value integer)  
  RETURNS named_value  
AS $$  
  return ( name, value )  
  # or alternatively, as tuple: return [ name, value ]
```

```
$$ LANGUAGE plpythonu;
```

To return a SQL null for any column, insert None at the corresponding position.

When an array of composite types is returned, it cannot be returned as a list, because it is ambiguous whether the Python list represents a composite type, or another array dimension.

Mapping (dictionary)

The value for each result type column is retrieved from the mapping with the column name as key. Example:

```
CREATE FUNCTION make_pair (name text, value integer)
  RETURNS named_value
AS $$
  return { "name": name, "value": value }
$$ LANGUAGE plpythonu;
```

Any extra dictionary key/value pairs are ignored. Missing keys are treated as errors. To return a SQL null value for any column, insert None with the corresponding column name as the key.

Object (any object providing method `__getattr__`)

This works the same as a mapping. Example:

```
CREATE FUNCTION make_pair (name text, value integer)
  RETURNS named_value
AS $$
  class named_value:
    def __init__ (self, n, v):
      self.name = n
      self.value = v
  return named_value(name, value)

  # or simply
  class nv: pass
  nv.name = name
  nv.value = value
  return nv
$$ LANGUAGE plpythonu;
```

Functions with OUT parameters are also supported. For example:

```
CREATE FUNCTION multiout_simple(OUT i integer, OUT j integer) AS $$
return (1, 2)
$$ LANGUAGE plpythonu;

SELECT * FROM multiout_simple();
```

Output parameters of procedures are passed back the same way. For example:

```
CREATE PROCEDURE python_triple(INOUT a integer, INOUT b integer) AS
  $$
return (a * 3, b * 3)
$$ LANGUAGE plpythonu;

CALL python_triple(5, 10);
```

45.3.5. Set-Returning Functions

A PL/Python function can also return sets of scalar or composite types. There are several ways to achieve this because the returned object is internally turned into an iterator. The following examples assume we have composite type:

```
CREATE TYPE greeting AS (  
    how text,  
    who text  
);
```

A set result can be returned from a:

Sequence type (tuple, list, set)

```
CREATE FUNCTION greet (how text)  
    RETURNS SETOF greeting  
AS $$  
    # return tuple containing lists as composite types  
    # all other combinations work also  
    return ( [ how, "World" ], [ how, "PostgreSQL" ], [ how, "PL/  
Python" ] )  
$$ LANGUAGE plpythonu;
```

Iterator (any object providing `__iter__` and `next` methods)

```
CREATE FUNCTION greet (how text)  
    RETURNS SETOF greeting  
AS $$  
    class producer:  
        def __init__ (self, how, who):  
            self.how = how  
            self.who = who  
            self.ndx = -1  
  
        def __iter__ (self):  
            return self  
  
        def next (self):  
            self.ndx += 1  
            if self.ndx == len(self.who):  
                raise StopIteration  
            return ( self.how, self.who[self.ndx] )  
  
    return producer(how, [ "World", "PostgreSQL", "PL/Python" ])  
$$ LANGUAGE plpythonu;
```

Generator (yield)

```
CREATE FUNCTION greet (how text)  
    RETURNS SETOF greeting  
AS $$  
    for who in [ "World", "PostgreSQL", "PL/Python" ]:  
        yield ( how, who )  
$$ LANGUAGE plpythonu;
```

Set-returning functions with OUT parameters (using RETURNS SETOF record) are also supported. For example:

```
CREATE FUNCTION multiout_simple_setof(n integer, OUT integer, OUT
integer) RETURNS SETOF record AS $$
return [(1, 2)] * n
$$ LANGUAGE plpythonu;

SELECT * FROM multiout_simple_setof(3);
```

45.4. Sharing Data

The global dictionary SD is available to store private data between repeated calls to the same function. The global dictionary GD is public data, that is available to all Python functions within a session; use with care.

Each function gets its own execution environment in the Python interpreter, so that global data and function arguments from myfunc are not available to myfunc2. The exception is the data in the GD dictionary, as mentioned above.

45.5. Anonymous Code Blocks

PL/Python also supports anonymous code blocks called with the DO statement:

```
DO $$
# PL/Python code
$$ LANGUAGE plpythonu;
```

An anonymous code block receives no arguments, and whatever value it might return is discarded. Otherwise it behaves just like a function.

45.6. Trigger Functions

When a function is used as a trigger, the dictionary TD contains trigger-related values:

TD["event"]

contains the event as a string: INSERT, UPDATE, DELETE, or TRUNCATE.

TD["when"]

contains one of BEFORE, AFTER, or INSTEAD OF.

TD["level"]

contains ROW or STATEMENT.

TD["new"]

TD["old"]

For a row-level trigger, one or both of these fields contain the respective trigger rows, depending on the trigger event.

TD["name"]

contains the trigger name.

TD["table_name"]

contains the name of the table on which the trigger occurred.

TD["table_schema"]

contains the schema of the table on which the trigger occurred.

TD["relid"]

contains the OID of the table on which the trigger occurred.

TD["args"]

If the CREATE TRIGGER command included arguments, they are available in TD["args"] [0] to TD["args"] [n-1].

If TD["when"] is BEFORE or INSTEAD OF and TD["level"] is ROW, you can return None or "OK" from the Python function to indicate the row is unmodified, "SKIP" to abort the event, or if TD["event"] is INSERT or UPDATE you can return "MODIFY" to indicate you've modified the new row. Otherwise the return value is ignored.

45.7. Database Access

The PL/Python language module automatically imports a Python module called `plpy`. The functions and constants in this module are available to you in the Python code as `plpy.foo`.

45.7.1. Database Access Functions

The `plpy` module provides several functions to execute database commands:

```
plpy.execute(query [, max-rows])
```

Calling `plpy.execute` with a query string and an optional row limit argument causes that query to be run and the result to be returned in a result object.

The result object emulates a list or dictionary object. The result object can be accessed by row number and column name. For example:

```
rv = plpy.execute("SELECT * FROM my_table", 5)
```

returns up to 5 rows from `my_table`. If `my_table` has a column `my_column`, it would be accessed as:

```
foo = rv[i]["my_column"]
```

The number of rows returned can be obtained using the built-in `len` function.

The result object has these additional methods:

```
nrows()
```

Returns the number of rows processed by the command. Note that this is not necessarily the same as the number of rows returned. For example, an UPDATE command will set this value but won't return any rows (unless RETURNING is used).

```
status()
```

The `SPI_execute()` return value.

```
colnames()  
coltypes()  
coltypmods()
```

Return a list of column names, list of column type OIDs, and list of type-specific type modifiers for the columns, respectively.

These methods raise an exception when called on a result object from a command that did not produce a result set, e.g., `UPDATE` without `RETURNING`, or `DROP TABLE`. But it is OK to use these methods on a result set containing zero rows.

```
__str__()
```

The standard `__str__` method is defined so that it is possible for example to debug query execution results using `plpy.debug(rv)`.

The result object can be modified.

Note that calling `plpy.execute` will cause the entire result set to be read into memory. Only use that function when you are sure that the result set will be relatively small. If you don't want to risk excessive memory usage when fetching large results, use `plpy.cursor` rather than `plpy.execute`.

```
plpy.prepare(query [, argtypes])  
plpy.execute(plan [, arguments [, max-rows]])
```

`plpy.prepare` prepares the execution plan for a query. It is called with a query string and a list of parameter types, if you have parameter references in the query. For example:

```
plan = plpy.prepare("SELECT last_name FROM my_users WHERE  
first_name = $1", ["text"])
```

`text` is the type of the variable you will be passing for `$1`. The second argument is optional if you don't want to pass any parameters to the query.

After preparing a statement, you use a variant of the function `plpy.execute` to run it:

```
rv = plpy.execute(plan, ["name"], 5)
```

Pass the plan as the first argument (instead of the query string), and a list of values to substitute into the query as the second argument. The second argument is optional if the query does not expect any parameters. The third argument is the optional row limit as before.

Alternatively, you can call the `execute` method on the plan object:

```
rv = plan.execute(["name"], 5)
```

Query parameters and result row fields are converted between PostgreSQL and Python data types as described in Section 45.3.

When you prepare a plan using the PL/Python module it is automatically saved. Read the SPI documentation (Chapter 46) for a description of what this means. In order to make effective use of this across function calls one needs to use one of the persistent storage dictionaries `SD` or `GD` (see Section 45.4). For example:

```
CREATE FUNCTION usesavedplan() RETURNS trigger AS $$
```

```

    if "plan" in SD:
        plan = SD["plan"]
    else:
        plan = plpy.prepare("SELECT 1")
        SD["plan"] = plan
    # rest of function
$$ LANGUAGE plpythonu;

plpy.cursor(query)
plpy.cursor(plan [, arguments])

```

The `plpy.cursor` function accepts the same arguments as `plpy.execute` (except for the row limit) and returns a cursor object, which allows you to process large result sets in smaller chunks. As with `plpy.execute`, either a query string or a plan object along with a list of arguments can be used, or the `cursor` function can be called as a method of the plan object.

The cursor object provides a `fetch` method that accepts an integer parameter and returns a result object. Each time you call `fetch`, the returned object will contain the next batch of rows, never larger than the parameter value. Once all rows are exhausted, `fetch` starts returning an empty result object. Cursor objects also provide an iterator interface⁴, yielding one row at a time until all rows are exhausted. Data fetched that way is not returned as result objects, but rather as dictionaries, each dictionary corresponding to a single result row.

An example of two ways of processing data from a large table is:

```

CREATE FUNCTION count_odd_iterator() RETURNS integer AS $$
odd = 0
for row in plpy.cursor("select num from largetable"):
    if row['num'] % 2:
        odd += 1
return odd
$$ LANGUAGE plpythonu;

CREATE FUNCTION count_odd_fetch(batch_size integer) RETURNS
integer AS $$
odd = 0
cursor = plpy.cursor("select num from largetable")
while True:
    rows = cursor.fetch(batch_size)
    if not rows:
        break
    for row in rows:
        if row['num'] % 2:
            odd += 1
return odd
$$ LANGUAGE plpythonu;

CREATE FUNCTION count_odd_prepared() RETURNS integer AS $$
odd = 0
plan = plpy.prepare("select num from largetable where num % $1
<> 0", ["integer"])
rows = list(plpy.cursor(plan, [2])) # or: =
list(plan.cursor([2]))

return len(rows)
$$ LANGUAGE plpythonu;

```

⁴ <https://docs.python.org/library/stdtypes.html#iterator-types>

Cursors are automatically disposed of. But if you want to explicitly release all resources held by a cursor, use the `close` method. Once closed, a cursor cannot be fetched from anymore.

Tip

Do not confuse objects created by `plpy.cursor` with DB-API cursors as defined by the Python Database API specification⁵. They don't have anything in common except for the name.

45.7.2. Trapping Errors

Functions accessing the database might encounter errors, which will cause them to abort and raise an exception. Both `plpy.execute` and `plpy.prepare` can raise an instance of a subclass of `plpy.SPIError`, which by default will terminate the function. This error can be handled just like any other Python exception, by using the `try/except` construct. For example:

```
CREATE FUNCTION try_adding_joe() RETURNS text AS $$
  try:
    plpy.execute("INSERT INTO users(username) VALUES ('joe')")
  except plpy.SPIError:
    return "something went wrong"
  else:
    return "Joe added"
$$ LANGUAGE plpythonu;
```

The actual class of the exception being raised corresponds to the specific condition that caused the error. Refer to Table A.1 for a list of possible conditions. The module `plpy.spiexceptions` defines an exception class for each PostgreSQL condition, deriving their names from the condition name. For instance, `division_by_zero` becomes `DivisionByZero`, `unique_violation` becomes `UniqueViolation`, `fdw_error` becomes `FdwError`, and so on. Each of these exception classes inherits from `SPIError`. This separation makes it easier to handle specific errors, for instance:

```
CREATE FUNCTION insert_fraction(numerator int, denominator int)
  RETURNS text AS $$
from plpy import spiexceptions
try:
  plan = plpy.prepare("INSERT INTO fractions (frac) VALUES ($1 /
    $2)", ["int", "int"])
  plpy.execute(plan, [numerator, denominator])
except spiexceptions.DivisionByZero:
  return "denominator cannot equal zero"
except spiexceptions.UniqueViolation:
  return "already have that fraction"
except plpy.SPIError, e:
  return "other error, SQLSTATE %s" % e.sqlstate
else:
  return "fraction inserted"
$$ LANGUAGE plpythonu;
```

Note that because all exceptions from the `plpy.spiexceptions` module inherit from `SPIError`, an `except` clause handling it will catch any database access error.

⁵ <https://www.python.org/dev/peps/pep-0249/>

As an alternative way of handling different error conditions, you can catch the `SPiError` exception and determine the specific error condition inside the `except` block by looking at the `sqlstate` attribute of the exception object. This attribute is a string value containing the “SQLSTATE” error code. This approach provides approximately the same functionality

45.8. Explicit Subtransactions

Recovering from errors caused by database access as described in Section 45.7.2 can lead to an undesirable situation where some operations succeed before one of them fails, and after recovering from that error the data is left in an inconsistent state. PL/Python offers a solution to this problem in the form of explicit subtransactions.

45.8.1. Subtransaction Context Managers

Consider a function that implements a transfer between two accounts:

```
CREATE FUNCTION transfer_funds() RETURNS void AS $$
try:
    plpy.execute("UPDATE accounts SET balance = balance - 100 WHERE
account_name = 'joe'")
    plpy.execute("UPDATE accounts SET balance = balance + 100 WHERE
account_name = 'mary'")
except plpy.SPiError, e:
    result = "error transferring funds: %s" % e.args
else:
    result = "funds transferred correctly"
plan = plpy.prepare("INSERT INTO operations (result) VALUES ($1)",
["text"])
plpy.execute(plan, [result])
$$ LANGUAGE plpythonu;
```

If the second `UPDATE` statement results in an exception being raised, this function will report the error, but the result of the first `UPDATE` will nevertheless be committed. In other words, the funds will be withdrawn from Joe's account, but will not be transferred to Mary's account.

To avoid such issues, you can wrap your `plpy.execute` calls in an explicit subtransaction. The `plpy` module provides a helper object to manage explicit subtransactions that gets created with the `plpy.subtransaction()` function. Objects created by this function implement the context manager interface⁶. Using explicit subtransactions we can rewrite our function as:

```
CREATE FUNCTION transfer_funds2() RETURNS void AS $$
try:
    with plpy.subtransaction():
        plpy.execute("UPDATE accounts SET balance = balance - 100
WHERE account_name = 'joe'")
        plpy.execute("UPDATE accounts SET balance = balance + 100
WHERE account_name = 'mary'")
except plpy.SPiError, e:
    result = "error transferring funds: %s" % e.args
else:
    result = "funds transferred correctly"
plan = plpy.prepare("INSERT INTO operations (result) VALUES ($1)",
["text"])
plpy.execute(plan, [result])
```

⁶ <https://docs.python.org/library/stdtypes.html#context-manager-types>

```
$$ LANGUAGE plpythonu;
```

Note that the use of `try/catch` is still required. Otherwise the exception would propagate to the top of the Python stack and would cause the whole function to abort with a PostgreSQL error, so that the `operations` table would not have any row inserted into it. The subtransaction context manager does not trap errors, it only assures that all database operations executed inside its scope will be atomically committed or rolled back. A rollback of the subtransaction block occurs on any kind of exception exit, not only ones caused by errors originating from database access. A regular Python exception raised inside an explicit subtransaction block would also cause the subtransaction to be rolled back.

45.8.2. Older Python Versions

Context managers syntax using the `with` keyword is available by default in Python 2.6. If using PL/Python with an older Python version, it is still possible to use explicit subtransactions, although not as transparently. You can call the subtransaction manager's `__enter__` and `__exit__` functions using the `enter` and `exit` convenience aliases. The example function that transfers funds could be written as:

```
CREATE FUNCTION transfer_funds_old() RETURNS void AS $$
try:
    subxact = plpy.subtransaction()
    subxact.enter()
    try:
        plpy.execute("UPDATE accounts SET balance = balance - 100
WHERE account_name = 'joe'")
        plpy.execute("UPDATE accounts SET balance = balance + 100
WHERE account_name = 'mary'")
    except:
        import sys
        subxact.exit(*sys.exc_info())
        raise
    else:
        subxact.exit(None, None, None)
except plpy.SPIError, e:
    result = "error transferring funds: %s" % e.args
else:
    result = "funds transferred correctly"

plan = plpy.prepare("INSERT INTO operations (result) VALUES ($1)",
["text"])
plpy.execute(plan, [result])
$$ LANGUAGE plpythonu;
```

Note

Although context managers were implemented in Python 2.5, to use the `with` syntax in that version you need to use a future statement⁷. Because of implementation details, however, you cannot use future statements in PL/Python functions.

45.9. Transaction Management

In a procedure called from the top level or an anonymous code block (`DO` command) called from the top level it is possible to control transactions. To commit the current transaction, call `plpy.commit()`.

⁷ <https://docs.python.org/release/2.5/ref/future.html>

To roll back the current transaction, call `plpy.rollback()`. (Note that it is not possible to run the SQL commands `COMMIT` or `ROLLBACK` via `plpy.execute` or similar. It has to be done using these functions.) After a transaction is ended, a new transaction is automatically started, so there is no separate function for that.

Here is an example:

```
CREATE PROCEDURE transaction_test1()
LANGUAGE plpythonu
AS $$
for i in range(0, 10):
    plpy.execute("INSERT INTO test1 (a) VALUES (%d)" % i)
    if i % 2 == 0:
        plpy.commit()
    else:
        plpy.rollback()
$$;

CALL transaction_test1();
```

Transactions cannot be ended when an explicit subtransaction is active.

45.10. Utility Functions

The `plpy` module also provides the functions

```
plpy.debug(msg, **kwargs)
plpy.log(msg, **kwargs)
plpy.info(msg, **kwargs)
plpy.notice(msg, **kwargs)
plpy.warning(msg, **kwargs)
plpy.error(msg, **kwargs)
plpy.fatal(msg, **kwargs)
```

`plpy.error` and `plpy.fatal` actually raise a Python exception which, if uncaught, propagates out to the calling query, causing the current transaction or subtransaction to be aborted. `raise plpy.Error(msg)` and `raise plpy.Fatal(msg)` are equivalent to calling `plpy.error(msg)` and `plpy.fatal(msg)`, respectively but the `raise` form does not allow passing keyword arguments. The other functions only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the `log_min_messages` and `client_min_messages` configuration variables. See Chapter 19 for more information.

The `msg` argument is given as a positional argument. For backward compatibility, more than one positional argument can be given. In that case, the string representation of the tuple of positional arguments becomes the message reported to the client.

The following keyword-only arguments are accepted:

```
detail
hint
sqlstate
schema_name
table_name
column_name
datatype_name
constraint_name
```

The string representation of the objects passed as keyword-only arguments is used to enrich the messages reported to the client. For example:

```
CREATE FUNCTION raise_custom_exception() RETURNS void AS $$
plpy.error("custom exception message",
           detail="some info about exception",
           hint="hint for users")
$$ LANGUAGE plpythonu;

=# SELECT raise_custom_exception();
ERROR:  plpy.Error: custom exception message
DETAIL:  some info about exception
HINT:   hint for users
CONTEXT: Traceback (most recent call last):
         PL/Python function "raise_custom_exception", line 4, in <module>
           hint="hint for users")
         PL/Python function "raise_custom_exception"
```

Another set of utility functions are `plpy.quote_literal(string)`, `plpy.quote_nullable(string)`, and `plpy.quote_ident(string)`. They are equivalent to the built-in quoting functions described in Section 9.4. They are useful when constructing ad-hoc queries. A PL/Python equivalent of dynamic SQL from Example 42.1 would be:

```
plpy.execute("UPDATE tbl SET %s = %s WHERE key = %s" % (
    plpy.quote_ident(colname),
    plpy.quote_nullable(newvalue),
    plpy.quote_literal(keyvalue)))
```

45.11. Environment Variables

Some of the environment variables that are accepted by the Python interpreter can also be used to affect PL/Python behavior. They would need to be set in the environment of the main PostgreSQL server process, for example in a start script. The available environment variables depend on the version of Python; see the Python documentation for details. At the time of this writing, the following environment variables have an affect on PL/Python, assuming an adequate Python version:

- PYTHONHOME
- PYTHONPATH
- PYTHONY2K
- PYTHONOPTIMIZE
- PYTHONDEBUG
- PYTHONVERBOSE
- PYTHONCASEOK
- PYTHONDONTWRITEBYTECODE
- PYTHONIOENCODING
- PYTHONUSERBASE
- PYTHONHASHSEED

(It appears to be a Python implementation detail beyond the control of PL/Python that some of the environment variables listed on the `python` man page are only effective in a command-line interpreter and not an embedded Python interpreter.)

Chapter 46. Server Programming Interface

The *Server Programming Interface* (SPI) gives writers of user-defined C functions the ability to run SQL commands inside their functions. SPI is a set of interface functions to simplify access to the parser, planner, and executor. SPI also does some memory management.

Note

The available procedural languages provide various means to execute SQL commands from functions. Most of these facilities are based on SPI, so this documentation might be of use for users of those languages as well.

Note that if a command invoked via SPI fails, then control will not be returned to your C function. Rather, the transaction or subtransaction in which your C function executes will be rolled back. (This might seem surprising given that the SPI functions mostly have documented error-return conventions. Those conventions only apply for errors detected within the SPI functions themselves, however.) It is possible to recover control after an error by establishing your own subtransaction surrounding SPI calls that might fail.

SPI functions return a nonnegative result on success (either via a returned integer value or in the global variable `SPI_result`, as described below). On error, a negative result or `NULL` will be returned.

Source code files that use SPI must include the header file `executor/spi.h`.

46.1. Interface Functions

SPI_connect

`SPI_connect`, `SPI_connect_ext` — connect a C function to the SPI manager

Synopsis

```
int SPI_connect(void)
```

```
int SPI_connect_ext(int options)
```

Description

`SPI_connect` opens a connection from a C function invocation to the SPI manager. You must call this function if you want to execute commands through SPI. Some utility SPI functions can be called from unconnected C functions.

`SPI_connect_ext` does the same but has an argument that allows passing option flags. Currently, the following option values are available:

`SPI_OPT_NONATOMIC`

Sets the SPI connection to be *nonatomic*, which means that transaction control calls `SPI_commit`, `SPI_rollback`, and `SPI_start_transaction` are allowed. Otherwise, calling these functions will result in an immediate error.

`SPI_connect()` is equivalent to `SPI_connect_ext(0)`.

Return Value

`SPI_OK_CONNECT`

on success

`SPI_ERROR_CONNECT`

on error

SPI_finish

SPI_finish — disconnect a C function from the SPI manager

Synopsis

```
int SPI_finish(void)
```

Description

SPI_finish closes an existing connection to the SPI manager. You must call this function after completing the SPI operations needed during your C function's current invocation. You do not need to worry about making this happen, however, if you abort the transaction via `elog(ERROR)`. In that case SPI will clean itself up automatically.

Return Value

SPI_OK_FINISH

if properly disconnected

SPI_ERROR_UNCONNECTED

if called from an unconnected C function

SPI_execute

SPI_execute — execute a command

Synopsis

```
int SPI_execute(const char * command, bool read_only, long count)
```

Description

SPI_execute executes the specified SQL command for *count* rows. If *read_only* is true, the command must be read-only, and execution overhead is somewhat reduced.

This function can only be called from a connected C function.

If *count* is zero then the command is executed for all rows that it applies to. If *count* is greater than zero, then no more than *count* rows will be retrieved; execution stops when the count is reached, much like adding a LIMIT clause to the query. For example,

```
SPI_execute("SELECT * FROM foo", true, 5);
```

will retrieve at most 5 rows from the table. Note that such a limit is only effective when the command actually returns rows. For example,

```
SPI_execute("INSERT INTO foo SELECT * FROM bar", false, 5);
```

inserts all rows from bar, ignoring the *count* parameter. However, with

```
SPI_execute("INSERT INTO foo SELECT * FROM bar RETURNING *", false, 5);
```

at most 5 rows would be inserted, since execution would stop after the fifth RETURNING result row is retrieved.

You can pass multiple commands in one string; SPI_execute returns the result for the command executed last. The *count* limit applies to each command separately (even though only the last result will actually be returned). The limit is not applied to any hidden commands generated by rules.

When *read_only* is false, SPI_execute increments the command counter and computes a new *snapshot* before executing each command in the string. The snapshot does not actually change if the current transaction isolation level is SERIALIZABLE or REPEATABLE READ, but in READ COMMITTED mode the snapshot update allows each command to see the results of newly committed transactions from other sessions. This is essential for consistent behavior when the commands are modifying the database.

When *read_only* is true, SPI_execute does not update either the snapshot or the command counter, and it allows only plain SELECT commands to appear in the command string. The commands are executed using the snapshot previously established for the surrounding query. This execution mode is somewhat faster than the read/write mode due to eliminating per-command overhead. It also allows genuinely *stable* functions to be built: since successive executions will all use the same snapshot, there will be no change in the results.

It is generally unwise to mix read-only and read-write commands within a single function using SPI; that could result in very confusing behavior, since the read-only queries would not see the results of any database updates done by the read-write queries.

The actual number of rows for which the (last) command was executed is returned in the global variable `SPI_processed`. If the return value of the function is `SPI_OK_SELECT`, `SPI_OK_INSERT_RETURNING`, `SPI_OK_DELETE_RETURNING`, or `SPI_OK_UPDATE_RETURNING`, then you can use the global pointer `SPITupleTable *SPI_tuptable` to access the result rows. Some utility commands (such as `EXPLAIN`) also return row sets, and `SPI_tuptable` will contain the result in these cases too. Some utility commands (`COPY`, `CREATE TABLE AS`) don't return a row set, so `SPI_tuptable` is `NULL`, but they still return the number of rows processed in `SPI_processed`.

The structure `SPITupleTable` is defined thus:

```
typedef struct
{
    MemoryContext tuptabcxt;    /* memory context of result table
    */
    uint64        allocated;    /* number of allocated vals */
    uint64        free;        /* number of free vals */
    TupleDesc     tupdesc;     /* row descriptor */
    HeapTuple     *vals;       /* rows */
} SPITupleTable;
```

`vals` is an array of pointers to rows. (The number of valid entries is given by `SPI_processed`.) `tupdesc` is a row descriptor which you can pass to SPI functions dealing with rows. `tuptabcxt`, `allocated`, and `free` are internal fields not intended for use by SPI callers.

`SPI_finish` frees all `SPITupleTables` allocated during the current C function. You can free a particular result table earlier, if you are done with it, by calling `SPI_freetuptable`.

Arguments

`const char * command`

string containing command to execute

`bool read_only`

true for read-only execution

`long count`

maximum number of rows to return, or 0 for no limit

Return Value

If the execution of the command was successful then one of the following (nonnegative) values will be returned:

`SPI_OK_SELECT`

if a `SELECT` (but not `SELECT INTO`) was executed

`SPI_OK_SELINTO`

if a `SELECT INTO` was executed

`SPI_OK_INSERT`

if an `INSERT` was executed

SPI_OK_DELETE

if a DELETE was executed

SPI_OK_UPDATE

if an UPDATE was executed

SPI_OK_INSERT_RETURNING

if an INSERT RETURNING was executed

SPI_OK_DELETE_RETURNING

if a DELETE RETURNING was executed

SPI_OK_UPDATE_RETURNING

if an UPDATE RETURNING was executed

SPI_OK_UTILITY

if a utility command (e.g., CREATE TABLE) was executed

SPI_OK_REWRITTEN

if the command was rewritten into another kind of command (e.g., UPDATE became an INSERT) by a rule.

On error, one of the following negative values is returned:

SPI_ERROR_ARGUMENT

if *command* is NULL or *count* is less than 0

SPI_ERROR_COPY

if COPY TO stdout or COPY FROM stdin was attempted

SPI_ERROR_TRANSACTION

if a transaction manipulation command was attempted (BEGIN, COMMIT, ROLLBACK, SAVE-POINT, PREPARE TRANSACTION, COMMIT PREPARED, ROLLBACK PREPARED, or any variant thereof)

SPI_ERROR_OPUNKNOWN

if the command type is unknown (shouldn't happen)

SPI_ERROR_UNCONNECTED

if called from an unconnected C function

Notes

All SPI query-execution functions set both `SPI_processed` and `SPI_tuptable` (just the pointer, not the contents of the structure). Save these two global variables into local C function variables if you need to access the result table of `SPI_execute` or another query-execution function across later calls.

SPI_exec

SPI_exec — execute a read/write command

Synopsis

```
int SPI_exec(const char * command, long count)
```

Description

SPI_exec is the same as SPI_execute, with the latter's *read_only* parameter always taken as false.

Arguments

```
const char * command
```

string containing command to execute

```
long count
```

maximum number of rows to return, or 0 for no limit

Return Value

See SPI_execute.

SPI_execute_with_args

SPI_execute_with_args — execute a command with out-of-line parameters

Synopsis

```
int SPI_execute_with_args(const char *command,
                          int nargs, Oid *argtypes,
                          Datum *values, const char *nulls,
                          bool read_only, long count)
```

Description

SPI_execute_with_args executes a command that might include references to externally supplied parameters. The command text refers to a parameter as $\$n$, and the call specifies data types and values for each such symbol. *read_only* and *count* have the same interpretation as in SPI_execute.

The main advantage of this routine compared to SPI_execute is that data values can be inserted into the command without tedious quoting/escaping, and thus with much less risk of SQL-injection attacks.

Similar results can be achieved with SPI_prepare followed by SPI_execute_plan; however, when using this function the query plan is always customized to the specific parameter values provided. For one-time query execution, this function should be preferred. If the same command is to be executed with many different parameters, either method might be faster, depending on the cost of re-planning versus the benefit of custom plans.

Arguments

*const char * command*

command string

int nargs

number of input parameters ($\$1$, $\$2$, etc.)

*Oid * argtypes*

an array of length *nargs*, containing the OIDs of the data types of the parameters

*Datum * values*

an array of length *nargs*, containing the actual parameter values

*const char * nulls*

an array of length *nargs*, describing which parameters are null

If *nulls* is NULL then SPI_execute_with_args assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

bool read_only

true for read-only execution

long *count*

maximum number of rows to return, or 0 for no limit

Return Value

The return value is the same as for `SPI_execute`.

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute` if successful.

SPI_prepare

SPI_prepare — prepare a statement, without executing it yet

Synopsis

```
SPIPlanPtr SPI_prepare(const char * command, int nargs, Oid  
* argtypes)
```

Description

SPI_prepare creates and returns a prepared statement for the specified command, but doesn't execute the command. The prepared statement can later be executed repeatedly using SPI_execute_plan.

When the same or a similar command is to be executed repeatedly, it is generally advantageous to perform parse analysis only once, and might furthermore be advantageous to re-use an execution plan for the command. SPI_prepare converts a command string into a prepared statement that encapsulates the results of parse analysis. The prepared statement also provides a place for caching an execution plan if it is found that generating a custom plan for each execution is not helpful.

A prepared command can be generalized by writing parameters (\$1, \$2, etc.) in place of what would be constants in a normal command. The actual values of the parameters are then specified when SPI_execute_plan is called. This allows the prepared command to be used over a wider range of situations than would be possible without parameters.

The statement returned by SPI_prepare can be used only in the current invocation of the C function, since SPI_finish frees memory allocated for such a statement. But the statement can be saved for longer using the functions SPI_keepplan or SPI_saveplan.

Arguments

const char * *command*

command string

int *nargs*

number of input parameters (\$1, \$2, etc.)

Oid * *argtypes*

pointer to an array containing the OIDs of the data types of the parameters

Return Value

SPI_prepare returns a non-null pointer to an SPIPlan, which is an opaque struct representing a prepared statement. On error, NULL will be returned, and SPI_result will be set to one of the same error codes used by SPI_execute, except that it is set to SPI_ERROR_ARGUMENT if *command* is NULL, or if *nargs* is less than 0, or if *nargs* is greater than 0 and *argtypes* is NULL.

Notes

If no parameters are defined, a generic plan will be created at the first use of SPI_execute_plan, and used for all subsequent executions as well. If there are parameters, the first few uses of SPI_execute_plan will generate custom plans that are specific to the supplied parameter values. Af-

ter enough uses of the same prepared statement, `SPI_execute_plan` will build a generic plan, and if that is not too much more expensive than the custom plans, it will start using the generic plan instead of re-planning each time. If this default behavior is unsuitable, you can alter it by passing the `CURSOR_OPT_GENERIC_PLAN` or `CURSOR_OPT_CUSTOM_PLAN` flag to `SPI_prepare_cursor`, to force use of generic or custom plans respectively.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, PostgreSQL will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of `search_path` changes from one use to the next, the statement will be re-parsed using the new `search_path`. (This latter behavior is new as of PostgreSQL 9.3.) See `PREPARE` for more information about the behavior of prepared statements.

This function should only be called from a connected C function.

`SPIPlanPtr` is declared as a pointer to an opaque struct type in `spi.h`. It is unwise to try to access its contents directly, as that makes your code much more likely to break in future revisions of PostgreSQL.

The name `SPIPlanPtr` is somewhat historical, since the data structure no longer necessarily contains an execution plan.

SPI_prepare_cursor

SPI_prepare_cursor — prepare a statement, without executing it yet

Synopsis

```
SPIPlanPtr SPI_prepare_cursor(const char * command, int nargs,  
                             Oid * argtypes, int cursorOptions)
```

Description

SPI_prepare_cursor is identical to SPI_prepare, except that it also allows specification of the planner's "cursor options" parameter. This is a bit mask having the values shown in nodes/parsenodes.h for the options field of DeclareCursorStmt. SPI_prepare always takes the cursor options as zero.

Arguments

const char * *command*

command string

int *nargs*

number of input parameters (\$1, \$2, etc.)

Oid * *argtypes*

pointer to an array containing the OIDs of the data types of the parameters

int *cursorOptions*

integer bit mask of cursor options; zero produces default behavior

Return Value

SPI_prepare_cursor has the same return conventions as SPI_prepare.

Notes

Useful bits to set in *cursorOptions* include CURSOR_OPT_SCROLL, CURSOR_OPT_NO_SCROLL, CURSOR_OPT_FAST_PLAN, CURSOR_OPT_GENERIC_PLAN, and CURSOR_OPT_CUSTOM_PLAN. Note in particular that CURSOR_OPT_HOLD is ignored.

SPI_prepare_params

SPI_prepare_params — prepare a statement, without executing it yet

Synopsis

```
SPIPlanPtr SPI_prepare_params(const char * command,
                             ParserSetupHook parserSetup,
                             void * parserSetupArg,
                             int cursorOptions)
```

Description

SPI_prepare_params creates and returns a prepared statement for the specified command, but doesn't execute the command. This function is equivalent to SPI_prepare_cursor, with the addition that the caller can specify parser hook functions to control the parsing of external parameter references.

Arguments

const char * *command*

command string

ParserSetupHook *parserSetup*

Parser hook setup function

void * *parserSetupArg*

pass-through argument for *parserSetup*

int *cursorOptions*

integer bit mask of cursor options; zero produces default behavior

Return Value

SPI_prepare_params has the same return conventions as SPI_prepare.

SPI_getargcount

`SPI_getargcount` — return the number of arguments needed by a statement prepared by `SPI_prepare`

Synopsis

```
int SPI_getargcount(SPIPlanPtr plan)
```

Description

`SPI_getargcount` returns the number of arguments needed to execute a statement prepared by `SPI_prepare`.

Arguments

`SPIPlanPtr plan`

prepared statement (returned by `SPI_prepare`)

Return Value

The count of expected arguments for the *plan*. If the *plan* is `NULL` or invalid, `SPI_result` is set to `SPI_ERROR_ARGUMENT` and -1 is returned.

SPI_getargtypeid

`SPI_getargtypeid` — return the data type OID for an argument of a statement prepared by `SPI_prepare`

Synopsis

```
Oid SPI_getargtypeid(SPIPlanPtr plan, int argIndex)
```

Description

`SPI_getargtypeid` returns the OID representing the type for the *argIndex*'th argument of a statement prepared by `SPI_prepare`. First argument is at index zero.

Arguments

`SPIPlanPtr` *plan*

prepared statement (returned by `SPI_prepare`)

int *argIndex*

zero based index of the argument

Return Value

The type OID of the argument at the given index. If the *plan* is NULL or invalid, or *argIndex* is less than 0 or not less than the number of arguments declared for the *plan*, `SPI_result` is set to `SPI_ERROR_ARGUMENT` and `InvalidOid` is returned.

SPI_is_cursor_plan

`SPI_is_cursor_plan` — return true if a statement prepared by `SPI_prepare` can be used with `SPI_cursor_open`

Synopsis

```
bool SPI_is_cursor_plan(SPIPlanPtr plan)
```

Description

`SPI_is_cursor_plan` returns true if a statement prepared by `SPI_prepare` can be passed as an argument to `SPI_cursor_open`, or false if that is not the case. The criteria are that the *plan* represents one single command and that this command returns tuples to the caller; for example, `SELECT` is allowed unless it contains an `INTO` clause, and `UPDATE` is allowed only if it contains a `RETURNING` clause.

Arguments

`SPIPlanPtr` *plan*

prepared statement (returned by `SPI_prepare`)

Return Value

true or false to indicate if the *plan* can produce a cursor or not, with `SPI_result` set to zero. If it is not possible to determine the answer (for example, if the *plan* is NULL or invalid, or if called when not connected to SPI), then `SPI_result` is set to a suitable error code and false is returned.

SPI_execute_plan

SPI_execute_plan — execute a statement prepared by SPI_prepare

Synopsis

```
int SPI_execute_plan(SPIPlanPtr plan, Datum * values, const char
* nulls,
                    bool read_only, long count)
```

Description

SPI_execute_plan executes a statement prepared by SPI_prepare or one of its siblings. *read_only* and *count* have the same interpretation as in SPI_execute.

Arguments

SPIPlanPtr *plan*

prepared statement (returned by SPI_prepare)

Datum * *values*

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char * *nulls*

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If *nulls* is NULL then SPI_execute_plan assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

bool *read_only*

true for read-only execution

long *count*

maximum number of rows to return, or 0 for no limit

Return Value

The return value is the same as for SPI_execute, with the following additional possible error (negative) results:

SPI_ERROR_ARGUMENT

if *plan* is NULL or invalid, or *count* is less than 0

SPI_ERROR_PARAM

if *values* is NULL and *plan* was prepared with some parameters

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute` if successful.

SPI_execute_plan_with_paramlist

`SPI_execute_plan_with_paramlist` — execute a statement prepared by `SPI_prepare`

Synopsis

```
int SPI_execute_plan_with_paramlist(SPIPlanPtr plan,
                                   ParamListInfo params,
                                   bool read_only,
                                   long count)
```

Description

`SPI_execute_plan_with_paramlist` executes a statement prepared by `SPI_prepare`. This function is equivalent to `SPI_execute_plan` except that information about the parameter values to be passed to the query is presented differently. The `ParamListInfo` representation can be convenient for passing down values that are already available in that format. It also supports use of dynamic parameter sets via hook functions specified in `ParamListInfo`.

Arguments

`SPIPlanPtr` *plan*

prepared statement (returned by `SPI_prepare`)

`ParamListInfo` *params*

data structure containing parameter types and values; NULL if none

bool *read_only*

true for read-only execution

long *count*

maximum number of rows to return, or 0 for no limit

Return Value

The return value is the same as for `SPI_execute_plan`.

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute_plan` if successful.

SPI_execp

SPI_execp — execute a statement in read/write mode

Synopsis

```
int SPI_execp(SPIPlanPtr plan, Datum * values, const char * nulls,
              long count)
```

Description

SPI_execp is the same as SPI_execute_plan, with the latter's *read_only* parameter always taken as *false*.

Arguments

SPIPlanPtr *plan*

prepared statement (returned by SPI_prepare)

Datum * *values*

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char * *nulls*

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If *nulls* is NULL then SPI_execp assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

long *count*

maximum number of rows to return, or 0 for no limit

Return Value

See SPI_execute_plan.

SPI_processed and SPI_tuptable are set as in SPI_execute if successful.

SPI_cursor_open

SPI_cursor_open — set up a cursor using a statement created with SPI_prepare

Synopsis

```
Portal SPI_cursor_open(const char * name, SPIPlanPtr plan,
                      Datum * values, const char * nulls,
                      bool read_only)
```

Description

SPI_cursor_open sets up a cursor (internally, a portal) that will execute a statement prepared by SPI_prepare. The parameters have the same meanings as the corresponding parameters to SPI_execute_plan.

Using a cursor instead of executing the statement directly has two benefits. First, the result rows can be retrieved a few at a time, avoiding memory overrun for queries that return many rows. Second, a portal can outlive the current C function (it can, in fact, live to the end of the current transaction). Returning the portal name to the C function's caller provides a way of returning a row set as result.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

Arguments

const char * name

name for portal, or NULL to let the system select a name

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

Datum * values

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char * nulls

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If nulls is NULL then SPI_cursor_open assumes that no parameters are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding values entry doesn't matter.) Note that nulls is not a text string, just an array: it does not need a '\\0' terminator.

bool read_only

true for read-only execution

Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via elog.

SPI_cursor_open_with_args

SPI_cursor_open_with_args — set up a cursor using a query and parameters

Synopsis

```
Portal SPI_cursor_open_with_args(const char *name,  
                                const char *command,  
                                int nargs, Oid *argtypes,  
                                Datum *values, const char *nulls,  
                                bool read_only, int cursorOptions)
```

Description

SPI_cursor_open_with_args sets up a cursor (internally, a portal) that will execute the specified query. Most of the parameters have the same meanings as the corresponding parameters to SPI_prepare_cursor and SPI_cursor_open.

For one-time query execution, this function should be preferred over SPI_prepare_cursor followed by SPI_cursor_open. If the same command is to be executed with many different parameters, either method might be faster, depending on the cost of re-planning versus the benefit of custom plans.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

Arguments

const char * *name*

name for portal, or NULL to let the system select a name

const char * *command*

command string

int *nargs*

number of input parameters (\$1, \$2, etc.)

Oid * *argtypes*

an array of length *nargs*, containing the OIDs of the data types of the parameters

Datum * *values*

an array of length *nargs*, containing the actual parameter values

const char * *nulls*

an array of length *nargs*, describing which parameters are null

If *nulls* is NULL then SPI_cursor_open_with_args assumes that no parameters are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\0' terminator.

`bool read_only`

true for read-only execution

`int cursorOptions`

integer bit mask of cursor options; zero produces default behavior

Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via `elog`.

SPI_cursor_open_with_paramlist

SPI_cursor_open_with_paramlist — set up a cursor using parameters

Synopsis

```
Portal SPI_cursor_open_with_paramlist(const char *name,  
                                     SPIPlanPtr plan,  
                                     ParamListInfo params,  
                                     bool read_only)
```

Description

SPI_cursor_open_with_paramlist sets up a cursor (internally, a portal) that will execute a statement prepared by SPI_prepare. This function is equivalent to SPI_cursor_open except that information about the parameter values to be passed to the query is presented differently. The ParamListInfo representation can be convenient for passing down values that are already available in that format. It also supports use of dynamic parameter sets via hook functions specified in ParamListInfo.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

Arguments

const char * *name*

name for portal, or NULL to let the system select a name

SPIPlanPtr *plan*

prepared statement (returned by SPI_prepare)

ParamListInfo *params*

data structure containing parameter types and values; NULL if none

bool *read_only*

true for read-only execution

Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via elog.

SPI_cursor_find

SPI_cursor_find — find an existing cursor by name

Synopsis

```
Portal SPI_cursor_find(const char * name)
```

Description

SPI_cursor_find finds an existing portal by name. This is primarily useful to resolve a cursor name returned as text by some other function.

Arguments

```
const char * name
```

name of the portal

Return Value

pointer to the portal with the specified name, or NULL if none was found

SPI_cursor_fetch

SPI_cursor_fetch — fetch some rows from a cursor

Synopsis

```
void SPI_cursor_fetch(Portal portal, bool forward, long count)
```

Description

SPI_cursor_fetch fetches some rows from a cursor. This is equivalent to a subset of the SQL command FETCH (see SPI_scroll_cursor_fetch for more functionality).

Arguments

Portal *portal*

portal containing the cursor

bool *forward*

true for fetch forward, false for fetch backward

long *count*

maximum number of rows to fetch

Return Value

SPI_processed and SPI_tuptable are set as in SPI_execute if successful.

Notes

Fetching backward may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_cursor_move

SPI_cursor_move — move a cursor

Synopsis

```
void SPI_cursor_move(Portal portal, bool forward, long count)
```

Description

SPI_cursor_move skips over some number of rows in a cursor. This is equivalent to a subset of the SQL command MOVE (see SPI_scroll_cursor_move for more functionality).

Arguments

Portal *portal*

portal containing the cursor

bool *forward*

true for move forward, false for move backward

long *count*

maximum number of rows to move

Notes

Moving backward may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_scroll_cursor_fetch

SPI_scroll_cursor_fetch — fetch some rows from a cursor

Synopsis

```
void SPI_scroll_cursor_fetch(Portal portal,
    FetchDirection direction,
                               long count)
```

Description

SPI_scroll_cursor_fetch fetches some rows from a cursor. This is equivalent to the SQL command FETCH.

Arguments

Portal *portal*

portal containing the cursor

FetchDirection *direction*

one of FETCH_FORWARD, FETCH_BACKWARD, FETCH_ABSOLUTE or FETCH_RELATIVE

long *count*

number of rows to fetch for FETCH_FORWARD or FETCH_BACKWARD; absolute row number to fetch for FETCH_ABSOLUTE; or relative row number to fetch for FETCH_RELATIVE

Return Value

SPI_processed and SPI_tuptable are set as in SPI_execute if successful.

Notes

See the SQL FETCH command for details of the interpretation of the *direction* and *count* parameters.

Direction values other than FETCH_FORWARD may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_scroll_cursor_move

SPI_scroll_cursor_move — move a cursor

Synopsis

```
void SPI_scroll_cursor_move(Portal portal,
    FetchDirection direction,
                           long count)
```

Description

SPI_scroll_cursor_move skips over some number of rows in a cursor. This is equivalent to the SQL command MOVE.

Arguments

Portal *portal*

portal containing the cursor

FetchDirection *direction*

one of FETCH_FORWARD, FETCH_BACKWARD, FETCH_ABSOLUTE or FETCH_RELATIVE

long *count*

number of rows to move for FETCH_FORWARD or FETCH_BACKWARD; absolute row number to move to for FETCH_ABSOLUTE; or relative row number to move to for FETCH_RELATIVE

Return Value

SPI_processed is set as in SPI_execute if successful. SPI_tuptable is set to NULL, since no rows are returned by this function.

Notes

See the SQL FETCH command for details of the interpretation of the *direction* and *count* parameters.

Direction values other than FETCH_FORWARD may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_cursor_close

SPI_cursor_close — close a cursor

Synopsis

```
void SPI_cursor_close(Portal portal)
```

Description

SPI_cursor_close closes a previously created cursor and releases its portal storage.

All open cursors are closed automatically at the end of a transaction. SPI_cursor_close need only be invoked if it is desirable to release resources sooner.

Arguments

Portal *portal*

portal containing the cursor

SPI_keepplan

SPI_keepplan — save a prepared statement

Synopsis

```
int SPI_keepplan(SPIPlanPtr plan)
```

Description

SPI_keepplan saves a passed statement (prepared by SPI_prepare) so that it will not be freed by SPI_finish nor by the transaction manager. This gives you the ability to reuse prepared statements in the subsequent invocations of your C function in the current session.

Arguments

SPIPlanPtr *plan*

the prepared statement to be saved

Return Value

0 on success; SPI_ERROR_ARGUMENT if *plan* is NULL or invalid

Notes

The passed-in statement is relocated to permanent storage by means of pointer adjustment (no data copying is required). If you later wish to delete it, use SPI_freeplan on it.

SPI_saveplan

SPI_saveplan — save a prepared statement

Synopsis

```
SPIPlanPtr SPI_saveplan(SPIPlanPtr plan)
```

Description

SPI_saveplan copies a passed statement (prepared by SPI_prepare) into memory that will not be freed by SPI_finish nor by the transaction manager, and returns a pointer to the copied statement. This gives you the ability to reuse prepared statements in the subsequent invocations of your C function in the current session.

Arguments

```
SPIPlanPtr plan
```

the prepared statement to be saved

Return Value

Pointer to the copied statement; or NULL if unsuccessful. On error, SPI_result is set thus:

```
SPI_ERROR_ARGUMENT
```

if *plan* is NULL or invalid

```
SPI_ERROR_UNCONNECTED
```

if called from an unconnected C function

Notes

The originally passed-in statement is not freed, so you might wish to do SPI_freeplan on it to avoid leaking memory until SPI_finish.

In most cases, SPI_keepplan is preferred to this function, since it accomplishes largely the same result without needing to physically copy the prepared statement's data structures.

SPI_register_relation

SPI_register_relation — make an ephemeral named relation available by name in SPI queries

Synopsis

```
int SPI_register_relation(EphemeralNamedRelation enr)
```

Description

SPI_register_relation makes an ephemeral named relation, with associated information, available to queries planned and executed through the current SPI connection.

Arguments

EphemeralNamedRelation *enr*

the ephemeral named relation registry entry

Return Value

If the execution of the command was successful then the following (nonnegative) value will be returned:

SPI_OK_REL_REGISTER

if the relation has been successfully registered by name

On error, one of the following negative values is returned:

SPI_ERROR_ARGUMENT

if *enr* is NULL or its name field is NULL

SPI_ERROR_UNCONNECTED

if called from an unconnected C function

SPI_ERROR_REL_DUPLICATE

if the name specified in the name field of *enr* is already registered for this connection

SPI_unregister_relation

SPI_unregister_relation — remove an ephemeral named relation from the registry

Synopsis

```
int SPI_unregister_relation(const char * name)
```

Description

SPI_unregister_relation removes an ephemeral named relation from the registry for the current connection.

Arguments

```
const char * name
```

the relation registry entry name

Return Value

If the execution of the command was successful then the following (nonnegative) value will be returned:

```
SPI_OK_REL_UNREGISTER
```

if the tuplestore has been successfully removed from the registry

On error, one of the following negative values is returned:

```
SPI_ERROR_ARGUMENT
```

if *name* is NULL

```
SPI_ERROR_UNCONNECTED
```

if called from an unconnected C function

```
SPI_ERROR_REL_NOT_FOUND
```

if *name* is not found in the registry for the current connection

SPI_register_trigger_data

SPI_register_trigger_data — make ephemeral trigger data available in SPI queries

Synopsis

```
int SPI_register_trigger_data(TriggerData *tdata)
```

Description

SPI_register_trigger_data makes any ephemeral relations captured by a trigger available to queries planned and executed through the current SPI connection. Currently, this means the transition tables captured by an AFTER trigger defined with a REFERENCING OLD/NEW TABLE AS ... clause. This function should be called by a PL trigger handler function after connecting.

Arguments

TriggerData *tdata

the TriggerData object passed to a trigger handler function as fcinfo->context

Return Value

If the execution of the command was successful then the following (nonnegative) value will be returned:

SPI_OK_TD_REGISTER

if the captured trigger data (if any) has been successfully registered

On error, one of the following negative values is returned:

SPI_ERROR_ARGUMENT

if tdata is NULL

SPI_ERROR_UNCONNECTED

if called from an unconnected C function

SPI_ERROR_REL_DUPLICATE

if the name of any trigger data transient relation is already registered for this connection

46.2. Interface Support Functions

The functions described here provide an interface for extracting information from result sets returned by SPI_execute and other SPI functions.

All functions described in this section can be used by both connected and unconnected C functions.

SPI_fname

SPI_fname — determine the column name for the specified column number

Synopsis

```
char * SPI_fname(TupleDesc rowdesc, int colnumber)
```

Description

SPI_fname returns a copy of the column name of the specified column. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

The column name; NULL if `colnumber` is out of range. `SPI_result` set to `SPI_ERROR_NOATTRIBUTE` on error.

SPI_fnumber

`SPI_fnumber` — determine the column number for the specified column name

Synopsis

```
int SPI_fnumber(TupleDesc rowdesc, const char * colname)
```

Description

`SPI_fnumber` returns the column number for the column with the specified name.

If `colname` refers to a system column (e.g., `ctid`) then the appropriate negative column number will be returned. The caller should be careful to test the return value for exact equality to `SPI_ERROR_NOATTRIBUTE` to detect an error; testing the result for less than or equal to 0 is not correct unless system columns should be rejected.

Arguments

`TupleDesc rowdesc`

input row description

`const char * colname`

column name

Return Value

Column number (count starts at 1 for user-defined columns), or `SPI_ERROR_NOATTRIBUTE` if the named column was not found.

SPI_getvalue

SPI_getvalue — return the string value of the specified column

Synopsis

```
char * SPI_getvalue(HeapTuple row, TupleDesc rowdesc,  
int colnumber)
```

Description

SPI_getvalue returns the string representation of the value of the specified column.

The result is returned in memory allocated using `palloc`. (You can use `pfree` to release the memory when you don't need it anymore.)

Arguments

HeapTuple *row*

input row to be examined

TupleDesc *rowdesc*

input row description

int *colnumber*

column number (count starts at 1)

Return Value

Column value, or NULL if the column is null, *colnumber* is out of range (SPI_result is set to SPI_ERROR_NOATTRIBUTE), or no output function is available (SPI_result is set to SPI_ERROR_NOOUTFUNC).

SPI_getbinval

SPI_getbinval — return the binary value of the specified column

Synopsis

```
Datum SPI_getbinval(HeapTuple row, TupleDesc rowdesc,
    int colnumber,
                    bool * isnull)
```

Description

SPI_getbinval returns the value of the specified column in the internal form (as type Datum).

This function does not allocate new space for the datum. In the case of a pass-by-reference data type, the return value will be a pointer into the passed row.

Arguments

HeapTuple *row*

input row to be examined

TupleDesc *rowdesc*

input row description

int *colnumber*

column number (count starts at 1)

bool * *isnull*

flag for a null value in the column

Return Value

The binary value of the column is returned. The variable pointed to by *isnull* is set to true if the column is null, else to false.

SPI_result is set to SPI_ERROR_NOATTRIBUTE on error.

SPI_gettype

`SPI_gettype` — return the data type name of the specified column

Synopsis

```
char * SPI_gettype(TupleDesc rowdesc, int colnumber)
```

Description

`SPI_gettype` returns a copy of the data type name of the specified column. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

The data type name of the specified column, or NULL on error. `SPI_result` is set to `SPI_ERROR_NOATTRIBUTE` on error.

SPI_gettypeid

SPI_gettypeid — return the data type OID of the specified column

Synopsis

```
Oid SPI_gettypeid(TupleDesc rowdesc, int colnumber)
```

Description

SPI_gettypeid returns the OID of the data type of the specified column.

Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

The OID of the data type of the specified column or `InvalidOid` on error. On error, `SPI_result` is set to `SPI_ERROR_NOATTRIBUTE`.

SPI_getrelname

SPI_getrelname — return the name of the specified relation

Synopsis

```
char * SPI_getrelname(Relation rel)
```

Description

SPI_getrelname returns a copy of the name of the specified relation. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

Arguments

Relation *rel*

input relation

Return Value

The name of the specified relation.

SPI_getnspname

SPI_getnspname — return the namespace of the specified relation

Synopsis

```
char * SPI_getnspname(Relation rel)
```

Description

SPI_getnspname returns a copy of the name of the namespace that the specified `Relation` belongs to. This is equivalent to the relation's schema. You should `pfree` the return value of this function when you are finished with it.

Arguments

`Relation rel`

input relation

Return Value

The name of the specified relation's namespace.

SPI_result_code_string

SPI_result_code_string — return error code as string

Synopsis

```
const char * SPI_result_code_string(int code);
```

Description

SPI_result_code_string returns a string representation of the result code returned by various SPI functions or stored in SPI_result.

Arguments

```
int code
```

result code

Return Value

A string representation of the result code.

46.3. Memory Management

PostgreSQL allocates memory within *memory contexts*, which provide a convenient method of managing allocations made in many different places that need to live for differing amounts of time. Destroying a context releases all the memory that was allocated in it. Thus, it is not necessary to keep track of individual objects to avoid memory leaks; instead only a relatively small number of contexts have to be managed. `palloc` and related functions allocate memory from the “current” context.

`SPI_connect` creates a new memory context and makes it current. `SPI_finish` restores the previous current memory context and destroys the context created by `SPI_connect`. These actions ensure that transient memory allocations made inside your C function are reclaimed at C function exit, avoiding memory leakage.

However, if your C function needs to return an object in allocated memory (such as a value of a pass-by-reference data type), you cannot allocate that memory using `palloc`, at least not while you are connected to SPI. If you try, the object will be deallocated by `SPI_finish`, and your C function will not work reliably. To solve this problem, use `SPI_palloc` to allocate memory for your return object. `SPI_palloc` allocates memory in the “upper executor context”, that is, the memory context that was current when `SPI_connect` was called, which is precisely the right context for a value returned from your C function. Several of the other utility functions described in this section also return objects created in the upper executor context.

When `SPI_connect` is called, the private context of the C function, which is created by `SPI_connect`, is made the current context. All allocations made by `palloc`, `repalloc`, or SPI utility functions (except as described in this section) are made in this context. When a C function disconnects from the SPI manager (via `SPI_finish`) the current context is restored to the upper executor context, and all allocations made in the C function memory context are freed and cannot be used any more.

SPI_palloc

SPI_palloc — allocate memory in the upper executor context

Synopsis

```
void * SPI_palloc(Size size)
```

Description

SPI_palloc allocates memory in the upper executor context.

This function can only be used while connected to SPI. Otherwise, it throws an error.

Arguments

Size *size*

size in bytes of storage to allocate

Return Value

pointer to new storage space of the specified size

SPI_realloc

SPI_realloc — reallocate memory in the upper executor context

Synopsis

```
void * SPI_realloc(void * pointer, Size size)
```

Description

SPI_realloc changes the size of a memory segment previously allocated using SPI_palloc.

This function is no longer different from plain realloc. It's kept just for backward compatibility of existing code.

Arguments

```
void * pointer
```

pointer to existing storage to change

```
Size size
```

size in bytes of storage to allocate

Return Value

pointer to new storage space of specified size with the contents copied from the existing area

SPI_pfree

SPI_pfree — free memory in the upper executor context

Synopsis

```
void SPI_pfree(void * pointer)
```

Description

SPI_pfree frees memory previously allocated using SPI_palloc or SPI_realloc.

This function is no longer different from plain pfree. It's kept just for backward compatibility of existing code.

Arguments

```
void * pointer
```

pointer to existing storage to free

SPI_copytuple

SPI_copytuple — make a copy of a row in the upper executor context

Synopsis

```
HeapTuple SPI_copytuple(HeapTuple row)
```

Description

SPI_copytuple makes a copy of a row in the upper executor context. This is normally used to return a modified row from a trigger. In a function declared to return a composite type, use SPI_returntuple instead.

This function can only be used while connected to SPI. Otherwise, it returns NULL and sets SPI_result to SPI_ERROR_UNCONNECTED.

Arguments

HeapTuple *row*

row to be copied

Return Value

the copied row, or NULL on error (see SPI_result for an error indication)

SPI_returntuple

SPI_returntuple — prepare to return a tuple as a Datum

Synopsis

```
HeapTupleHeader SPI_returntuple(HeapTuple row, TupleDesc rowdesc)
```

Description

SPI_returntuple makes a copy of a row in the upper executor context, returning it in the form of a row type Datum. The returned pointer need only be converted to Datum via PointerGetDatum before returning.

This function can only be used while connected to SPI. Otherwise, it returns NULL and sets SPI_result to SPI_ERROR_UNCONNECTED.

Note that this should be used for functions that are declared to return composite types. It is not used for triggers; use SPI_copytuple for returning a modified row in a trigger.

Arguments

HeapTuple *row*

row to be copied

TupleDesc *rowdesc*

descriptor for row (pass the same descriptor each time for most effective caching)

Return Value

HeapTupleHeader pointing to copied row, or NULL on error (see SPI_result for an error indication)

SPI_modifytuple

SPI_modifytuple — create a row by replacing selected fields of a given row

Synopsis

```
HeapTuple SPI_modifytuple(Relation rel, HeapTuple row, int ncols,
                          int * colnum, Datum * values, const char
                          * nulls)
```

Description

SPI_modifytuple creates a new row by substituting new values for selected columns, copying the original row's columns at other positions. The input row is not modified. The new row is returned in the upper executor context.

This function can only be used while connected to SPI. Otherwise, it returns NULL and sets SPI_result to SPI_ERROR_UNCONNECTED.

Arguments

Relation *rel*

Used only as the source of the row descriptor for the row. (Passing a relation rather than a row descriptor is a misfeature.)

HeapTuple *row*

row to be modified

int *ncols*

number of columns to be changed

int * *colnum*

an array of length *ncols*, containing the numbers of the columns that are to be changed (column numbers start at 1)

Datum * *values*

an array of length *ncols*, containing the new values for the specified columns

const char * *nulls*

an array of length *ncols*, describing which new values are null

If *nulls* is NULL then SPI_modifytuple assumes that no new values are null. Otherwise, each entry of the *nulls* array should be ' ' if the corresponding new value is non-null, or 'n' if the corresponding new value is null. (In the latter case, the actual value in the corresponding *values* entry doesn't matter.) Note that *nulls* is not a text string, just an array: it does not need a '\\0' terminator.

Return Value

new row with modifications, allocated in the upper executor context, or NULL on error (see SPI_result for an error indication)

On error, `SPI_result` is set as follows:

`SPI_ERROR_ARGUMENT`

if `rel` is NULL, or if `row` is NULL, or if `ncols` is less than or equal to 0, or if `colnum` is NULL, or if `values` is NULL.

`SPI_ERROR_NOATTRIBUTE`

if `colnum` contains an invalid column number (less than or equal to 0 or greater than the number of columns in `row`)

`SPI_ERROR_UNCONNECTED`

if SPI is not active

SPI_freetuple

`SPI_freetuple` — free a row allocated in the upper executor context

Synopsis

```
void SPI_freetuple(HeapTuple row)
```

Description

`SPI_freetuple` frees a row previously allocated in the upper executor context.

This function is no longer different from plain `heap_freetuple`. It's kept just for backward compatibility of existing code.

Arguments

HeapTuple *row*

row to free

SPI_freetuptable

`SPI_freetuptable` — free a row set created by `SPI_execute` or a similar function

Synopsis

```
void SPI_freetuptable(SPITupleTable * tuptable)
```

Description

`SPI_freetuptable` frees a row set created by a prior SPI command execution function, such as `SPI_execute`. Therefore, this function is often called with the global variable `SPI_tuptable` as argument.

This function is useful if an SPI-using C function needs to execute multiple commands and does not want to keep the results of earlier commands around until it ends. Note that any unfreed row sets will be freed anyway at `SPI_finish`. Also, if a subtransaction is started and then aborted within execution of an SPI-using C function, SPI automatically frees any row sets created while the subtransaction was running.

Beginning in PostgreSQL 9.3, `SPI_freetuptable` contains guard logic to protect against duplicate deletion requests for the same row set. In previous releases, duplicate deletions would lead to crashes.

Arguments

```
SPITupleTable * tuptable
```

pointer to row set to free, or NULL to do nothing

SPI_freeplan

SPI_freeplan — free a previously saved prepared statement

Synopsis

```
int SPI_freeplan(SPIPlanPtr plan)
```

Description

SPI_freeplan releases a prepared statement previously returned by SPI_prepare or saved by SPI_keepplan or SPI_saveplan.

Arguments

SPIPlanPtr *plan*

pointer to statement to free

Return Value

0 on success; SPI_ERROR_ARGUMENT if *plan* is NULL or invalid

46.4. Transaction Management

It is not possible to run transaction control commands such as COMMIT and ROLLBACK through SPI functions such as SPI_execute. There are, however, separate interface functions that allow transaction control through SPI.

It is not generally safe and sensible to start and end transactions in arbitrary user-defined SQL-callable functions without taking into account the context in which they are called. For example, a transaction boundary in the middle of a function that is part of a complex SQL expression that is part of some SQL command will probably result in obscure internal errors or crashes. The interface functions presented here are primarily intended to be used by procedural language implementations to support transaction management in SQL-level procedures that are invoked by the CALL command, taking the context of the CALL invocation into account. SPI-using procedures implemented in C can implement the same logic, but the details of that are beyond the scope of this documentation.

SPI_commit

SPI_commit, SPI_commit_and_chain — commit the current transaction

Synopsis

```
void SPI_commit(void)
```

```
void SPI_commit_and_chain(void)
```

Description

SPI_commit commits the current transaction. It is approximately equivalent to running the SQL command COMMIT. After a transaction is committed, a new transaction has to be started using SPI_start_transaction before further database actions can be executed.

SPI_commit_and_chain is the same, but a new transaction is immediately started with the same transaction characteristics as the just finished one, like with the SQL command COMMIT AND CHAIN.

These functions can only be executed if the SPI connection has been set as nonatomic in the call to SPI_connect_ext.

SPI_rollback

SPI_rollback, SPI_rollback_and_chain — abort the current transaction

Synopsis

```
void SPI_rollback(void)
```

```
void SPI_rollback_and_chain(void)
```

Description

SPI_rollback rolls back the current transaction. It is approximately equivalent to running the SQL command ROLLBACK. After a transaction is rolled back, a new transaction has to be started using SPI_start_transaction before further database actions can be executed.

SPI_rollback_and_chain is the same, but a new transaction is immediately started with the same transaction characteristics as the just finished one, like with the SQL command ROLLBACK AND CHAIN.

These functions can only be executed if the SPI connection has been set as nonatomic in the call to SPI_connect_ext.

SPI_start_transaction

SPI_start_transaction — start a new transaction

Synopsis

```
void SPI_start_transaction(void)
```

Description

SPI_start_transaction starts a new transaction. It can only be called after SPI_commit or SPI_rollback, as there is no transaction active at that point. Normally, when an SPI-using procedure is called, there is already a transaction active, so attempting to start another one before closing out the current one will result in an error.

This function can only be executed if the SPI connection has been set as nonatomic in the call to SPI_connect_ext.

46.5. Visibility of Data Changes

The following rules govern the visibility of data changes in functions that use SPI (or any other C function):

- During the execution of an SQL command, any data changes made by the command are invisible to the command itself. For example, in:

```
INSERT INTO a SELECT * FROM a;
```

the inserted rows are invisible to the SELECT part.

- Changes made by a command C are visible to all commands that are started after C, no matter whether they are started inside C (during the execution of C) or after C is done.
- Commands executed via SPI inside a function called by an SQL command (either an ordinary function or a trigger) follow one or the other of the above rules depending on the read/write flag passed to SPI. Commands executed in read-only mode follow the first rule: they cannot see changes of the calling command. Commands executed in read-write mode follow the second rule: they can see all changes made so far.
- All standard procedural languages set the SPI read-write mode depending on the volatility attribute of the function. Commands of STABLE and IMMUTABLE functions are done in read-only mode, while commands of VOLATILE functions are done in read-write mode. While authors of C functions are able to violate this convention, it's unlikely to be a good idea to do so.

The next section contains an example that illustrates the application of these rules.

46.6. Examples

This section contains a very simple example of SPI usage. The C function `execq` takes an SQL command as its first argument and a row count as its second, executes the command using `SPI_exec` and returns the number of rows that were processed by the command. You can find more complex examples for SPI in the source tree in `src/test/regress/regress.c` and in the `spi` module.

```
#include "postgres.h"
```

```
#include "executor/spi.h"
#include "utils/builtins.h"

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(execq);

Datum
execq(PG_FUNCTION_ARGS)
{
    char *command;
    int cnt;
    int ret;
    uint64 proc;

    /* Convert given text object to a C string */
    command = text_to_cstring(PG_GETARG_TEXT_PP(0));
    cnt = PG_GETARG_INT32(1);

    SPI_connect();

    ret = SPI_exec(command, cnt);

    proc = SPI_processed;

    /*
     * If some rows were fetched, print them via elog(INFO).
     */
    if (ret > 0 && SPI_tuptable != NULL)
    {
        TupleDesc tupdesc = SPI_tuptable->tupdesc;
        SPITupleTable *tuptable = SPI_tuptable;
        char buf[8192];
        uint64 j;

        for (j = 0; j < proc; j++)
        {
            HeapTuple tuple = tuptable->vals[j];
            int i;

            for (i = 1, buf[0] = 0; i <= tupdesc->natts; i++)
                snprintf(buf + strlen(buf), sizeof(buf) -
strlen(buf), " %s%s",
                        SPI_getvalue(tuple, tupdesc, i),
                        (i == tupdesc->natts) ? " " : " |");
            elog(INFO, "EXECQ: %s", buf);
        }
    }

    SPI_finish();
    pfree(command);

    PG_RETURN_INT64(proc);
}
```

This is how you declare the function after having compiled it into a shared library (details are in Section 37.10.5):

```
CREATE FUNCTION execq(text, integer) RETURNS int8
  AS 'filename'
  LANGUAGE C STRICT;
```

Here is a sample session:

```
=> SELECT execq('CREATE TABLE a (x integer)', 0);
execq
-----
      0
(1 row)

=> INSERT INTO a VALUES (execq('INSERT INTO a VALUES (0)', 0));
INSERT 0 1
=> SELECT execq('SELECT * FROM a', 0);
INFO: EXECQ: 0    -- inserted by execq
INFO: EXECQ: 1    -- returned by execq and inserted by upper
INSERT

execq
-----
      2
(1 row)

=> SELECT execq('INSERT INTO a SELECT x + 2 FROM a', 1);
execq
-----
      1
(1 row)

=> SELECT execq('SELECT * FROM a', 10);
INFO: EXECQ: 0
INFO: EXECQ: 1
INFO: EXECQ: 2    -- 0 + 2, only one row inserted - as specified

execq
-----
      3          -- 10 is the max value only, 3 is the real
number of rows
(1 row)

=> DELETE FROM a;
DELETE 3
=> INSERT INTO a VALUES (execq('SELECT * FROM a', 0) + 1);
INSERT 0 1
=> SELECT * FROM a;
 x
---
  1          -- no rows in a (0) + 1
(1 row)

=> INSERT INTO a VALUES (execq('SELECT * FROM a', 0) + 1);
INFO: EXECQ: 1
INSERT 0 1
=> SELECT * FROM a;
 x
```

```

---
1
2          -- there was one row in a + 1
(2 rows)

-- This demonstrates the data changes visibility rule:

=> INSERT INTO a SELECT execq('SELECT * FROM a', 0) * x FROM a;
INFO: EXECQ: 1
INFO: EXECQ: 2
INFO: EXECQ: 1
INFO: EXECQ: 2
INFO: EXECQ: 2
INSERT 0 2
=> SELECT * FROM a;
x
---
1
2
2          -- 2 rows * 1 (x in first row)
6          -- 3 rows (2 + 1 just inserted) * 2 (x in
second row)
(4 rows)          ^^^^^^
                      rows visible to execq() in different
invocations

```

Chapter 47. Background Worker Processes

PostgreSQL can be extended to run user-supplied code in separate processes. Such processes are started, stopped and monitored by `postgres`, which permits them to have a lifetime closely linked to the server's status. These processes have the option to attach to PostgreSQL's shared memory area and to connect to databases internally; they can also run multiple transactions serially, just like a regular client-connected server process. Also, by linking to `libpq` they can connect to the server and behave like a regular client application.

Warning

There are considerable robustness and security risks in using background worker processes because, being written in the C language, they have unrestricted access to data. Administrators wishing to enable modules that include background worker processes should exercise extreme caution. Only carefully audited modules should be permitted to run background worker processes.

Background workers can be initialized at the time that PostgreSQL is started by including the module name in `shared_preload_libraries`. A module wishing to run a background worker can register it by calling `RegisterBackgroundWorker(BackgroundWorker *worker)` from its `_PG_init()`. Background workers can also be started after the system is up and running by calling the function `RegisterDynamicBackgroundWorker(BackgroundWorker *worker, BackgroundWorkerHandle **handle)`. Unlike `RegisterBackgroundWorker`, which can only be called from within the postmaster, `RegisterDynamicBackgroundWorker` must be called from a regular backend or another background worker.

The structure `BackgroundWorker` is defined thus:

```
typedef void (*bgworker_main_type)(Datum main_arg);
typedef struct BackgroundWorker
{
    char          bgw_name[BGW_MAXLEN];
    char          bgw_type[BGW_MAXLEN];
    int           bgw_flags;
    BgWorkerStartTime bgw_start_time;
    int           bgw_restart_time;          /* in seconds, or
BGW_NEVER_RESTART */
    char          bgw_library_name[BGW_MAXLEN];
    char          bgw_function_name[BGW_MAXLEN];
    Datum        bgw_main_arg;
    char          bgw_extra[BGW_EXTRALEN];
    int           bgw_notify_pid;
} BackgroundWorker;
```

`bgw_name` and `bgw_type` are strings to be used in log messages, process listings and similar contexts. `bgw_type` should be the same for all background workers of the same type, so that it is possible to group such workers in a process listing, for example. `bgw_name` on the other hand can contain additional information about the specific process. (Typically, the string for `bgw_name` will contain the type somehow, but that is not strictly required.)

`bgw_flags` is a bitwise-or'd bit mask indicating the capabilities that the module wants. Possible values are:

BGWORKER_SHMEM_ACCESS

Requests shared memory access. Workers without shared memory access cannot access any of PostgreSQL's shared data structures, such as heavyweight or lightweight locks, shared buffers, or any custom data structures which the worker itself may wish to create and use.

BGWORKER_BACKEND_DATABASE_CONNECTION

Requests the ability to establish a database connection through which it can later run transactions and queries. A background worker using `BGWORKER_BACKEND_DATABASE_CONNECTION` to connect to a database must also attach shared memory using `BGWORKER_SHMEM_ACCESS`, or worker start-up will fail.

`bgw_start_time` is the server state during which `postgres` should start the process; it can be one of `BgWorkerStart_PostmasterStart` (start as soon as `postgres` itself has finished its own initialization; processes requesting this are not eligible for database connections), `BgWorkerStart_ConsistentState` (start as soon as a consistent state has been reached in a hot standby, allowing processes to connect to databases and run read-only queries), and `BgWorkerStart_RecoveryFinished` (start as soon as the system has entered normal read-write state). Note the last two values are equivalent in a server that's not a hot standby. Note that this setting only indicates when the processes are to be started; they do not stop when a different state is reached.

`bgw_restart_time` is the interval, in seconds, that `postgres` should wait before restarting the process, in case it crashes. It can be any positive value, or `BGW_NEVER_RESTART`, indicating not to restart the process in case of a crash.

`bgw_library_name` is the name of a library in which the initial entry point for the background worker should be sought. The named library will be dynamically loaded by the worker process and `bgw_function_name` will be used to identify the function to be called. If loading a function from the core code, this must be set to "postgres".

`bgw_function_name` is the name of a function in a dynamically loaded library which should be used as the initial entry point for a new background worker.

`bgw_main_arg` is the `Datum` argument to the background worker main function. This main function should take a single argument of type `Datum` and return `void`. `bgw_main_arg` will be passed as the argument. In addition, the global variable `MyBgworkerEntry` points to a copy of the `BackgroundWorker` structure passed at registration time; the worker may find it helpful to examine this structure.

On Windows (and anywhere else where `EXEC_BACKEND` is defined) or in dynamic background workers it is not safe to pass a `Datum` by reference, only by value. If an argument is required, it is safest to pass an `int32` or other small value and use that as an index into an array allocated in shared memory. If a value like a `cstring` or `text` is passed then the pointer won't be valid from the new background worker process.

`bgw_extra` can contain extra data to be passed to the background worker. Unlike `bgw_main_arg`, this data is not passed as an argument to the worker's main function, but it can be accessed via `MyBgworkerEntry`, as discussed above.

`bgw_notify_pid` is the PID of a PostgreSQL backend process to which the postmaster should send `SIGUSR1` when the process is started or exits. It should be 0 for workers registered at postmaster startup time, or when the backend registering the worker does not wish to wait for the worker to start up. Otherwise, it should be initialized to `MyProcPid`.

Once running, the process can connect to a database by calling `BackgroundWorkerInitializeConnection(char *dbname, char *username, uint32 flags)` or `BackgroundWorkerInitializeConnectionByOid(Oid dboid, Oid useroid, uint32 flags)`. This allows the process to run transactions and queries using the SPI interface. If `dbname` is `NULL` or `dboid` is `InvalidOid`, the session is not connected to any particular database, but

shared catalogs can be accessed. If `username` is `NULL` or `userid` is `InvalidOid`, the process will run as the superuser created during `initdb`. If `BGWORKER_BYPASS_ALLOWCONN` is specified as `flags` it is possible to bypass the restriction to connect to databases not allowing user connections. A background worker can only call one of these two functions, and only once. It is not possible to switch databases.

Signals are initially blocked when control reaches the background worker's main function, and must be unblocked by it; this is to allow the process to customize its signal handlers, if necessary. Signals can be unblocked in the new process by calling `BackgroundWorkerUnblockSignals` and blocked by calling `BackgroundWorkerBlockSignals`.

If `bgw_restart_time` for a background worker is configured as `BGW_NEVER_RESTART`, or if it exits with an exit code of 0 or is terminated by `TerminateBackgroundWorker`, it will be automatically unregistered by the postmaster on exit. Otherwise, it will be restarted after the time period configured via `bgw_restart_time`, or immediately if the postmaster reinitializes the cluster due to a backend failure. Backends which need to suspend execution only temporarily should use an interruptible sleep rather than exiting; this can be achieved by calling `WaitLatch()`. Make sure the `WL_POSTMASTER_DEATH` flag is set when calling that function, and verify the return code for a prompt exit in the emergency case that `postgres` itself has terminated.

When a background worker is registered using the `RegisterDynamicBackgroundWorker` function, it is possible for the backend performing the registration to obtain information regarding the status of the worker. Backends wishing to do this should pass the address of a `BackgroundWorkerHandle *` as the second argument to `RegisterDynamicBackgroundWorker`. If the worker is successfully registered, this pointer will be initialized with an opaque handle that can subsequently be passed to `GetBackgroundWorkerPid(BackgroundWorkerHandle *, pid_t *)` or `TerminateBackgroundWorker(BackgroundWorkerHandle *)`. `GetBackgroundWorkerPid` can be used to poll the status of the worker: a return value of `BGWH_NOT_YET_STARTED` indicates that the worker has not yet been started by the postmaster; `BGWH_STOPPED` indicates that it has been started but is no longer running; and `BGWH_STARTED` indicates that it is currently running. In this last case, the PID will also be returned via the second argument. `TerminateBackgroundWorker` causes the postmaster to send `SIGTERM` to the worker if it is running, and to unregister it as soon as it is not.

In some cases, a process which registers a background worker may wish to wait for the worker to start up. This can be accomplished by initializing `bgw_notify_pid` to `MyProcPid` and then passing the `BackgroundWorkerHandle *` obtained at registration time to `WaitForBackgroundWorkerStartup(BackgroundWorkerHandle *handle, pid_t *)` function. This function will block until the postmaster has attempted to start the background worker, or until the postmaster dies. If the background worker is running, the return value will be `BGWH_STARTED`, and the PID will be written to the provided address. Otherwise, the return value will be `BGWH_STOPPED` or `BGWH_POSTMASTER_DIED`.

A process can also wait for a background worker to shut down, by using the `WaitForBackgroundWorkerShutdown(BackgroundWorkerHandle *handle)` function and passing the `BackgroundWorkerHandle *` obtained at registration. This function will block until the background worker exits, or postmaster dies. When the background worker exits, the return value is `BGWH_STOPPED`, if postmaster dies it will return `BGWH_POSTMASTER_DIED`.

If a background worker sends asynchronous notifications with the `NOTIFY` command via the Server Programming Interface (SPI), it should call `ProcessCompletedNotifies` explicitly after committing the enclosing transaction so that any notifications can be delivered. If a background worker registers to receive asynchronous notifications with the `LISTEN` through SPI, the worker will log those notifications, but there is no programmatic way for the worker to intercept and respond to those notifications.

The `src/test/modules/worker_spi` module contains a working example, which demonstrates some useful techniques.

The maximum number of registered background workers is limited by `max_worker_processes`.

Chapter 48. Logical Decoding

PostgreSQL provides infrastructure to stream the modifications performed via SQL to external consumers. This functionality can be used for a variety of purposes, including replication solutions and auditing.

Changes are sent out in streams identified by logical replication slots.

The format in which those changes are streamed is determined by the output plugin used. An example plugin is provided in the PostgreSQL distribution. Additional plugins can be written to extend the choice of available formats without modifying any core code. Every output plugin has access to each individual new row produced by `INSERT` and the new row version created by `UPDATE`. Availability of old row versions for `UPDATE` and `DELETE` depends on the configured replica identity (see `REPLICA IDENTITY`).

Changes can be consumed either using the streaming replication protocol (see Section 52.4 and Section 48.3), or by calling functions via SQL (see Section 48.4). It is also possible to write additional methods of consuming the output of a replication slot without modifying core code (see Section 48.7).

48.1. Logical Decoding Examples

The following example demonstrates controlling logical decoding using the SQL interface.

Before you can use logical decoding, you must set `wal_level` to `logical` and `max_replication_slots` to at least 1. Then, you should connect to the target database (in the example below, `postgres`) as a superuser.

```
postgres=# -- Create a slot named 'regression_slot' using the
output plugin 'test_decoding'
postgres=# SELECT * FROM
pg_create_logical_replication_slot('regression_slot',
' test_decoding');
 slot_name | lsn
-----+-----
 regression_slot | 0/16B1970
(1 row)

postgres=# SELECT slot_name, plugin, slot_type, database, active,
restart_lsn, confirmed_flush_lsn FROM pg_replication_slots;
 slot_name | plugin | slot_type | database | active |
restart_lsn | confirmed_flush_lsn
-----+-----+-----+-----+-----+
 regression_slot | test_decoding | logical | postgres | f |
0/16A4408 | 0/16A4440
(1 row)

postgres=# -- There are no changes to see yet
postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
 lsn | xid | data
-----+-----+-----
(0 rows)

postgres=# CREATE TABLE data(id serial primary key, data text);
CREATE TABLE
```

```

postgres=# -- DDL isn't replicated, so all you'll see is the
transaction
postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
   lsn   |   xid   |      data
-----+-----+-----
 0/BA2DA58 | 10297 | BEGIN 10297
 0/BA5A5A0 | 10297 | COMMIT 10297
(2 rows)

postgres=# -- Once changes are read, they're consumed and not
emitted
postgres=# -- in a subsequent call:
postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
   lsn   |   xid   |      data
-----+-----+-----
(0 rows)

postgres=# BEGIN;
postgres=# INSERT INTO data(data) VALUES('1');
postgres=# INSERT INTO data(data) VALUES('2');
postgres=# COMMIT;

postgres=# SELECT * FROM
pg_logical_slot_get_changes('regression_slot', NULL, NULL);
   lsn   |   xid   |      data
-----+-----+-----
 0/BA5A688 | 10298 | BEGIN 10298
 0/BA5A6F0 | 10298 | table public.data: INSERT: id[integer]:1
data[text]:'1'
 0/BA5A7F8 | 10298 | table public.data: INSERT: id[integer]:2
data[text]:'2'
 0/BA5A8A8 | 10298 | COMMIT 10298
(4 rows)

postgres=# INSERT INTO data(data) VALUES('3');

postgres=# -- You can also peek ahead in the change stream without
consuming changes
postgres=# SELECT * FROM
pg_logical_slot_peek_changes('regression_slot', NULL, NULL);
   lsn   |   xid   |      data
-----+-----+-----
 0/BA5A8E0 | 10299 | BEGIN 10299
 0/BA5A8E0 | 10299 | table public.data: INSERT: id[integer]:3
data[text]:'3'
 0/BA5A990 | 10299 | COMMIT 10299
(3 rows)

postgres=# -- The next call to pg_logical_slot_peek_changes()
returns the same changes again
postgres=# SELECT * FROM
pg_logical_slot_peek_changes('regression_slot', NULL, NULL);

```

```

      lsn      |  xid  |      data
-----+-----
0/BA5A8E0 | 10299 | BEGIN 10299
0/BA5A8E0 | 10299 | table public.data: INSERT: id[integer]:3
data[text]:'3'
0/BA5A990 | 10299 | COMMIT 10299
(3 rows)

```

postgres=# -- options can be passed to output plugin, to influence the formatting

```

postgres=# SELECT * FROM
pg_logical_slot_peek_changes('regression_slot', NULL, NULL,
'include-timestamp', 'on');
      lsn      |  xid  |      data
-----+-----

```

```

0/BA5A8E0 | 10299 | BEGIN 10299
0/BA5A8E0 | 10299 | table public.data: INSERT: id[integer]:3
data[text]:'3'
0/BA5A990 | 10299 | COMMIT 10299 (at 2017-05-10
12:07:21.272494-04)
(3 rows)

```

postgres=# -- Remember to destroy a slot you no longer need to stop it consuming

```

postgres=# -- server resources:
postgres=# SELECT pg_drop_replication_slot('regression_slot');
pg_drop_replication_slot
-----

```

(1 row)

The following example shows how logical decoding is controlled over the streaming replication protocol, using the program `pg_recvlogical` included in the PostgreSQL distribution. This requires that client authentication is set up to allow replication connections (see Section 26.2.5.1) and that `max_wal_senders` is set sufficiently high to allow an additional connection.

```

$ pg_recvlogical -d postgres --slot=test --create-slot
$ pg_recvlogical -d postgres --slot=test --start -f -
Control+Z
$ psql -d postgres -c "INSERT INTO data(data) VALUES('4');"
$ fg
BEGIN 693
table public.data: INSERT: id[integer]:4 data[text]:'4'
COMMIT 693
Control+C
$ pg_recvlogical -d postgres --slot=test --drop-slot

```

48.2. Logical Decoding Concepts

48.2.1. Logical Decoding

Logical decoding is the process of extracting all persistent changes to a database's tables into a coherent, easy to understand format which can be interpreted without detailed knowledge of the database's internal state.

In PostgreSQL, logical decoding is implemented by decoding the contents of the write-ahead log, which describe changes on a storage level, into an application-specific form such as a stream of tuples or SQL statements.

48.2.2. Replication Slots

In the context of logical replication, a slot represents a stream of changes that can be replayed to a client in the order they were made on the origin server. Each slot streams a sequence of changes from a single database.

Note

PostgreSQL also has streaming replication slots (see Section 26.2.5), but they are used somewhat differently there.

A replication slot has an identifier that is unique across all databases in a PostgreSQL cluster. Slots persist independently of the connection using them and are crash-safe.

A logical slot will emit each change just once in normal operation. The current position of each slot is persisted only at checkpoint, so in the case of a crash the slot may return to an earlier LSN, which will then cause recent changes to be resent when the server restarts. Logical decoding clients are responsible for avoiding ill effects from handling the same message more than once. Clients may wish to record the last LSN they saw when decoding and skip over any repeated data or (when using the replication protocol) request that decoding start from that LSN rather than letting the server determine the start point. The Replication Progress Tracking feature is designed for this purpose, refer to replication origins.

Multiple independent slots may exist for a single database. Each slot has its own state, allowing different consumers to receive changes from different points in the database change stream. For most applications, a separate slot will be required for each consumer.

A logical replication slot knows nothing about the state of the receiver(s). It's even possible to have multiple different receivers using the same slot at different times; they'll just get the changes following on from when the last receiver stopped consuming them. Only one receiver may consume changes from a slot at any given time.

Caution

Replication slots persist across crashes and know nothing about the state of their consumer(s). They will prevent removal of required resources even when there is no connection using them. This consumes storage because neither required WAL nor required rows from the system catalogs can be removed by `VACUUM` as long as they are required by a replication slot. In extreme cases this could cause the database to shut down to prevent transaction ID wraparound (see Section 24.1.5). So if a slot is no longer required it should be dropped.

48.2.3. Output Plugins

Output plugins transform the data from the write-ahead log's internal representation into the format the consumer of a replication slot desires.

48.2.4. Exported Snapshots

When a new replication slot is created using the streaming replication interface (see `CREATE_REPLICATION_SLOT`), a snapshot is exported (see Section 9.26.5), which will show exactly the state of the database after which all changes will be included in the change stream. This can be used to create a new replica by using `SET TRANSACTION SNAPSHOT` to read the state of the database at the moment the slot was created. This transaction can then be used to dump the database's state at that point in time, which afterwards can be updated using the slot's contents without losing any changes.

Creation of a snapshot is not always possible. In particular, it will fail when connected to a hot standby. Applications that do not require snapshot export may suppress it with the `NOEXPORT_SNAPSHOT` option.

48.3. Streaming Replication Protocol Interface

The commands

- `CREATE_REPLICATION_SLOT slot_name LOGICAL output_plugin`
- `DROP_REPLICATION_SLOT slot_name [WAIT]`
- `START_REPLICATION SLOT slot_name LOGICAL ...`

are used to create, drop, and stream changes from a replication slot, respectively. These commands are only available over a replication connection; they cannot be used via SQL. See Section 52.4 for details on these commands.

The command `pg_recvlogical` can be used to control logical decoding over a streaming replication connection. (It uses these commands internally.)

48.4. Logical Decoding SQL Interface

See Section 9.26.6 for detailed documentation on the SQL-level API for interacting with logical decoding.

Synchronous replication (see Section 26.2.8) is only supported on replication slots used over the streaming replication interface. The function interface and additional, non-core interfaces do not support synchronous replication.

48.5. System Catalogs Related to Logical Decoding

The `pg_replication_slots` view and the `pg_stat_replication` view provide information about the current state of replication slots and streaming replication connections respectively. These views apply to both physical and logical replication.

48.6. Logical Decoding Output Plugins

An example output plugin can be found in the `contrib/test_decoding` subdirectory of the PostgreSQL source tree.

48.6.1. Initialization Function

An output plugin is loaded by dynamically loading a shared library with the output plugin's name as the library base name. The normal library search path is used to locate the library. To provide the required output plugin callbacks and to indicate that the library is actually an output plugin it needs to provide a function named `_PG_output_plugin_init`. This function is passed a struct that needs to be filled with the callback function pointers for individual actions.

```
typedef struct OutputPluginCallbacks
{
    LogicalDecodeStartupCB startup_cb;
    LogicalDecodeBeginCB begin_cb;
    LogicalDecodeChangeCB change_cb;
    LogicalDecodeTruncateCB truncate_cb;
    LogicalDecodeCommitCB commit_cb;
    LogicalDecodeMessageCB message_cb;
    LogicalDecodeFilterByOriginCB filter_by_origin_cb;
    LogicalDecodeShutdownCB shutdown_cb;
} OutputPluginCallbacks;

typedef void (*LogicalOutputPluginInit) (struct
    OutputPluginCallbacks *cb);
```

The `begin_cb`, `change_cb` and `commit_cb` callbacks are required, while `startup_cb`, `filter_by_origin_cb`, `truncate_cb`, and `shutdown_cb` are optional. If `truncate_cb` is not set but a TRUNCATE is to be decoded, the action will be ignored.

48.6.2. Capabilities

To decode, format and output changes, output plugins can use most of the backend's normal infrastructure, including calling output functions. Read only access to relations is permitted as long as only relations are accessed that either have been created by `initdb` in the `pg_catalog` schema, or have been marked as user provided catalog tables using

```
ALTER TABLE user_catalog_table SET (user_catalog_table = true);
CREATE TABLE another_catalog_table(data text) WITH
    (user_catalog_table = true);
```

Any actions leading to transaction ID assignment are prohibited. That, among others, includes writing to tables, performing DDL changes, and calling `txid_current()`.

48.6.3. Output Modes

Output plugin callbacks can pass data to the consumer in nearly arbitrary formats. For some use cases, like viewing the changes via SQL, returning data in a data type that can contain arbitrary data (e.g., `bytea`) is cumbersome. If the output plugin only outputs textual data in the server's encoding, it can declare that by setting `OutputPluginOptions.output_type` to `OUTPUT_PLUGIN_TEXTUAL_OUTPUT` instead of `OUTPUT_PLUGIN_BINARY_OUTPUT` in the startup callback. In that case, all the data has to be in the server's encoding so that a `text` datum can contain it. This is checked in assertion-enabled builds.

48.6.4. Output Plugin Callbacks

An output plugin gets notified about changes that are happening via various callbacks it needs to provide.

Concurrent transactions are decoded in commit order, and only changes belonging to a specific transaction are decoded between the `begin` and `commit` callbacks. Transactions that were rolled back

explicitly or implicitly never get decoded. Successful savepoints are folded into the transaction containing them in the order they were executed within that transaction.

Note

Only transactions that have already safely been flushed to disk will be decoded. That can lead to a COMMIT not immediately being decoded in a directly following `pg_logical_slot_get_changes()` when `synchronous_commit` is set to `off`.

48.6.4.1. Startup Callback

The optional `startup_cb` callback is called whenever a replication slot is created or asked to stream changes, independent of the number of changes that are ready to be put out.

```
typedef void (*LogicalDecodeStartupCB) (struct
    LogicalDecodingContext *ctx,
                                     OutputPluginOptions
    *options,
                                     bool is_init);
```

The `is_init` parameter will be true when the replication slot is being created and false otherwise. `options` points to a struct of options that output plugins can set:

```
typedef struct OutputPluginOptions
{
    OutputPluginOutputType output_type;
    bool receive_rewrites;
} OutputPluginOptions;
```

`output_type` has to either be set to `OUTPUT_PLUGIN_TEXTUAL_OUTPUT` or `OUTPUT_PLUGIN_BINARY_OUTPUT`. See also Section 48.6.3. If `receive_rewrites` is true, the output plugin will also be called for changes made by heap rewrites during certain DDL operations. These are of interest to plugins that handle DDL replication, but they require special handling.

The startup callback should validate the options present in `ctx->output_plugin_options`. If the output plugin needs to have a state, it can use `ctx->output_plugin_private` to store it.

48.6.4.2. Shutdown Callback

The optional `shutdown_cb` callback is called whenever a formerly active replication slot is not used anymore and can be used to deallocate resources private to the output plugin. The slot isn't necessarily being dropped, streaming is just being stopped.

```
typedef void (*LogicalDecodeShutdownCB) (struct
    LogicalDecodingContext *ctx);
```

48.6.4.3. Transaction Begin Callback

The required `begin_cb` callback is called whenever a start of a committed transaction has been decoded. Aborted transactions and their contents never get decoded.

```
typedef void (*LogicalDecodeBeginCB) (struct LogicalDecodingContext
    *ctx,
```

```
ReorderBufferTXN *txn);
```

The *txn* parameter contains meta information about the transaction, like the time stamp at which it has been committed and its XID.

48.6.4.4. Transaction End Callback

The required `commit_cb` callback is called whenever a transaction commit has been decoded. The `change_cb` callbacks for all modified rows will have been called before this, if there have been any modified rows.

```
typedef void (*LogicalDecodeCommitCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
                                     XLogRecPtr commit_lsn);
```

48.6.4.5. Change Callback

The required `change_cb` callback is called for every individual row modification inside a transaction, may it be an INSERT, UPDATE, or DELETE. Even if the original command modified several rows at once the callback will be called individually for each row.

```
typedef void (*LogicalDecodeChangeCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
                                     Relation relation,
                                     ReorderBufferChange
    *change);
```

The *ctx* and *txn* parameters have the same contents as for the `begin_cb` and `commit_cb` callbacks, but additionally the relation descriptor *relation* points to the relation the row belongs to and a struct *change* describing the row modification are passed in.

Note

Only changes in user defined tables that are not unlogged (see UNLOGGED) and not temporary (see TEMPORARY or TEMP) can be extracted using logical decoding.

48.6.4.6. Truncate Callback

The `truncate_cb` callback is called for a TRUNCATE command.

```
typedef void (*LogicalDecodeTruncateCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
                                     int nrelations,
                                     Relation relations[],
                                     ReorderBufferChange
    *change);
```

The parameters are analogous to the `change_cb` callback. However, because TRUNCATE actions on tables connected by foreign keys need to be executed together, this callback receives an array of relations instead of just a single one. See the description of the TRUNCATE statement for details.

48.6.4.7. Origin Filter Callback

The optional `filter_by_origin_cb` callback is called to determine whether data that has been replayed from `origin_id` is of interest to the output plugin.

```
typedef bool (*LogicalDecodeFilterByOriginCB) (struct
    LogicalDecodingContext *ctx,
                                           RepOriginId
    origin_id);
```

The `ctx` parameter has the same contents as for the other callbacks. No information but the origin is available. To signal that changes originating on the passed in node are irrelevant, return true, causing them to be filtered away; false otherwise. The other callbacks will not be called for transactions and changes that have been filtered away.

This is useful when implementing cascading or multidirectional replication solutions. Filtering by the origin allows to prevent replicating the same changes back and forth in such setups. While transactions and changes also carry information about the origin, filtering via this callback is noticeably more efficient.

48.6.4.8. Generic Message Callback

The optional `message_cb` callback is called whenever a logical decoding message has been decoded.

```
typedef void (*LogicalDecodeMessageCB) (struct
    LogicalDecodingContext *ctx,
                                     ReorderBufferTXN *txn,
                                     XLogRecPtr message_lsn,
                                     bool transactional,
                                     const char *prefix,
                                     Size message_size,
                                     const char *message);
```

The `txn` parameter contains meta information about the transaction, like the time stamp at which it has been committed and its XID. Note however that it can be NULL when the message is non-transactional and the XID was not assigned yet in the transaction which logged the message. The `lsn` has WAL location of the message. The `transactional` says if the message was sent as transactional or not. The `prefix` is arbitrary null-terminated prefix which can be used for identifying interesting messages for the current plugin. And finally the `message` parameter holds the actual message of `message_size` size.

Extra care should be taken to ensure that the prefix the output plugin considers interesting is unique. Using name of the extension or the output plugin itself is often a good choice.

48.6.5. Functions for Producing Output

To actually produce output, output plugins can write data to the `StringInfo` output buffer in `ctx->out` when inside the `begin_cb`, `commit_cb`, or `change_cb` callbacks. Before writing to the output buffer, `OutputPluginPrepareWrite(ctx, last_write)` has to be called, and after finishing writing to the buffer, `OutputPluginWrite(ctx, last_write)` has to be called to perform the write. The `last_write` indicates whether a particular write was the callback's last write.

The following example shows how to output data to the consumer of an output plugin:

```
OutputPluginPrepareWrite(ctx, true);
appendStringInfo(ctx->out, "BEGIN %u", txn->xid);
```

```
OutputPluginWrite(ctx, true);
```

48.7. Logical Decoding Output Writers

It is possible to add more output methods for logical decoding. For details, see `src/backend/replication/logical/logicalfuncs.c`. Essentially, three functions need to be provided: one to read WAL, one to prepare writing output, and one to write the output (see Section 48.6.5).

48.8. Synchronous Replication Support for Logical Decoding

Logical decoding can be used to build synchronous replication solutions with the same user interface as synchronous replication for streaming replication. To do this, the streaming replication interface (see Section 48.3) must be used to stream out data. Clients have to send `Standby status update (F)` (see Section 52.4) messages, just like streaming replication clients do.

Note

A synchronous replica receiving changes via logical decoding will work in the scope of a single database. Since, in contrast to that, *synchronous_standby_names* currently is server wide, this means this technique will not work properly if more than one database is actively used.

Chapter 49. Replication Progress Tracking

Replication origins are intended to make it easier to implement logical replication solutions on top of logical decoding. They provide a solution to two common problems:

- How to safely keep track of replication progress
- How to change replication behavior based on the origin of a row; for example, to prevent loops in bi-directional replication setups

Replication origins have just two properties, a name and an OID. The name, which is what should be used to refer to the origin across systems, is free-form text. It should be used in a way that makes conflicts between replication origins created by different replication solutions unlikely; e.g. by prefixing the replication solution's name to it. The OID is used only to avoid having to store the long version in situations where space efficiency is important. It should never be shared across systems.

Replication origins can be created using the function `pg_replication_origin_create()`; dropped using `pg_replication_origin_drop()`; and seen in the `pg_replication_origin` system catalog.

One nontrivial part of building a replication solution is to keep track of replay progress in a safe manner. When the applying process, or the whole cluster, dies, it needs to be possible to find out up to where data has successfully been replicated. Naive solutions to this, such as updating a row in a table for every replayed transaction, have problems like run-time overhead and database bloat.

Using the replication origin infrastructure a session can be marked as replaying from a remote node (using the `pg_replication_origin_session_setup()` function). Additionally the LSN and commit time stamp of every source transaction can be configured on a per transaction basis using `pg_replication_origin_xact_setup()`. If that's done replication progress will persist in a crash safe manner. Replay progress for all replication origins can be seen in the `pg_replication_origin_status` view. An individual origin's progress, e.g. when resuming replication, can be acquired using `pg_replication_origin_progress()` for any origin or `pg_replication_origin_session_progress()` for the origin configured in the current session.

In replication topologies more complex than replication from exactly one system to one other system, another problem can be that it is hard to avoid replicating replayed rows again. That can lead both to cycles in the replication and inefficiencies. Replication origins provide an optional mechanism to recognize and prevent that. When configured using the functions referenced in the previous paragraph, every change and transaction passed to output plugin callbacks (see Section 48.6) generated by the session is tagged with the replication origin of the generating session. This allows treating them differently in the output plugin, e.g. ignoring all but locally-originating rows. Additionally the `filter_by_origin_cb` callback can be used to filter the logical decoding change stream based on the source. While less flexible, filtering via that callback is considerably more efficient than doing it in the output plugin.

Part VI. Reference

The entries in this Reference are meant to provide in reasonable length an authoritative, complete, and formal summary about their respective subjects. More information about the use of PostgreSQL, in narrative, tutorial, or example form, can be found in other parts of this book. See the cross-references listed on each reference page.

The reference entries are also available as traditional “man” pages.

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SQL Commands

This part contains reference information for the SQL commands supported by PostgreSQL. By “SQL” the language in general is meant; information about the standards conformance and compatibility of each command can be found on the respective reference page.

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ABORT

ABORT — abort the current transaction

Synopsis

```
ABORT [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

Description

ABORT rolls back the current transaction and causes all the updates made by the transaction to be discarded. This command is identical in behavior to the standard SQL command ROLLBACK, and is present only for historical reasons.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use COMMIT to successfully terminate a transaction.

Issuing ABORT outside of a transaction block emits a warning and otherwise has no effect.

Examples

To abort all changes:

```
ABORT ;
```

Compatibility

This command is a PostgreSQL extension present for historical reasons. ROLLBACK is the equivalent standard SQL command.

See Also

BEGIN, COMMIT, ROLLBACK

ALTER AGGREGATE

ALTER AGGREGATE — change the definition of an aggregate function

Synopsis

```
ALTER AGGREGATE name ( aggregate_signature ) RENAME TO new_name
ALTER AGGREGATE name ( aggregate_signature )
                    OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
ALTER AGGREGATE name ( aggregate_signature ) SET SCHEMA new_schema
```

where *aggregate_signature* is:

```
* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]
```

Description

ALTER AGGREGATE changes the definition of an aggregate function.

You must own the aggregate function to use ALTER AGGREGATE. To change the schema of an aggregate function, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the aggregate function's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the aggregate function. However, a superuser can alter ownership of any aggregate function anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing aggregate function.

argmode

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

argname

The name of an argument. Note that ALTER AGGREGATE does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

argtype

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write * in place of the list of argument specifications. To reference an ordered-set aggregate function, write ORDER BY between the direct and aggregated argument specifications.

new_name

The new name of the aggregate function.

new_owner

The new owner of the aggregate function.

new_schema

The new schema for the aggregate function.

Notes

The recommended syntax for referencing an ordered-set aggregate is to write `ORDER BY` between the direct and aggregated argument specifications, in the same style as in `CREATE AGGREGATE`. However, it will also work to omit `ORDER BY` and just run the direct and aggregated argument specifications into a single list. In this abbreviated form, if `VARIADIC "any"` was used in both the direct and aggregated argument lists, write `VARIADIC "any"` only once.

Examples

To rename the aggregate function `myavg` for type `integer` to `my_average`:

```
ALTER AGGREGATE myavg(integer) RENAME TO my_average;
```

To change the owner of the aggregate function `myavg` for type `integer` to `joe`:

```
ALTER AGGREGATE myavg(integer) OWNER TO joe;
```

To move the ordered-set aggregate `mypercentile` with direct argument of type `float8` and aggregated argument of type `integer` into schema `myschema`:

```
ALTER AGGREGATE mypercentile(float8 ORDER BY integer) SET SCHEMA
myschema;
```

This will work too:

```
ALTER AGGREGATE mypercentile(float8, integer) SET SCHEMA myschema;
```

Compatibility

There is no `ALTER AGGREGATE` statement in the SQL standard.

See Also

`CREATE AGGREGATE`, `DROP AGGREGATE`

ALTER COLLATION

ALTER COLLATION — change the definition of a collation

Synopsis

```
ALTER COLLATION name REFRESH VERSION
```

```
ALTER COLLATION name RENAME TO new_name
```

```
ALTER COLLATION name OWNER TO { new_owner | CURRENT_USER |  
SESSION_USER }
```

```
ALTER COLLATION name SET SCHEMA new_schema
```

Description

ALTER COLLATION changes the definition of a collation.

You must own the collation to use ALTER COLLATION. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the collation's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the collation. However, a superuser can alter ownership of any collation anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing collation.

new_name

The new name of the collation.

new_owner

The new owner of the collation.

new_schema

The new schema for the collation.

REFRESH VERSION

Update the collation's version. See Notes below.

Notes

When using collations provided by the ICU library, the ICU-specific version of the collator is recorded in the system catalog when the collation object is created. When the collation is used, the current version is checked against the recorded version, and a warning is issued when there is a mismatch, for example:

```
WARNING: collation "xx-x-icu" has version mismatch  
DETAIL: The collation in the database was created using version  
1.2.3.4, but the operating system provides version 2.3.4.5.
```

HINT: Rebuild all objects affected by this collation and run `ALTER COLLATION pg_catalog."xx-x-icu" REFRESH VERSION`, or build PostgreSQL with the right library version.

A change in collation definitions can lead to corrupt indexes and other problems because the database system relies on stored objects having a certain sort order. Generally, this should be avoided, but it can happen in legitimate circumstances, such as when using `pg_upgrade` to upgrade to server binaries linked with a newer version of ICU. When this happens, all objects depending on the collation should be rebuilt, for example, using `REINDEX`. When that is done, the collation version can be refreshed using the command `ALTER COLLATION ... REFRESH VERSION`. This will update the system catalog to record the current collator version and will make the warning go away. Note that this does not actually check whether all affected objects have been rebuilt correctly.

The following query can be used to identify all collations in the current database that need to be refreshed and the objects that depend on them:

```
SELECT pg_describe_object(refclassid, refobjid, refobjsubid) AS
"Collation",
       pg_describe_object(classid, objid, objsubid) AS "Object"
FROM pg_depend d JOIN pg_collation c
ON refclassid = 'pg_collation'::regclass AND refobjid =
c.oid
WHERE c.collversion <> pg_collation_actual_version(c.oid)
ORDER BY 1, 2;
```

Examples

To rename the collation `de_DE` to `german`:

```
ALTER COLLATION "de_DE" RENAME TO german;
```

To change the owner of the collation `en_US` to `joe`:

```
ALTER COLLATION "en_US" OWNER TO joe;
```

Compatibility

There is no `ALTER COLLATION` statement in the SQL standard.

See Also

[CREATE COLLATION](#), [DROP COLLATION](#)

ALTER CONVERSION

ALTER CONVERSION — change the definition of a conversion

Synopsis

```
ALTER CONVERSION name RENAME TO new_name
ALTER CONVERSION name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
ALTER CONVERSION name SET SCHEMA new_schema
```

Description

ALTER CONVERSION changes the definition of a conversion.

You must own the conversion to use ALTER CONVERSION. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the conversion's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the conversion. However, a superuser can alter ownership of any conversion anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing conversion.

new_name

The new name of the conversion.

new_owner

The new owner of the conversion.

new_schema

The new schema for the conversion.

Examples

To rename the conversion `iso_8859_1_to_utf8` to `latin1_to_unicode`:

```
ALTER CONVERSION iso_8859_1_to_utf8 RENAME TO latin1_to_unicode;
```

To change the owner of the conversion `iso_8859_1_to_utf8` to `joe`:

```
ALTER CONVERSION iso_8859_1_to_utf8 OWNER TO joe;
```

Compatibility

There is no ALTER CONVERSION statement in the SQL standard.

See Also

CREATE CONVERSION, DROP CONVERSION

ALTER DATABASE

ALTER DATABASE — change a database

Synopsis

```
ALTER DATABASE name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
ALLOW_CONNECTIONS allowconn  
CONNECTION LIMIT connlimit  
IS_TEMPLATE istemplate
```

```
ALTER DATABASE name RENAME TO new_name
```

```
ALTER DATABASE name OWNER TO { new_owner | CURRENT_USER |  
SESSION_USER }
```

```
ALTER DATABASE name SET TABLESPACE new_tablespace
```

```
ALTER DATABASE name SET configuration_parameter { TO | = } { value  
| DEFAULT }
```

```
ALTER DATABASE name SET configuration_parameter FROM CURRENT
```

```
ALTER DATABASE name RESET configuration_parameter
```

```
ALTER DATABASE name RESET ALL
```

Description

ALTER DATABASE changes the attributes of a database.

The first form changes certain per-database settings. (See below for details.) Only the database owner or a superuser can change these settings.

The second form changes the name of the database. Only the database owner or a superuser can rename a database; non-superuser owners must also have the CREATEDB privilege. The current database cannot be renamed. (Connect to a different database if you need to do that.)

The third form changes the owner of the database. To alter the owner, you must own the database and also be a direct or indirect member of the new owning role, and you must have the CREATEDB privilege. (Note that superusers have all these privileges automatically.)

The fourth form changes the default tablespace of the database. Only the database owner or a superuser can do this; you must also have create privilege for the new tablespace. This command physically moves any tables or indexes in the database's old default tablespace to the new tablespace. The new default tablespace must be empty for this database, and no one can be connected to the database. Tables and indexes in non-default tablespaces are unaffected.

The remaining forms change the session default for a run-time configuration variable for a PostgreSQL database. Whenever a new session is subsequently started in that database, the specified value becomes the session default value. The database-specific default overrides whatever setting is present in `postgresql.conf` or has been received from the `postgres` command line. Only the database owner or a superuser can change the session defaults for a database. Certain variables cannot be set this way, or can only be set by a superuser.

Parameters

name

The name of the database whose attributes are to be altered.

allowconn

If false then no one can connect to this database.

conlimit

How many concurrent connections can be made to this database. -1 means no limit.

istemplate

If true, then this database can be cloned by any user with CREATEDB privileges; if false, then only superusers or the owner of the database can clone it.

new_name

The new name of the database.

new_owner

The new owner of the database.

new_tablespace

The new default tablespace of the database.

This form of the command cannot be executed inside a transaction block.

configuration_parameter

value

Set this database's session default for the specified configuration parameter to the given value. If *value* is DEFAULT or, equivalently, RESET is used, the database-specific setting is removed, so the system-wide default setting will be inherited in new sessions. Use RESET ALL to clear all database-specific settings. SET FROM CURRENT saves the session's current value of the parameter as the database-specific value.

See SET and Chapter 19 for more information about allowed parameter names and values.

Notes

It is also possible to tie a session default to a specific role rather than to a database; see ALTER ROLE. Role-specific settings override database-specific ones if there is a conflict.

Examples

To disable index scans by default in the database test:

```
ALTER DATABASE test SET enable_indexscan TO off;
```

Compatibility

The ALTER DATABASE statement is a PostgreSQL extension.

See Also

CREATE DATABASE, DROP DATABASE, SET, CREATE TABLESPACE

ALTER DEFAULT PRIVILEGES

ALTER DEFAULT PRIVILEGES — define default access privileges

Synopsis

```
ALTER DEFAULT PRIVILEGES
  [ FOR { ROLE | USER } target_role [, ...] ]
  [ IN SCHEMA schema_name [, ...] ]
  abbreviated_grant_or_revoke
```

where *abbreviated_grant_or_revoke* is one of:

```
GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES
  | TRIGGER }
  [, ...] | ALL [ PRIVILEGES ] }
  ON TABLES
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { { USAGE | SELECT | UPDATE }
  [, ...] | ALL [ PRIVILEGES ] }
  ON SEQUENCES
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { EXECUTE | ALL [ PRIVILEGES ] }
  ON { FUNCTIONS | ROUTINES }
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON TYPES
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
GRANT { USAGE | CREATE | ALL [ PRIVILEGES ] }
  ON SCHEMAS
  TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT
  OPTION ]
```

```
REVOKE [ GRANT OPTION FOR ]
  { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES |
  TRIGGER }
  [, ...] | ALL [ PRIVILEGES ] }
  ON TABLES
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
  [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
  { { USAGE | SELECT | UPDATE }
  [, ...] | ALL [ PRIVILEGES ] }
  ON SEQUENCES
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
```

```
[ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
  { EXECUTE | ALL [ PRIVILEGES ] }
  ON { FUNCTIONS | ROUTINES }
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
  [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
  { USAGE | ALL [ PRIVILEGES ] }
  ON TYPES
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
  [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
  { USAGE | CREATE | ALL [ PRIVILEGES ] }
  ON SCHEMAS
  FROM { [ GROUP ] role_name | PUBLIC } [, ...]
  [ CASCADE | RESTRICT ]
```

Description

ALTER DEFAULT PRIVILEGES allows you to set the privileges that will be applied to objects created in the future. (It does not affect privileges assigned to already-existing objects.) Currently, only the privileges for schemas, tables (including views and foreign tables), sequences, functions, and types (including domains) can be altered. For this command, functions include aggregates and procedures. The words FUNCTIONS and ROUTINES are equivalent in this command. (ROUTINES is preferred going forward as the standard term for functions and procedures taken together. In earlier PostgreSQL releases, only the word FUNCTIONS was allowed. It is not possible to set default privileges for functions and procedures separately.)

You can change default privileges only for objects that will be created by yourself or by roles that you are a member of. The privileges can be set globally (i.e., for all objects created in the current database), or just for objects created in specified schemas. Default privileges that are specified per-schema are added to whatever the global default privileges are for the particular object type.

As explained in Section 5.7, the default privileges for any object type normally grant all grantable permissions to the object owner, and may grant some privileges to PUBLIC as well. However, this behavior can be changed by altering the global default privileges with ALTER DEFAULT PRIVILEGES.

Parameters

target_role

The name of an existing role of which the current role is a member. If FOR ROLE is omitted, the current role is assumed.

schema_name

The name of an existing schema. If specified, the default privileges are altered for objects later created in that schema. If IN SCHEMA is omitted, the global default privileges are altered. IN SCHEMA is not allowed when using ON SCHEMAS as schemas can't be nested.

role_name

The name of an existing role to grant or revoke privileges for. This parameter, and all the other parameters in *abbreviated_grant_or_revoke*, act as described under GRANT or REVOKE, except that one is setting permissions for a whole class of objects rather than specific named objects.

Notes

Use `psql`'s `\ddp` command to obtain information about existing assignments of default privileges. The meaning of the privilege display is the same as explained for `\dp` in Section 5.7.

If you wish to drop a role for which the default privileges have been altered, it is necessary to reverse the changes in its default privileges or use `DROP OWNED BY` to get rid of the default privileges entry for the role.

Examples

Grant `SELECT` privilege to everyone for all tables (and views) you subsequently create in schema `myschema`, and allow role `webuser` to `INSERT` into them too:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT SELECT ON TABLES
TO PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT INSERT ON TABLES
TO webuser;
```

Undo the above, so that subsequently-created tables won't have any more permissions than normal:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE SELECT ON TABLES
FROM PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE INSERT ON TABLES
FROM webuser;
```

Remove the public `EXECUTE` permission that is normally granted on functions, for all functions subsequently created by role `admin`:

```
ALTER DEFAULT PRIVILEGES FOR ROLE admin REVOKE EXECUTE ON FUNCTIONS
FROM PUBLIC;
```

Compatibility

There is no `ALTER DEFAULT PRIVILEGES` statement in the SQL standard.

See Also

`GRANT`, `REVOKE`

ALTER DOMAIN

ALTER DOMAIN — change the definition of a domain

Synopsis

```
ALTER DOMAIN name
    { SET DEFAULT expression | DROP DEFAULT }
ALTER DOMAIN name
    { SET | DROP } NOT NULL
ALTER DOMAIN name
    ADD domain_constraint [ NOT VALID ]
ALTER DOMAIN name
    DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT |
    CASCADE ]
ALTER DOMAIN name
    RENAME CONSTRAINT constraint_name TO new_constraint_name
ALTER DOMAIN name
    VALIDATE CONSTRAINT constraint_name
ALTER DOMAIN name
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER DOMAIN name
    RENAME TO new_name
ALTER DOMAIN name
    SET SCHEMA new_schema
```

Description

ALTER DOMAIN changes the definition of an existing domain. There are several sub-forms:

SET/DROP DEFAULT

These forms set or remove the default value for a domain. Note that defaults only apply to subsequent INSERT commands; they do not affect rows already in a table using the domain.

SET/DROP NOT NULL

These forms change whether a domain is marked to allow NULL values or to reject NULL values. You can only SET NOT NULL when the columns using the domain contain no null values.

ADD *domain_constraint* [NOT VALID]

This form adds a new constraint to a domain using the same syntax as CREATE DOMAIN. When a new constraint is added to a domain, all columns using that domain will be checked against the newly added constraint. These checks can be suppressed by adding the new constraint using the NOT VALID option; the constraint can later be made valid using ALTER DOMAIN ... VALIDATE CONSTRAINT. Newly inserted or updated rows are always checked against all constraints, even those marked NOT VALID. NOT VALID is only accepted for CHECK constraints.

DROP CONSTRAINT [IF EXISTS]

This form drops constraints on a domain. If IF EXISTS is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

RENAME CONSTRAINT

This form changes the name of a constraint on a domain.

VALIDATE CONSTRAINT

This form validates a constraint previously added as `NOT VALID`, that is, it verifies that all values in table columns of the domain type satisfy the specified constraint.

OWNER

This form changes the owner of the domain to the specified user.

RENAME

This form changes the name of the domain.

SET SCHEMA

This form changes the schema of the domain. Any constraints associated with the domain are moved into the new schema as well.

You must own the domain to use `ALTER DOMAIN`. To change the schema of a domain, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the domain's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the domain. However, a superuser can alter ownership of any domain anyway.)

Parameters

name

The name (possibly schema-qualified) of an existing domain to alter.

domain_constraint

New domain constraint for the domain.

constraint_name

Name of an existing constraint to drop or rename.

`NOT VALID`

Do not verify existing stored data for constraint validity.

`CASCADE`

Automatically drop objects that depend on the constraint, and in turn all objects that depend on those objects (see Section 5.14).

`RESTRICT`

Refuse to drop the constraint if there are any dependent objects. This is the default behavior.

new_name

The new name for the domain.

new_constraint_name

The new name for the constraint.

new_owner

The user name of the new owner of the domain.

new_schema

The new schema for the domain.

Notes

Although `ALTER DOMAIN ADD CONSTRAINT` attempts to verify that existing stored data satisfies the new constraint, this check is not bulletproof, because the command cannot “see” table rows that are newly inserted or updated and not yet committed. If there is a hazard that concurrent operations might insert bad data, the way to proceed is to add the constraint using the `NOT VALID` option, commit that command, wait until all transactions started before that commit have finished, and then issue `ALTER DOMAIN VALIDATE CONSTRAINT` to search for data violating the constraint. This method is reliable because once the constraint is committed, all new transactions are guaranteed to enforce it against new values of the domain type.

Currently, `ALTER DOMAIN ADD CONSTRAINT`, `ALTER DOMAIN VALIDATE CONSTRAINT`, and `ALTER DOMAIN SET NOT NULL` will fail if the named domain or any derived domain is used within a container-type column (a composite, array, or range column) in any table in the database. They should eventually be improved to be able to verify the new constraint for such nested values.

Examples

To add a `NOT NULL` constraint to a domain:

```
ALTER DOMAIN zipcode SET NOT NULL;
```

To remove a `NOT NULL` constraint from a domain:

```
ALTER DOMAIN zipcode DROP NOT NULL;
```

To add a check constraint to a domain:

```
ALTER DOMAIN zipcode ADD CONSTRAINT zipchk CHECK
(char_length(VALUE) = 5);
```

To remove a check constraint from a domain:

```
ALTER DOMAIN zipcode DROP CONSTRAINT zipchk;
```

To rename a check constraint on a domain:

```
ALTER DOMAIN zipcode RENAME CONSTRAINT zipchk TO zip_check;
```

To move the domain into a different schema:

```
ALTER DOMAIN zipcode SET SCHEMA customers;
```

Compatibility

`ALTER DOMAIN` conforms to the SQL standard, except for the `OWNER`, `RENAME`, `SET SCHEMA`, and `VALIDATE CONSTRAINT` variants, which are PostgreSQL extensions. The `NOT VALID` clause of the `ADD CONSTRAINT` variant is also a PostgreSQL extension.

See Also

CREATE DOMAIN, DROP DOMAIN

ALTER EVENT TRIGGER

ALTER EVENT TRIGGER — change the definition of an event trigger

Synopsis

```
ALTER EVENT TRIGGER name DISABLE
ALTER EVENT TRIGGER name ENABLE [ REPLICAS | ALWAYS ]
ALTER EVENT TRIGGER name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
ALTER EVENT TRIGGER name RENAME TO new_name
```

Description

ALTER EVENT TRIGGER changes properties of an existing event trigger.

You must be superuser to alter an event trigger.

Parameters

name

The name of an existing trigger to alter.

new_owner

The user name of the new owner of the event trigger.

new_name

The new name of the event trigger.

DISABLE/ENABLE [REPLICAS | ALWAYS] TRIGGER

These forms configure the firing of event triggers. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. See also `session_replication_role`.

Compatibility

There is no ALTER EVENT TRIGGER statement in the SQL standard.

See Also

CREATE EVENT TRIGGER, DROP EVENT TRIGGER

ALTER EXTENSION

ALTER EXTENSION — change the definition of an extension

Synopsis

```
ALTER EXTENSION name UPDATE [ TO new_version ]
ALTER EXTENSION name SET SCHEMA new_schema
ALTER EXTENSION name ADD member_object
ALTER EXTENSION name DROP member_object
```

where *member_object* is:

```
ACCESS METHOD object_name |
AGGREGATE aggregate_name ( aggregate_signature ) |
CAST ( source_type AS target_type ) |
COLLATION object_name |
CONVERSION object_name |
DOMAIN object_name |
EVENT TRIGGER object_name |
FOREIGN DATA WRAPPER object_name |
FOREIGN TABLE object_name |
FUNCTION function_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
MATERIALIZED VIEW object_name |
OPERATOR operator_name ( left_type , right_type ) |
OPERATOR CLASS object_name USING index_method |
OPERATOR FAMILY object_name USING index_method |
[ PROCEDURAL ] LANGUAGE object_name |
PROCEDURE procedure_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
ROUTINE routine_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
SCHEMA object_name |
SEQUENCE object_name |
SERVER object_name |
TABLE object_name |
TEXT SEARCH CONFIGURATION object_name |
TEXT SEARCH DICTIONARY object_name |
TEXT SEARCH PARSER object_name |
TEXT SEARCH TEMPLATE object_name |
TRANSFORM FOR type_name LANGUAGE lang_name |
TYPE object_name |
VIEW object_name
```

and *aggregate_signature* is:

```
* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]
```

Description

ALTER EXTENSION changes the definition of an installed extension. There are several subforms:

UPDATE

This form updates the extension to a newer version. The extension must supply a suitable update script (or series of scripts) that can modify the currently-installed version into the requested version.

SET SCHEMA

This form moves the extension's objects into another schema. The extension has to be *relocatable* for this command to succeed.

ADD *member_object*

This form adds an existing object to the extension. This is mainly useful in extension update scripts. The object will subsequently be treated as a member of the extension; notably, it can only be dropped by dropping the extension.

DROP *member_object*

This form removes a member object from the extension. This is mainly useful in extension update scripts. The object is not dropped, only disassociated from the extension.

See Section 37.17 for more information about these operations.

You must own the extension to use ALTER EXTENSION. The ADD/DROP forms require ownership of the added/dropped object as well.

Parameters

name

The name of an installed extension.

new_version

The desired new version of the extension. This can be written as either an identifier or a string literal. If not specified, ALTER EXTENSION UPDATE attempts to update to whatever is shown as the default version in the extension's control file.

new_schema

The new schema for the extension.

object_name

aggregate_name

function_name

operator_name

procedure_name

routine_name

The name of an object to be added to or removed from the extension. Names of tables, aggregates, domains, foreign tables, functions, operators, operator classes, operator families, procedures, routines, sequences, text search objects, types, and views can be schema-qualified.

source_type

The name of the source data type of the cast.

target_type

The name of the target data type of the cast.

argmode

The mode of a function, procedure, or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER EXTENSION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of a function, procedure, or aggregate argument. Note that ALTER EXTENSION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type of a function, procedure, or aggregate argument.

left_type

right_type

The data type(s) of the operator's arguments (optionally schema-qualified). Write NONE for the missing argument of a prefix or postfix operator.

PROCEDURAL

This is a noise word.

type_name

The name of the data type of the transform.

lang_name

The name of the language of the transform.

Examples

To update the hstore extension to version 2.0:

```
ALTER EXTENSION hstore UPDATE TO '2.0';
```

To change the schema of the hstore extension to utils:

```
ALTER EXTENSION hstore SET SCHEMA utils;
```

To add an existing function to the hstore extension:

```
ALTER EXTENSION hstore ADD FUNCTION populate_record(anelement,  
hstore);
```

Compatibility

ALTER EXTENSION is a PostgreSQL extension.

See Also

CREATE EXTENSION, DROP EXTENSION

ALTER FOREIGN DATA WRAPPER

ALTER FOREIGN DATA WRAPPER — change the definition of a foreign-data wrapper

Synopsis

```
ALTER FOREIGN DATA WRAPPER name
    [ HANDLER handler_function | NO HANDLER ]
    [ VALIDATOR validator_function | NO VALIDATOR ]
    [ OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] ) ]
ALTER FOREIGN DATA WRAPPER name OWNER TO { new_owner | CURRENT_USER
| SESSION_USER }
ALTER FOREIGN DATA WRAPPER name RENAME TO new_name
```

Description

ALTER FOREIGN DATA WRAPPER changes the definition of a foreign-data wrapper. The first form of the command changes the support functions or the generic options of the foreign-data wrapper (at least one clause is required). The second form changes the owner of the foreign-data wrapper.

Only superusers can alter foreign-data wrappers. Additionally, only superusers can own foreign-data wrappers.

Parameters

name

The name of an existing foreign-data wrapper.

HANDLER *handler_function*

Specifies a new handler function for the foreign-data wrapper.

NO HANDLER

This is used to specify that the foreign-data wrapper should no longer have a handler function.

Note that foreign tables that use a foreign-data wrapper with no handler cannot be accessed.

VALIDATOR *validator_function*

Specifies a new validator function for the foreign-data wrapper.

Note that it is possible that pre-existing options of the foreign-data wrapper, or of dependent servers, user mappings, or foreign tables, are invalid according to the new validator. PostgreSQL does not check for this. It is up to the user to make sure that these options are correct before using the modified foreign-data wrapper. However, any options specified in this ALTER FOREIGN DATA WRAPPER command will be checked using the new validator.

NO VALIDATOR

This is used to specify that the foreign-data wrapper should no longer have a validator function.

OPTIONS ([ADD | SET | DROP] *option* ['*value*'] [, ...])

Change options for the foreign-data wrapper. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; names and values are also validated using the foreign data wrapper's validator function, if any.

new_owner

The user name of the new owner of the foreign-data wrapper.

new_name

The new name for the foreign-data wrapper.

Examples

Change a foreign-data wrapper `dbi`, add option `foo`, drop `bar`:

```
ALTER FOREIGN DATA WRAPPER dbi OPTIONS (ADD foo '1', DROP 'bar');
```

Change the foreign-data wrapper `dbi` validator to `bob.myvalidator`:

```
ALTER FOREIGN DATA WRAPPER dbi VALIDATOR bob.myvalidator;
```

Compatibility

`ALTER FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), except that the `HANDLER`, `VALIDATOR`, `OWNER TO`, and `RENAME` clauses are extensions.

See Also

`CREATE FOREIGN DATA WRAPPER`, `DROP FOREIGN DATA WRAPPER`

ALTER FOREIGN TABLE

ALTER FOREIGN TABLE — change the definition of a foreign table

Synopsis

```
ALTER FOREIGN TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    action [, ... ]
ALTER FOREIGN TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER FOREIGN TABLE [ IF EXISTS ] name
    RENAME TO new_name
ALTER FOREIGN TABLE [ IF EXISTS ] name
    SET SCHEMA new_schema
```

where *action* is one of:

```
    ADD [ COLUMN ] column_name data_type [ COLLATE collation ]
    [ column_constraint [ ... ] ]
    DROP [ COLUMN ] [ IF EXISTS ] column_name [ RESTRICT |
CASCADE ]
    ALTER [ COLUMN ] column_name [ SET DATA ] TYPE data_type
    [ COLLATE collation ]
    ALTER [ COLUMN ] column_name SET DEFAULT expression
    ALTER [ COLUMN ] column_name DROP DEFAULT
    ALTER [ COLUMN ] column_name { SET | DROP } NOT NULL
    ALTER [ COLUMN ] column_name SET STATISTICS integer
    ALTER [ COLUMN ] column_name SET ( attribute_option = value
[, ... ] )
    ALTER [ COLUMN ] column_name RESET ( attribute_option
[, ... ] )
    ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL |
EXTENDED | MAIN }
    ALTER [ COLUMN ] column_name OPTIONS ( [ ADD | SET |
DROP ] option ['value'] [, ... ] )
    ADD table_constraint [ NOT VALID ]
    VALIDATE CONSTRAINT constraint_name
    DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT |
CASCADE ]
    DISABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE REPLICA TRIGGER trigger_name
    ENABLE ALWAYS TRIGGER trigger_name
    SET WITHOUT OIDS
    INHERIT parent_table
    NO INHERIT parent_table
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
    OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

Description

ALTER FOREIGN TABLE changes the definition of an existing foreign table. There are several subforms:

ADD COLUMN

This form adds a new column to the foreign table, using the same syntax as CREATE FOREIGN TABLE. Unlike the case when adding a column to a regular table, nothing happens to the underlying storage: this action simply declares that some new column is now accessible through the foreign table.

DROP COLUMN [IF EXISTS]

This form drops a column from a foreign table. You will need to say CASCADE if anything outside the table depends on the column; for example, views. If IF EXISTS is specified and the column does not exist, no error is thrown. In this case a notice is issued instead.

SET DATA TYPE

This form changes the type of a column of a foreign table. Again, this has no effect on any underlying storage: this action simply changes the type that PostgreSQL believes the column to have.

SET/DROP DEFAULT

These forms set or remove the default value for a column. Default values only apply in subsequent INSERT or UPDATE commands; they do not cause rows already in the table to change.

SET/DROP NOT NULL

Mark a column as allowing, or not allowing, null values.

SET STATISTICS

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations. See the similar form of ALTER TABLE for more details.

```
SET ( attribute_option = value [, ... ] )  
RESET ( attribute_option [, ... ] )
```

This form sets or resets per-attribute options. See the similar form of ALTER TABLE for more details.

SET STORAGE

This form sets the storage mode for a column. See the similar form of ALTER TABLE for more details. Note that the storage mode has no effect unless the table's foreign-data wrapper chooses to pay attention to it.

ADD *table_constraint* [NOT VALID]

This form adds a new constraint to a foreign table, using the same syntax as CREATE FOREIGN TABLE. Currently only CHECK constraints are supported.

Unlike the case when adding a constraint to a regular table, nothing is done to verify the constraint is correct; rather, this action simply declares that some new condition should be assumed to hold for all rows in the foreign table. (See the discussion in CREATE FOREIGN TABLE.) If the constraint is marked NOT VALID, then it isn't assumed to hold, but is only recorded for possible future use.

VALIDATE CONSTRAINT

This form marks as valid a constraint that was previously marked as NOT VALID. No action is taken to verify the constraint, but future queries will assume that it holds.

DROP CONSTRAINT [IF EXISTS]

This form drops the specified constraint on a foreign table. If IF EXISTS is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

DISABLE/ENABLE [REPLICA | ALWAYS] TRIGGER

These forms configure the firing of trigger(s) belonging to the foreign table. See the similar form of ALTER TABLE for more details.

SET WITHOUT OIDS

Backward compatibility syntax for removing the oid system column. As oid system columns cannot be added anymore, this never has an effect.

INHERIT *parent_table*

This form adds the target foreign table as a new child of the specified parent table. See the similar form of ALTER TABLE for more details.

NO INHERIT *parent_table*

This form removes the target foreign table from the list of children of the specified parent table.

OWNER

This form changes the owner of the foreign table to the specified user.

OPTIONS ([ADD | SET | DROP] *option* ['*value*'] [, ...])

Change options for the foreign table or one of its columns. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Duplicate option names are not allowed (although it's OK for a table option and a column option to have the same name). Option names and values are also validated using the foreign data wrapper library.

RENAME

The RENAME forms change the name of a foreign table or the name of an individual column in a foreign table.

SET SCHEMA

This form moves the foreign table into another schema.

All the actions except RENAME and SET SCHEMA can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several columns and/or alter the type of several columns in a single command.

If the command is written as ALTER FOREIGN TABLE IF EXISTS . . . and the foreign table does not exist, no error is thrown. A notice is issued in this case.

You must own the table to use ALTER FOREIGN TABLE. To change the schema of a foreign table, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or alter a column type, you must also have USAGE privilege on the data type.

Parameters

name

The name (possibly schema-qualified) of an existing foreign table to alter. If ONLY is specified before the table name, only that table is altered. If ONLY is not specified, the table and all its descendant tables (if any) are altered. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

column_name

Name of a new or existing column.

new_column_name

New name for an existing column.

new_name

New name for the table.

data_type

Data type of the new column, or new data type for an existing column.

table_constraint

New table constraint for the foreign table.

constraint_name

Name of an existing constraint to drop.

CASCADE

Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

trigger_name

Name of a single trigger to disable or enable.

ALL

Disable or enable all triggers belonging to the foreign table. (This requires superuser privilege if any of the triggers are internally generated triggers. The core system does not add such triggers to foreign tables, but add-on code could do so.)

USER

Disable or enable all triggers belonging to the foreign table except for internally generated triggers.

parent_table

A parent table to associate or de-associate with this foreign table.

new_owner

The user name of the new owner of the table.

new_schema

The name of the schema to which the table will be moved.

Notes

The key word COLUMN is noise and can be omitted.

Consistency with the foreign server is not checked when a column is added or removed with `ADD COLUMN` or `DROP COLUMN`, a `NOT NULL` or `CHECK` constraint is added, or a column type is changed with `SET DATA TYPE`. It is the user's responsibility to ensure that the table definition matches the remote side.

Refer to `CREATE FOREIGN TABLE` for a further description of valid parameters.

Examples

To mark a column as not-null:

```
ALTER FOREIGN TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To change options of a foreign table:

```
ALTER FOREIGN TABLE myschema.distributors OPTIONS (ADD opt1  
'value', SET opt2 'value2', DROP opt3 'value3');
```

Compatibility

The forms `ADD`, `DROP`, and `SET DATA TYPE` conform with the SQL standard. The other forms are PostgreSQL extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER FOREIGN TABLE` command is an extension.

`ALTER FOREIGN TABLE DROP COLUMN` can be used to drop the only column of a foreign table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column foreign tables.

See Also

`CREATE FOREIGN TABLE`, `DROP FOREIGN TABLE`

ALTER FUNCTION

ALTER FUNCTION — change the definition of a function

Synopsis

```
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  action [ ... ] [ RESTRICT ]
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  RENAME TO new_name
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  SET SCHEMA new_schema
ALTER FUNCTION name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  DEPENDS ON EXTENSION extension_name
```

where *action* is one of:

```
CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
IMMUTABLE | STABLE | VOLATILE | [ NOT ] LEAKPROOF
[ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
PARALLEL { UNSAFE | RESTRICTED | SAFE }
COST execution_cost
ROWS result_rows
SUPPORT support_function
SET configuration_parameter { TO | = } { value | DEFAULT }
SET configuration_parameter FROM CURRENT
RESET configuration_parameter
RESET ALL
```

Description

ALTER FUNCTION changes the definition of a function.

You must own the function to use ALTER FUNCTION. To change a function's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the function's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the function. However, a superuser can alter ownership of any function anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing function. If no argument list is specified, the name must be unique in its schema.

argmode

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of an argument. Note that ALTER FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type(s) of the function's arguments (optionally schema-qualified), if any.

new_name

The new name of the function.

new_owner

The new owner of the function. Note that if the function is marked SECURITY DEFINER, it will subsequently execute as the new owner.

new_schema

The new schema for the function.

extension_name

The name of the extension that the function is to depend on.

CALLED ON NULL INPUT
RETURNS NULL ON NULL INPUT
STRICT

CALLED ON NULL INPUT changes the function so that it will be invoked when some or all of its arguments are null. RETURNS NULL ON NULL INPUT or STRICT changes the function so that it is not invoked if any of its arguments are null; instead, a null result is assumed automatically. See CREATE FUNCTION for more information.

IMMUTABLE
STABLE
VOLATILE

Change the volatility of the function to the specified setting. See CREATE FUNCTION for details.

[EXTERNAL] SECURITY INVOKER
[EXTERNAL] SECURITY DEFINER

Change whether the function is a security definer or not. The key word EXTERNAL is ignored for SQL conformance. See CREATE FUNCTION for more information about this capability.

PARALLEL

Change whether the function is deemed safe for parallelism. See CREATE FUNCTION for details.

LEAKPROOF

Change whether the function is considered leakproof or not. See `CREATE FUNCTION` for more information about this capability.

COST *execution_cost*

Change the estimated execution cost of the function. See `CREATE FUNCTION` for more information.

ROWS *result_rows*

Change the estimated number of rows returned by a set-returning function. See `CREATE FUNCTION` for more information.

SUPPORT *support_function*

Set or change the planner support function to use for this function. See Section 37.11 for details. You must be superuser to use this option.

This option cannot be used to remove the support function altogether, since it must name a new support function. Use `CREATE OR REPLACE FUNCTION` if you need to do that.

*configuration_parameter
value*

Add or change the assignment to be made to a configuration parameter when the function is called. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the function-local setting is removed, so that the function executes with the value present in its environment. Use `RESET ALL` to clear all function-local settings. `SET FROM CURRENT` saves the value of the parameter that is current when `ALTER FUNCTION` is executed as the value to be applied when the function is entered.

See `SET` and Chapter 19 for more information about allowed parameter names and values.

RESTRICT

Ignored for conformance with the SQL standard.

Examples

To rename the function `sqrt` for type `integer` to `square_root`:

```
ALTER FUNCTION sqrt(integer) RENAME TO square_root;
```

To change the owner of the function `sqrt` for type `integer` to `joe`:

```
ALTER FUNCTION sqrt(integer) OWNER TO joe;
```

To change the schema of the function `sqrt` for type `integer` to `maths`:

```
ALTER FUNCTION sqrt(integer) SET SCHEMA maths;
```

To mark the function `sqrt` for type `integer` as being dependent on the extension `mathlib`:

```
ALTER FUNCTION sqrt(integer) DEPENDS ON EXTENSION mathlib;
```

To adjust the search path that is automatically set for a function:

```
ALTER FUNCTION check_password(text) SET search_path = admin,  
pg_temp;
```

To disable automatic setting of `search_path` for a function:

```
ALTER FUNCTION check_password(text) RESET search_path;
```

The function will now execute with whatever search path is used by its caller.

Compatibility

This statement is partially compatible with the `ALTER FUNCTION` statement in the SQL standard. The standard allows more properties of a function to be modified, but does not provide the ability to rename a function, make a function a security definer, attach configuration parameter values to a function, or change the owner, schema, or volatility of a function. The standard also requires the `RESTRICT` key word, which is optional in PostgreSQL.

See Also

`CREATE FUNCTION`, `DROP FUNCTION`, `ALTER PROCEDURE`, `ALTER ROUTINE`

ALTER GROUP

ALTER GROUP — change role name or membership

Synopsis

```
ALTER GROUP role_specification ADD USER user_name [, ... ]
ALTER GROUP role_specification DROP USER user_name [, ... ]
```

where *role_specification* can be:

```
    role_name
  | CURRENT_USER
  | SESSION_USER
```

```
ALTER GROUP group_name RENAME TO new_name
```

Description

ALTER GROUP changes the attributes of a user group. This is an obsolete command, though still accepted for backwards compatibility, because groups (and users too) have been superseded by the more general concept of roles.

The first two variants add users to a group or remove them from a group. (Any role can play the part of either a “user” or a “group” for this purpose.) These variants are effectively equivalent to granting or revoking membership in the role named as the “group”; so the preferred way to do this is to use GRANT or REVOKE.

The third variant changes the name of the group. This is exactly equivalent to renaming the role with ALTER ROLE.

Parameters

group_name

The name of the group (role) to modify.

user_name

Users (roles) that are to be added to or removed from the group. The users must already exist; ALTER GROUP does not create or drop users.

new_name

The new name of the group.

Examples

Add users to a group:

```
ALTER GROUP staff ADD USER karl, john;
```

Remove a user from a group:

```
ALTER GROUP workers DROP USER beth;
```

Compatibility

There is no `ALTER GROUP` statement in the SQL standard.

See Also

GRANT, REVOKE, ALTER ROLE

ALTER INDEX

ALTER INDEX — change the definition of an index

Synopsis

```
ALTER INDEX [ IF EXISTS ] name RENAME TO new_name
ALTER INDEX [ IF EXISTS ] name SET TABLESPACE tablespace_name
ALTER INDEX name ATTACH PARTITION index_name
ALTER INDEX name DEPENDS ON EXTENSION extension_name
ALTER INDEX [ IF EXISTS ] name SET ( storage_parameter = value
    [, ... ] )
ALTER INDEX [ IF EXISTS ] name RESET ( storage_parameter [, ... ] )
ALTER INDEX [ IF EXISTS ] name ALTER [ COLUMN ] column_number
    SET STATISTICS integer
ALTER INDEX ALL IN TABLESPACE name [ OWNED BY role_name [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
```

Description

ALTER INDEX changes the definition of an existing index. There are several subforms described below. Note that the lock level required may differ for each subform. An ACCESS EXCLUSIVE lock is held unless explicitly noted. When multiple subcommands are listed, the lock held will be the strictest one required from any subcommand.

RENAME

The RENAME form changes the name of the index. If the index is associated with a table constraint (either UNIQUE, PRIMARY KEY, or EXCLUDE), the constraint is renamed as well. There is no effect on the stored data.

Renaming an index acquires a SHARE UPDATE EXCLUSIVE lock.

SET TABLESPACE

This form changes the index's tablespace to the specified tablespace and moves the data file(s) associated with the index to the new tablespace. To change the tablespace of an index, you must own the index and have CREATE privilege on the new tablespace. All indexes in the current database in a tablespace can be moved by using the ALL IN TABLESPACE form, which will lock all indexes to be moved and then move each one. This form also supports OWNED BY, which will only move indexes owned by the roles specified. If the NOWAIT option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs will not be moved by this command, use ALTER DATABASE or explicit ALTER INDEX invocations instead if desired. See also CREATE TABLESPACE.

ATTACH PARTITION

Causes the named index to become attached to the altered index. The named index must be on a partition of the table containing the index being altered, and have an equivalent definition. An attached index cannot be dropped by itself, and will automatically be dropped if its parent index is dropped.

DEPENDS ON EXTENSION

This form marks the index as dependent on the extension, such that if the extension is dropped, the index will automatically be dropped as well.

```
SET ( storage_parameter = value [, ... ] )
```

This form changes one or more index-method-specific storage parameters for the index. See CREATE INDEX for details on the available parameters. Note that the index contents will not be modified immediately by this command; depending on the parameter you might need to rebuild the index with REINDEX to get the desired effects.

```
RESET ( storage_parameter [, ... ] )
```

This form resets one or more index-method-specific storage parameters to their defaults. As with SET, a REINDEX might be needed to update the index entirely.

```
ALTER [ COLUMN ] column_number SET STATISTICS integer
```

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations, though can be used only on index columns that are defined as an expression. Since expressions lack a unique name, we refer to them using the ordinal number of the index column. The target can be set in the range 0 to 10000; alternatively, set it to -1 to revert to using the system default statistics target (`default_statistics_target`). For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

Parameters

IF EXISTS

Do not throw an error if the index does not exist. A notice is issued in this case.

column_number

The ordinal number refers to the ordinal (left-to-right) position of the index column.

name

The name (possibly schema-qualified) of an existing index to alter.

new_name

The new name for the index.

tablespace_name

The tablespace to which the index will be moved.

extension_name

The name of the extension that the index is to depend on.

storage_parameter

The name of an index-method-specific storage parameter.

value

The new value for an index-method-specific storage parameter. This might be a number or a word depending on the parameter.

Notes

These operations are also possible using ALTER TABLE. ALTER INDEX is in fact just an alias for the forms of ALTER TABLE that apply to indexes.

There was formerly an `ALTER INDEX OWNER` variant, but this is now ignored (with a warning). An index cannot have an owner different from its table's owner. Changing the table's owner automatically changes the index as well.

Changing any part of a system catalog index is not permitted.

Examples

To rename an existing index:

```
ALTER INDEX distributors RENAME TO suppliers;
```

To move an index to a different tablespace:

```
ALTER INDEX distributors SET TABLESPACE fasttablespace;
```

To change an index's fill factor (assuming that the index method supports it):

```
ALTER INDEX distributors SET (fillfactor = 75);  
REINDEX INDEX distributors;
```

Set the statistics-gathering target for an expression index:

```
CREATE INDEX coord_idx ON measured (x, y, (z + t));  
ALTER INDEX coord_idx ALTER COLUMN 3 SET STATISTICS 1000;
```

Compatibility

`ALTER INDEX` is a PostgreSQL extension.

See Also

`CREATE INDEX`, `REINDEX`

ALTER LANGUAGE

ALTER LANGUAGE — change the definition of a procedural language

Synopsis

```
ALTER [ PROCEDURAL ] LANGUAGE name RENAME TO new_name
ALTER [ PROCEDURAL ] LANGUAGE name OWNER TO { new_owner |
CURRENT_USER | SESSION_USER }
```

Description

ALTER LANGUAGE changes the definition of a procedural language. The only functionality is to rename the language or assign a new owner. You must be superuser or owner of the language to use ALTER LANGUAGE.

Parameters

name

Name of a language

new_name

The new name of the language

new_owner

The new owner of the language

Compatibility

There is no ALTER LANGUAGE statement in the SQL standard.

See Also

CREATE LANGUAGE, DROP LANGUAGE

ALTER LARGE OBJECT

ALTER LARGE OBJECT — change the definition of a large object

Synopsis

```
ALTER LARGE OBJECT large_object_oid OWNER TO { new_owner |  
CURRENT_USER | SESSION_USER }
```

Description

ALTER LARGE OBJECT changes the definition of a large object.

You must own the large object to use ALTER LARGE OBJECT. To alter the owner, you must also be a direct or indirect member of the new owning role. (However, a superuser can alter any large object anyway.) Currently, the only functionality is to assign a new owner, so both restrictions always apply.

Parameters

large_object_oid

OID of the large object to be altered

new_owner

The new owner of the large object

Compatibility

There is no ALTER LARGE OBJECT statement in the SQL standard.

See Also

Chapter 34

ALTER MATERIALIZED VIEW

ALTER MATERIALIZED VIEW — change the definition of a materialized view

Synopsis

```
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    action [, ... ]
ALTER MATERIALIZED VIEW name
    DEPENDS ON EXTENSION extension_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    RENAME TO new_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    SET SCHEMA new_schema
ALTER MATERIALIZED VIEW ALL IN TABLESPACE name [ OWNED BY role_name
    [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
```

where *action* is one of:

```
ALTER [ COLUMN ] column_name SET STATISTICS integer
ALTER [ COLUMN ] column_name SET ( attribute_option = value
    [, ... ] )
ALTER [ COLUMN ] column_name RESET ( attribute_option
    [, ... ] )
ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL |
    EXTENDED | MAIN }
CLUSTER ON index_name
SET WITHOUT CLUSTER
SET ( storage_parameter = value [, ... ] )
RESET ( storage_parameter [, ... ] )
OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
```

Description

ALTER MATERIALIZED VIEW changes various auxiliary properties of an existing materialized view.

You must own the materialized view to use ALTER MATERIALIZED VIEW. To change a materialized view's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the materialized view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the materialized view. However, a superuser can alter ownership of any view anyway.)

The DEPENDS ON EXTENSION form marks the materialized view as dependent on an extension, such that the materialized view will automatically be dropped if the extension is dropped.

The statement subforms and actions available for ALTER MATERIALIZED VIEW are a subset of those available for ALTER TABLE, and have the same meaning when used for materialized views. See the descriptions for ALTER TABLE for details.

Parameters

name

The name (optionally schema-qualified) of an existing materialized view.

column_name

Name of a new or existing column.

extension_name

The name of the extension that the materialized view is to depend on.

new_column_name

New name for an existing column.

new_owner

The user name of the new owner of the materialized view.

new_name

The new name for the materialized view.

new_schema

The new schema for the materialized view.

Examples

To rename the materialized view `foo` to `bar`:

```
ALTER MATERIALIZED VIEW foo RENAME TO bar;
```

Compatibility

`ALTER MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

`CREATE MATERIALIZED VIEW`, `DROP MATERIALIZED VIEW`, `REFRESH MATERIALIZED VIEW`

ALTER OPERATOR

ALTER OPERATOR — change the definition of an operator

Synopsis

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type |  
NONE } )  
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
```

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type |  
NONE } )  
    SET SCHEMA new_schema
```

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type |  
NONE } )  
    SET ( { RESTRICT = { res_proc | NONE }  
          | JOIN = { join_proc | NONE }  
          } [ , ... ] )
```

Description

ALTER OPERATOR changes the definition of an operator.

You must own the operator to use ALTER OPERATOR. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the operator's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the operator. However, a superuser can alter ownership of any operator anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing operator.

left_type

The data type of the operator's left operand; write NONE if the operator has no left operand.

right_type

The data type of the operator's right operand; write NONE if the operator has no right operand.

new_owner

The new owner of the operator.

new_schema

The new schema for the operator.

res_proc

The restriction selectivity estimator function for this operator; write NONE to remove existing selectivity estimator.

join_proc

The join selectivity estimator function for this operator; write NONE to remove existing selectivity estimator.

Examples

Change the owner of a custom operator a @@ b for type text:

```
ALTER OPERATOR @@ (text, text) OWNER TO joe;
```

Change the restriction and join selectivity estimator functions of a custom operator a && b for type int[]:

```
ALTER OPERATOR && (_int4, _int4) SET (RESTRICT = _int_contsel, JOIN  
= _int_contjoinssel);
```

Compatibility

There is no ALTER OPERATOR statement in the SQL standard.

See Also

CREATE OPERATOR, DROP OPERATOR

ALTER OPERATOR CLASS

ALTER OPERATOR CLASS — change the definition of an operator class

Synopsis

```
ALTER OPERATOR CLASS name USING index_method  
    RENAME TO new_name
```

```
ALTER OPERATOR CLASS name USING index_method  
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
```

```
ALTER OPERATOR CLASS name USING index_method  
    SET SCHEMA new_schema
```

Description

ALTER OPERATOR CLASS changes the definition of an operator class.

You must own the operator class to use ALTER OPERATOR CLASS. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the operator class's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the operator class. However, a superuser can alter ownership of any operator class anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing operator class.

index_method

The name of the index method this operator class is for.

new_name

The new name of the operator class.

new_owner

The new owner of the operator class.

new_schema

The new schema for the operator class.

Compatibility

There is no ALTER OPERATOR CLASS statement in the SQL standard.

See Also

CREATE OPERATOR CLASS, DROP OPERATOR CLASS, ALTER OPERATOR FAMILY

ALTER OPERATOR FAMILY

ALTER OPERATOR FAMILY — change the definition of an operator family

Synopsis

```
ALTER OPERATOR FAMILY name USING index_method ADD
{ OPERATOR strategy_number operator_name ( op_type, op_type )
  [ FOR SEARCH | FOR ORDER BY sort_family_name ]
| FUNCTION support_number [ ( op_type [ , op_type ] ) ]
  function_name [ ( argument_type [ , ... ] ) ]
} [ , ... ]

ALTER OPERATOR FAMILY name USING index_method DROP
{ OPERATOR strategy_number ( op_type [ , op_type ] )
| FUNCTION support_number ( op_type [ , op_type ] )
} [ , ... ]

ALTER OPERATOR FAMILY name USING index_method
  RENAME TO new_name

ALTER OPERATOR FAMILY name USING index_method
  OWNER TO { new_owner | CURRENT_USER | SESSION_USER }

ALTER OPERATOR FAMILY name USING index_method
  SET SCHEMA new_schema
```

Description

ALTER OPERATOR FAMILY changes the definition of an operator family. You can add operators and support functions to the family, remove them from the family, or change the family's name or owner.

When operators and support functions are added to a family with ALTER OPERATOR FAMILY, they are not part of any specific operator class within the family, but are just “loose” within the family. This indicates that these operators and functions are compatible with the family's semantics, but are not required for correct functioning of any specific index. (Operators and functions that are so required should be declared as part of an operator class, instead; see CREATE OPERATOR CLASS.) PostgreSQL will allow loose members of a family to be dropped from the family at any time, but members of an operator class cannot be dropped without dropping the whole class and any indexes that depend on it. Typically, single-data-type operators and functions are part of operator classes because they are needed to support an index on that specific data type, while cross-data-type operators and functions are made loose members of the family.

You must be a superuser to use ALTER OPERATOR FAMILY. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

ALTER OPERATOR FAMILY does not presently check whether the operator family definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator family.

Refer to Section 37.16 for further information.

Parameters

name

The name (optionally schema-qualified) of an existing operator family.

index_method

The name of the index method this operator family is for.

strategy_number

The index method's strategy number for an operator associated with the operator family.

operator_name

The name (optionally schema-qualified) of an operator associated with the operator family.

op_type

In an OPERATOR clause, the operand data type(s) of the operator, or NONE to signify a left-unary or right-unary operator. Unlike the comparable syntax in CREATE OPERATOR CLASS, the operand data types must always be specified.

In an ADD FUNCTION clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function. For B-tree comparison functions and hash functions it is not necessary to specify *op_type* since the function's input data type(s) are always the correct ones to use. For B-tree sort support functions and all functions in GiST, SP-GiST and GIN operator classes, it is necessary to specify the operand data type(s) the function is to be used with.

In a DROP FUNCTION clause, the operand data type(s) the function is intended to support must be specified.

sort_family_name

The name (optionally schema-qualified) of an existing btree operator family that describes the sort ordering associated with an ordering operator.

If neither FOR SEARCH nor FOR ORDER BY is specified, FOR SEARCH is the default.

support_number

The index method's support function number for a function associated with the operator family.

function_name

The name (optionally schema-qualified) of a function that is an index method support function for the operator family. If no argument list is specified, the name must be unique in its schema.

argument_type

The parameter data type(s) of the function.

new_name

The new name of the operator family.

new_owner

The new owner of the operator family.

new_schema

The new schema for the operator family.

The OPERATOR and FUNCTION clauses can appear in any order.

Notes

Notice that the DROP syntax only specifies the “slot” in the operator family, by strategy or support number and input data type(s). The name of the operator or function occupying the slot is not mentioned. Also, for DROP FUNCTION the type(s) to specify are the input data type(s) the function is intended to support; for GiST, SP-GiST and GIN indexes this might have nothing to do with the actual input argument types of the function.

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator family is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator family.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before PostgreSQL 8.4, the OPERATOR clause could include a RECHECK option. This is no longer supported because whether an index operator is “lossy” is now determined on-the-fly at run time. This allows efficient handling of cases where an operator might or might not be lossy.

Examples

The following example command adds cross-data-type operators and support functions to an operator family that already contains B-tree operator classes for data types `int4` and `int2`.

```
ALTER OPERATOR FAMILY integer_ops USING btree ADD
```

```
-- int4 vs int2
OPERATOR 1 < (int4, int2) ,
OPERATOR 2 <= (int4, int2) ,
OPERATOR 3 = (int4, int2) ,
OPERATOR 4 >= (int4, int2) ,
OPERATOR 5 > (int4, int2) ,
FUNCTION 1 btint42cmp(int4, int2) ,

-- int2 vs int4
OPERATOR 1 < (int2, int4) ,
OPERATOR 2 <= (int2, int4) ,
OPERATOR 3 = (int2, int4) ,
OPERATOR 4 >= (int2, int4) ,
OPERATOR 5 > (int2, int4) ,
FUNCTION 1 btint24cmp(int2, int4) ;
```

To remove these entries again:

```
ALTER OPERATOR FAMILY integer_ops USING btree DROP
```

```
-- int4 vs int2
OPERATOR 1 (int4, int2) ,
OPERATOR 2 (int4, int2) ,
OPERATOR 3 (int4, int2) ,
OPERATOR 4 (int4, int2) ,
```

```
OPERATOR 5 (int4, int2) ,  
FUNCTION 1 (int4, int2) ,  
  
-- int2 vs int4  
OPERATOR 1 (int2, int4) ,  
OPERATOR 2 (int2, int4) ,  
OPERATOR 3 (int2, int4) ,  
OPERATOR 4 (int2, int4) ,  
OPERATOR 5 (int2, int4) ,  
FUNCTION 1 (int2, int4) ;
```

Compatibility

There is no `ALTER OPERATOR FAMILY` statement in the SQL standard.

See Also

`CREATE OPERATOR FAMILY`, `DROP OPERATOR FAMILY`, `CREATE OPERATOR CLASS`,
`ALTER OPERATOR CLASS`, `DROP OPERATOR CLASS`

ALTER POLICY

ALTER POLICY — change the definition of a row level security policy

Synopsis

```
ALTER POLICY name ON table_name RENAME TO new_name

ALTER POLICY name ON table_name
    [ TO { role_name | PUBLIC | CURRENT_USER | SESSION_USER }
    [ , ... ] ]
    [ USING ( using_expression ) ]
    [ WITH CHECK ( check_expression ) ]
```

Description

ALTER POLICY changes the definition of an existing row-level security policy. Note that ALTER POLICY only allows the set of roles to which the policy applies and the USING and WITH CHECK expressions to be modified. To change other properties of a policy, such as the command to which it applies or whether it is permissive or restrictive, the policy must be dropped and recreated.

To use ALTER POLICY, you must own the table that the policy applies to.

In the second form of ALTER POLICY, the role list, *using_expression*, and *check_expression* are replaced independently if specified. When one of those clauses is omitted, the corresponding part of the policy is unchanged.

Parameters

name

The name of an existing policy to alter.

table_name

The name (optionally schema-qualified) of the table that the policy is on.

new_name

The new name for the policy.

role_name

The role(s) to which the policy applies. Multiple roles can be specified at one time. To apply the policy to all roles, use PUBLIC.

using_expression

The USING expression for the policy. See CREATE POLICY for details.

check_expression

The WITH CHECK expression for the policy. See CREATE POLICY for details.

Compatibility

ALTER POLICY is a PostgreSQL extension.

See Also

CREATE POLICY, DROP POLICY

ALTER PROCEDURE

ALTER PROCEDURE — change the definition of a procedure

Synopsis

```
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  action [ ... ] [ RESTRICT ]
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  RENAME TO new_name
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  SET SCHEMA new_schema
ALTER PROCEDURE name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ]
  DEPENDS ON EXTENSION extension_name
```

where *action* is one of:

```
[ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
SET configuration_parameter { TO | = } { value | DEFAULT }
SET configuration_parameter FROM CURRENT
RESET configuration_parameter
RESET ALL
```

Description

ALTER PROCEDURE changes the definition of a procedure.

You must own the procedure to use ALTER PROCEDURE. To change a procedure's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the procedure's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the procedure. However, a superuser can alter ownership of any procedure anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing procedure. If no argument list is specified, the name must be unique in its schema.

argmode

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

argname

The name of an argument. Note that `ALTER PROCEDURE` does not actually pay any attention to argument names, since only the argument data types are needed to determine the procedure's identity.

argtype

The data type(s) of the procedure's arguments (optionally schema-qualified), if any.

new_name

The new name of the procedure.

new_owner

The new owner of the procedure. Note that if the procedure is marked `SECURITY DEFINER`, it will subsequently execute as the new owner.

new_schema

The new schema for the procedure.

extension_name

The name of the extension that the procedure is to depend on.

[`EXTERNAL`] `SECURITY INVOKER`

[`EXTERNAL`] `SECURITY DEFINER`

Change whether the procedure is a security definer or not. The key word `EXTERNAL` is ignored for SQL conformance. See `CREATE PROCEDURE` for more information about this capability.

configuration_parameter

value

Add or change the assignment to be made to a configuration parameter when the procedure is called. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the procedure-local setting is removed, so that the procedure executes with the value present in its environment. Use `RESET ALL` to clear all procedure-local settings. `SET FROM CURRENT` saves the value of the parameter that is current when `ALTER PROCEDURE` is executed as the value to be applied when the procedure is entered.

See `SET` and Chapter 19 for more information about allowed parameter names and values.

`RESTRICT`

Ignored for conformance with the SQL standard.

Examples

To rename the procedure `insert_data` with two arguments of type `integer` to `insert_record`:

```
ALTER PROCEDURE insert_data(integer, integer) RENAME TO
insert_record;
```

To change the owner of the procedure `insert_data` with two arguments of type `integer` to `joe`:

```
ALTER PROCEDURE insert_data(integer, integer) OWNER TO joe;
```

To change the schema of the procedure `insert_data` with two arguments of type `integer` to `accounting`:

```
ALTER PROCEDURE insert_data(integer, integer) SET SCHEMA
accounting;
```

To mark the procedure `insert_data(integer, integer)` as being dependent on the extension `myext`:

```
ALTER PROCEDURE insert_data(integer, integer) DEPENDS ON EXTENSION
myext;
```

To adjust the search path that is automatically set for a procedure:

```
ALTER PROCEDURE check_password(text) SET search_path = admin,
pg_temp;
```

To disable automatic setting of `search_path` for a procedure:

```
ALTER PROCEDURE check_password(text) RESET search_path;
```

The procedure will now execute with whatever search path is used by its caller.

Compatibility

This statement is partially compatible with the `ALTER PROCEDURE` statement in the SQL standard. The standard allows more properties of a procedure to be modified, but does not provide the ability to rename a procedure, make a procedure a security definer, attach configuration parameter values to a procedure, or change the owner, schema, or volatility of a procedure. The standard also requires the `RESTRICT` key word, which is optional in PostgreSQL.

See Also

`CREATE PROCEDURE`, `DROP PROCEDURE`, `ALTER FUNCTION`, `ALTER ROUTINE`

ALTER PUBLICATION

ALTER PUBLICATION — change the definition of a publication

Synopsis

```
ALTER PUBLICATION name ADD TABLE [ ONLY ] table_name [ * ] [, ...]
ALTER PUBLICATION name SET TABLE [ ONLY ] table_name [ * ] [, ...]
ALTER PUBLICATION name DROP TABLE [ ONLY ] table_name [ * ] [, ...]
ALTER PUBLICATION name SET ( publication_parameter [= value]
    [, ... ] )
ALTER PUBLICATION name OWNER TO { new_owner | CURRENT_USER |
    SESSION_USER }
ALTER PUBLICATION name RENAME TO new_name
```

Description

The command ALTER PUBLICATION can change the attributes of a publication.

The first three variants change which tables are part of the publication. The SET TABLE clause will replace the list of tables in the publication with the specified one. The ADD TABLE and DROP TABLE clauses will add and remove one or more tables from the publication. Note that adding tables to a publication that is already subscribed to will require a ALTER SUBSCRIPTION ... REFRESH PUBLICATION action on the subscribing side in order to become effective.

The fourth variant of this command listed in the synopsis can change all of the publication properties specified in CREATE PUBLICATION. Properties not mentioned in the command retain their previous settings.

The remaining variants change the owner and the name of the publication.

You must own the publication to use ALTER PUBLICATION. To alter the owner, you must also be a direct or indirect member of the new owning role. The new owner must have CREATE privilege on the database. Also, the new owner of a FOR ALL TABLES publication must be a superuser. However, a superuser can change the ownership of a publication while circumventing these restrictions.

Parameters

name

The name of an existing publication whose definition is to be altered.

table_name

Name of an existing table. If ONLY is specified before the table name, only that table is affected. If ONLY is not specified, the table and all its descendant tables (if any) are affected. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

SET (*publication_parameter* [= *value*] [, ...])

This clause alters publication parameters originally set by CREATE PUBLICATION. See there for more information.

new_owner

The user name of the new owner of the publication.

new_name

The new name for the publication.

Examples

Change the publication to publish only deletes and updates:

```
ALTER PUBLICATION noinsert SET (publish = 'update, delete');
```

Add some tables to the publication:

```
ALTER PUBLICATION mypublication ADD TABLE users, departments;
```

Compatibility

ALTER PUBLICATION is a PostgreSQL extension.

See Also

CREATE PUBLICATION, DROP PUBLICATION, CREATE SUBSCRIPTION, ALTER SUBSCRIPTION

ALTER ROLE

ALTER ROLE — change a database role

Synopsis

```
ALTER ROLE role_specification [ WITH ] option [ ... ]
```

where *option* can be:

```
    SUPERUSER | NOSUPERUSER  
    |  
    CREATEDB | NOCREATEDB  
    |  
    CREATEROLE | NOCREATEROLE  
    |  
    INHERIT | NOINHERIT  
    |  
    LOGIN | NOLOGIN  
    |  
    REPLICATION | NOREPLICATION  
    |  
    BYPASSRLS | NOBYPASSRLS  
    |  
    CONNECTION LIMIT conlimit  
    |  
    [ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL  
    |  
    VALID UNTIL 'timestamp'
```

```
ALTER ROLE name RENAME TO new_name
```

```
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name  
] SET configuration_parameter { TO | = } { value | DEFAULT }  
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name  
] SET configuration_parameter FROM CURRENT  
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name  
] RESET configuration_parameter  
ALTER ROLE { role_specification | ALL } [ IN DATABASE database_name  
] RESET ALL
```

where *role_specification* can be:

```
    role_name  
    |  
    CURRENT_USER  
    |  
    SESSION_USER
```

Description

ALTER ROLE changes the attributes of a PostgreSQL role.

The first variant of this command listed in the synopsis can change many of the role attributes that can be specified in CREATE ROLE. (All the possible attributes are covered, except that there are no options for adding or removing memberships; use GRANT and REVOKE for that.) Attributes not mentioned in the command retain their previous settings. Database superusers can change any of these settings for any role. Roles having CREATEROLE privilege can change any of these settings, but only for non-superuser and non-replication roles. Ordinary roles can only change their own password.

The second variant changes the name of the role. Database superusers can rename any role. Roles having CREATEROLE privilege can rename non-superuser roles. The current session user cannot be renamed. (Connect as a different user if you need to do that.) Because MD5-encrypted passwords use the role name as cryptographic salt, renaming a role clears its password if the password is MD5-encrypted.

The remaining variants change a role's session default for a configuration variable, either for all databases or, when the `IN DATABASE` clause is specified, only for sessions in the named database. If `ALL` is specified instead of a role name, this changes the setting for all roles. Using `ALL` with `IN DATABASE` is effectively the same as using the command `ALTER DATABASE ... SET ...`.

Whenever the role subsequently starts a new session, the specified value becomes the session default, overriding whatever setting is present in `postgresql.conf` or has been received from the `postgres` command line. This only happens at login time; executing `SET ROLE` or `SET SESSION AUTHORIZATION` does not cause new configuration values to be set. Settings set for all databases are overridden by database-specific settings attached to a role. Settings for specific databases or specific roles override settings for all roles.

Superusers can change anyone's session defaults. Roles having `CREATEROLE` privilege can change defaults for non-superuser roles. Ordinary roles can only set defaults for themselves. Certain configuration variables cannot be set this way, or can only be set if a superuser issues the command. Only superusers can change a setting for all roles in all databases.

Parameters

name

The name of the role whose attributes are to be altered.

`CURRENT_USER`

Alter the current user instead of an explicitly identified role.

`SESSION_USER`

Alter the current session user instead of an explicitly identified role.

`SUPERUSER`

`NOSUPERUSER`

`CREATEDB`

`NOCREATEDB`

`CREATEROLE`

`NOCREATEROLE`

`INHERIT`

`NOINHERIT`

`LOGIN`

`NOLOGIN`

`REPLICATION`

`NOREPLICATION`

`BYPASSRLS`

`NOBYPASSRLS`

`CONNECTION LIMIT` *conlimit*

[`ENCRYPTED`] `PASSWORD` '*password*'

`PASSWORD NULL`

`VALID UNTIL` '*timestamp*'

These clauses alter attributes originally set by `CREATE ROLE`. For more information, see the `CREATE ROLE` reference page.

new_name

The new name of the role.

database_name

The name of the database the configuration variable should be set in.

configuration_parameter
value

Set this role's session default for the specified configuration parameter to the given value. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the role-specific variable setting is removed, so the role will inherit the system-wide default setting in new sessions. Use `RESET ALL` to clear all role-specific settings. `SET FROM CURRENT` saves the session's current value of the parameter as the role-specific value. If `IN DATABASE` is specified, the configuration parameter is set or removed for the given role and database only.

Role-specific variable settings take effect only at login; `SET ROLE` and `SET SESSION AUTHORIZATION` do not process role-specific variable settings.

See `SET` and Chapter 19 for more information about allowed parameter names and values.

Notes

Use `CREATE ROLE` to add new roles, and `DROP ROLE` to remove a role.

`ALTER ROLE` cannot change a role's memberships. Use `GRANT` and `REVOKE` to do that.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in cleartext, and it might also be logged in the client's command history or the server log. `psql` contains a command `\password` that can be used to change a role's password without exposing the cleartext password.

It is also possible to tie a session default to a specific database rather than to a role; see `ALTER DATABASE`. If there is a conflict, database-role-specific settings override role-specific ones, which in turn override database-specific ones.

Examples

Change a role's password:

```
ALTER ROLE davide WITH PASSWORD 'hu8jmn3';
```

Remove a role's password:

```
ALTER ROLE davide WITH PASSWORD NULL;
```

Change a password expiration date, specifying that the password should expire at midday on 4th May 2015 using the time zone which is one hour ahead of UTC:

```
ALTER ROLE chris VALID UNTIL 'May 4 12:00:00 2015 +1';
```

Make a password valid forever:

```
ALTER ROLE fred VALID UNTIL 'infinity';
```

Give a role the ability to create other roles and new databases:

```
ALTER ROLE miriam CREATEROLE CREATEDB;
```

Give a role a non-default setting of the `maintenance_work_mem` parameter:

```
ALTER ROLE worker_bee SET maintenance_work_mem = 100000;
```

Give a role a non-default, database-specific setting of the `client_min_messages` parameter:

```
ALTER ROLE fred IN DATABASE devel SET client_min_messages = DEBUG;
```

Compatibility

The `ALTER ROLE` statement is a PostgreSQL extension.

See Also

`CREATE ROLE`, `DROP ROLE`, `ALTER DATABASE`, `SET`

ALTER ROUTINE

ALTER ROUTINE — change the definition of a routine

Synopsis

```
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ]
    action [ ... ] [ RESTRICT ]
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ]
    RENAME TO new_name
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ]
    OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ]
    SET SCHEMA new_schema
ALTER ROUTINE name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ]
    DEPENDS ON EXTENSION extension_name
```

where *action* is one of:

```
IMMUTABLE | STABLE | VOLATILE | [ NOT ] LEAKPROOF
[ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
PARALLEL { UNSAFE | RESTRICTED | SAFE }
COST execution_cost
ROWS result_rows
SET configuration_parameter { TO | = } { value | DEFAULT }
SET configuration_parameter FROM CURRENT
RESET configuration_parameter
RESET ALL
```

Description

ALTER ROUTINE changes the definition of a routine, which can be an aggregate function, a normal function, or a procedure. See under ALTER AGGREGATE, ALTER FUNCTION, and ALTER PROCEDURE for the description of the parameters, more examples, and further details.

Examples

To rename the routine `foo` for type `integer` to `foobar`:

```
ALTER ROUTINE foo(integer) RENAME TO foobar;
```

This command will work independent of whether `foo` is an aggregate, function, or procedure.

Compatibility

This statement is partially compatible with the ALTER ROUTINE statement in the SQL standard. See under ALTER FUNCTION and ALTER PROCEDURE for more details. Allowing routine names to refer to aggregate functions is a PostgreSQL extension.

See Also

ALTER AGGREGATE, ALTER FUNCTION, ALTER PROCEDURE, DROP ROUTINE

Note that there is no `CREATE ROUTINE` command.

ALTER RULE

ALTER RULE — change the definition of a rule

Synopsis

```
ALTER RULE name ON table_name RENAME TO new_name
```

Description

ALTER RULE changes properties of an existing rule. Currently, the only available action is to change the rule's name.

To use ALTER RULE, you must own the table or view that the rule applies to.

Parameters

name

The name of an existing rule to alter.

table_name

The name (optionally schema-qualified) of the table or view that the rule applies to.

new_name

The new name for the rule.

Examples

To rename an existing rule:

```
ALTER RULE notify_all ON emp RENAME TO notify_me;
```

Compatibility

ALTER RULE is a PostgreSQL language extension, as is the entire query rewrite system.

See Also

CREATE RULE, DROP RULE

ALTER SCHEMA

ALTER SCHEMA — change the definition of a schema

Synopsis

```
ALTER SCHEMA name RENAME TO new_name
ALTER SCHEMA name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
```

Description

ALTER SCHEMA changes the definition of a schema.

You must own the schema to use ALTER SCHEMA. To rename a schema you must also have the CREATE privilege for the database. To alter the owner, you must also be a direct or indirect member of the new owning role, and you must have the CREATE privilege for the database. (Note that superusers have all these privileges automatically.)

Parameters

name

The name of an existing schema.

new_name

The new name of the schema. The new name cannot begin with pg_, as such names are reserved for system schemas.

new_owner

The new owner of the schema.

Compatibility

There is no ALTER SCHEMA statement in the SQL standard.

See Also

CREATE SCHEMA, DROP SCHEMA

ALTER SEQUENCE

ALTER SEQUENCE — change the definition of a sequence generator

Synopsis

```
ALTER SEQUENCE [ IF EXISTS ] name
  [ AS data_type ]
  [ INCREMENT [ BY ] increment ]
  [ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO
MAXVALUE ]
  [ START [ WITH ] start ]
  [ RESTART [ [ WITH ] restart ] ]
  [ CACHE cache ] [ [ NO ] CYCLE ]
  [ OWNED BY { table_name.column_name | NONE } ]
ALTER SEQUENCE [ IF EXISTS ] name OWNER TO { new_owner |
CURRENT_USER | SESSION_USER }
ALTER SEQUENCE [ IF EXISTS ] name RENAME TO new_name
ALTER SEQUENCE [ IF EXISTS ] name SET SCHEMA new_schema
```

Description

ALTER SEQUENCE changes the parameters of an existing sequence generator. Any parameters not specifically set in the ALTER SEQUENCE command retain their prior settings.

You must own the sequence to use ALTER SEQUENCE. To change a sequence's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the sequence's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the sequence. However, a superuser can alter ownership of any sequence anyway.)

Parameters

name

The name (optionally schema-qualified) of a sequence to be altered.

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

data_type

The optional clause AS *data_type* changes the data type of the sequence. Valid types are smallint, integer, and bigint.

Changing the data type automatically changes the minimum and maximum values of the sequence if and only if the previous minimum and maximum values were the minimum or maximum value of the old data type (in other words, if the sequence had been created using NO MINVALUE or NO MAXVALUE, implicitly or explicitly). Otherwise, the minimum and maximum values are preserved, unless new values are given as part of the same command. If the minimum and maximum values do not fit into the new data type, an error will be generated.

increment

The clause `INCREMENT BY increment` is optional. A positive value will make an ascending sequence, a negative one a descending sequence. If unspecified, the old increment value will be maintained.

minvalue

`NO MINVALUE`

The optional clause `MINVALUE minvalue` determines the minimum value a sequence can generate. If `NO MINVALUE` is specified, the defaults of 1 and the minimum value of the data type for ascending and descending sequences, respectively, will be used. If neither option is specified, the current minimum value will be maintained.

maxvalue

`NO MAXVALUE`

The optional clause `MAXVALUE maxvalue` determines the maximum value for the sequence. If `NO MAXVALUE` is specified, the defaults of the maximum value of the data type and -1 for ascending and descending sequences, respectively, will be used. If neither option is specified, the current maximum value will be maintained.

start

The optional clause `START WITH start` changes the recorded start value of the sequence. This has no effect on the *current* sequence value; it simply sets the value that future `ALTER SEQUENCE RESTART` commands will use.

restart

The optional clause `RESTART [WITH restart]` changes the current value of the sequence. This is similar to calling the `setval` function with `is_called = false`: the specified value will be returned by the *next* call of `nextval`. Writing `RESTART` with no *restart* value is equivalent to supplying the start value that was recorded by `CREATE SEQUENCE` or last set by `ALTER SEQUENCE START WITH`.

In contrast to a `setval` call, a `RESTART` operation on a sequence is transactional and blocks concurrent transactions from obtaining numbers from the same sequence. If that's not the desired mode of operation, `setval` should be used.

cache

The clause `CACHE cache` enables sequence numbers to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache). If unspecified, the old cache value will be maintained.

`CYCLE`

The optional `CYCLE` key word can be used to enable the sequence to wrap around when the *maxvalue* or *minvalue* has been reached by an ascending or descending sequence respectively. If the limit is reached, the next number generated will be the *minvalue* or *maxvalue*, respectively.

`NO CYCLE`

If the optional `NO CYCLE` key word is specified, any calls to `nextval` after the sequence has reached its maximum value will return an error. If neither `CYCLE` or `NO CYCLE` are specified, the old cycle behavior will be maintained.

`OWNED BY table_name.column_name`

`OWNED BY NONE`

The `OWNED BY` option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well.

If specified, this association replaces any previously specified association for the sequence. The specified table must have the same owner and be in the same schema as the sequence. Specifying `OWNED BY NONE` removes any existing association, making the sequence “free-standing”.

new_owner

The user name of the new owner of the sequence.

new_name

The new name for the sequence.

new_schema

The new schema for the sequence.

Notes

`ALTER SEQUENCE` will not immediately affect `nextval` results in backends, other than the current one, that have preallocated (cached) sequence values. They will use up all cached values prior to noticing the changed sequence generation parameters. The current backend will be affected immediately.

`ALTER SEQUENCE` does not affect the `currval` status for the sequence. (Before PostgreSQL 8.3, it sometimes did.)

`ALTER SEQUENCE` blocks concurrent `nextval`, `currval`, `lastval`, and `setval` calls.

For historical reasons, `ALTER TABLE` can be used with sequences too; but the only variants of `ALTER TABLE` that are allowed with sequences are equivalent to the forms shown above.

Examples

Restart a sequence called `serial`, at 105:

```
ALTER SEQUENCE serial RESTART WITH 105;
```

Compatibility

`ALTER SEQUENCE` conforms to the SQL standard, except for the `AS`, `START WITH`, `OWNED BY`, `OWNER TO`, `RENAME TO`, and `SET SCHEMA` clauses, which are PostgreSQL extensions.

See Also

`CREATE SEQUENCE`, `DROP SEQUENCE`

ALTER SERVER

ALTER SERVER — change the definition of a foreign server

Synopsis

```
ALTER SERVER name [ VERSION 'new_version' ]
    [ OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] ) ]
ALTER SERVER name OWNER TO { new_owner | CURRENT_USER |
    SESSION_USER }
ALTER SERVER name RENAME TO new_name
```

Description

ALTER SERVER changes the definition of a foreign server. The first form changes the server version string or the generic options of the server (at least one clause is required). The second form changes the owner of the server.

To alter the server you must be the owner of the server. Additionally to alter the owner, you must own the server and also be a direct or indirect member of the new owning role, and you must have USAGE privilege on the server's foreign-data wrapper. (Note that superusers satisfy all these criteria automatically.)

Parameters

name

The name of an existing server.

new_version

New server version.

OPTIONS ([ADD | SET | DROP] *option* ['*value*'] [, ...])

Change options for the server. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; names and values are also validated using the server's foreign-data wrapper library.

new_owner

The user name of the new owner of the foreign server.

new_name

The new name for the foreign server.

Examples

Alter server `foo`, add connection options:

```
ALTER SERVER foo OPTIONS (host 'foo', dbname 'foodb');
```

Alter server `foo`, change version, change `host` option:

```
ALTER SERVER foo VERSION '8.4' OPTIONS (SET host 'baz');
```

Compatibility

ALTER SERVER conforms to ISO/IEC 9075-9 (SQL/MED). The OWNER TO and RENAME forms are PostgreSQL extensions.

See Also

CREATE SERVER, DROP SERVER

ALTER STATISTICS

ALTER STATISTICS — change the definition of an extended statistics object

Synopsis

```
ALTER STATISTICS name OWNER TO { new_owner | CURRENT_USER |  
SESSION_USER }  
ALTER STATISTICS name RENAME TO new_name  
ALTER STATISTICS name SET SCHEMA new_schema
```

Description

ALTER STATISTICS changes the parameters of an existing extended statistics object. Any parameters not specifically set in the ALTER STATISTICS command retain their prior settings.

You must own the statistics object to use ALTER STATISTICS. To change a statistics object's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the statistics object's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the statistics object. However, a superuser can alter ownership of any statistics object anyway.)

Parameters

name

The name (optionally schema-qualified) of the statistics object to be altered.

new_owner

The user name of the new owner of the statistics object.

new_name

The new name for the statistics object.

new_schema

The new schema for the statistics object.

Compatibility

There is no ALTER STATISTICS command in the SQL standard.

See Also

CREATE STATISTICS, DROP STATISTICS

ALTER SUBSCRIPTION

ALTER SUBSCRIPTION — change the definition of a subscription

Synopsis

```
ALTER SUBSCRIPTION name CONNECTION 'conninfo'
ALTER SUBSCRIPTION name SET PUBLICATION publication_name [, ...]
  [ WITH ( set_publication_option [= value] [, ... ] ) ]
ALTER SUBSCRIPTION name REFRESH PUBLICATION [ WITH ( refresh_option
  [= value] [, ... ] ) ]
ALTER SUBSCRIPTION name ENABLE
ALTER SUBSCRIPTION name DISABLE
ALTER SUBSCRIPTION name SET ( subscription_parameter [= value]
  [, ... ] )
ALTER SUBSCRIPTION name OWNER TO { new_owner | CURRENT_USER |
  SESSION_USER }
ALTER SUBSCRIPTION name RENAME TO new_name
```

Description

ALTER SUBSCRIPTION can change most of the subscription properties that can be specified in CREATE SUBSCRIPTION.

You must own the subscription to use ALTER SUBSCRIPTION. To alter the owner, you must also be a direct or indirect member of the new owning role. The new owner has to be a superuser. (Currently, all subscription owners must be superusers, so the owner checks will be bypassed in practice. But this might change in the future.)

Parameters

name

The name of a subscription whose properties are to be altered.

CONNECTION '*conninfo*'

This clause alters the connection property originally set by CREATE SUBSCRIPTION. See there for more information.

SET PUBLICATION *publication_name*

Changes list of subscribed publications. See CREATE SUBSCRIPTION for more information. By default this command will also act like REFRESH PUBLICATION.

set_publication_option specifies additional options for this operation. The supported options are:

refresh (boolean)

When false, the command will not try to refresh table information. REFRESH PUBLICATION should then be executed separately. The default is true.

Additionally, refresh options as described under REFRESH PUBLICATION may be specified.

REFRESH PUBLICATION

Fetch missing table information from publisher. This will start replication of tables that were added to the subscribed-to publications since the last invocation of `REFRESH PUBLICATION` or since `CREATE SUBSCRIPTION`.

refresh_option specifies additional options for the refresh operation. The supported options are:

`copy_data` (boolean)

Specifies whether the existing data in the publications that are being subscribed to should be copied once the replication starts. The default is `true`.

ENABLE

Enables the previously disabled subscription, starting the logical replication worker at the end of transaction.

DISABLE

Disables the running subscription, stopping the logical replication worker at the end of transaction.

`SET (subscription_parameter [= value] [, ...])`

This clause alters parameters originally set by `CREATE SUBSCRIPTION`. See there for more information. The allowed options are `slot_name` and `synchronous_commit`

new_owner

The user name of the new owner of the subscription.

new_name

The new name for the subscription.

Examples

Change the publication subscribed by a subscription to `insert_only`:

```
ALTER SUBSCRIPTION mysub SET PUBLICATION insert_only;
```

Disable (stop) the subscription:

```
ALTER SUBSCRIPTION mysub DISABLE;
```

Compatibility

`ALTER SUBSCRIPTION` is a PostgreSQL extension.

See Also

`CREATE SUBSCRIPTION`, `DROP SUBSCRIPTION`, `CREATE PUBLICATION`, `ALTER PUBLICATION`

ALTER SYSTEM

ALTER SYSTEM — change a server configuration parameter

Synopsis

```
ALTER SYSTEM SET configuration_parameter { TO | = } { value |  
'value' | DEFAULT }
```

```
ALTER SYSTEM RESET configuration_parameter  
ALTER SYSTEM RESET ALL
```

Description

ALTER SYSTEM is used for changing server configuration parameters across the entire database cluster. It can be more convenient than the traditional method of manually editing the `postgresql.conf` file. ALTER SYSTEM writes the given parameter setting to the `postgresql.auto.conf` file, which is read in addition to `postgresql.conf`. Setting a parameter to `DEFAULT`, or using the `RESET` variant, removes that configuration entry from the `postgresql.auto.conf` file. Use `RESET ALL` to remove all such configuration entries.

Values set with ALTER SYSTEM will be effective after the next server configuration reload, or after the next server restart in the case of parameters that can only be changed at server start. A server configuration reload can be commanded by calling the SQL function `pg_reload_conf()`, running `pg_ctl reload`, or sending a `SIGHUP` signal to the main server process.

Only superusers can use ALTER SYSTEM. Also, since this command acts directly on the file system and cannot be rolled back, it is not allowed inside a transaction block or function.

Parameters

configuration_parameter

Name of a settable configuration parameter. Available parameters are documented in Chapter 19.

value

New value of the parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. `DEFAULT` can be written to specify removing the parameter and its value from `postgresql.auto.conf`.

Notes

This command can't be used to set `data_directory`, nor parameters that are not allowed in `postgresql.conf` (e.g., preset options).

See Section 19.1 for other ways to set the parameters.

Examples

Set the `wal_level`:

```
ALTER SYSTEM SET wal_level = replica;
```

Undo that, restoring whatever setting was effective in `postgresql.conf`:

```
ALTER SYSTEM RESET wal_level;
```

Compatibility

The `ALTER SYSTEM` statement is a PostgreSQL extension.

See Also

SET, SHOW

ALTER TABLE

ALTER TABLE — change the definition of a table

Synopsis

```
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    action [, ... ]
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME CONSTRAINT constraint_name TO new_constraint_name
ALTER TABLE [ IF EXISTS ] name
    RENAME TO new_name
ALTER TABLE [ IF EXISTS ] name
    SET SCHEMA new_schema
ALTER TABLE ALL IN TABLESPACE name [ OWNED BY role_name [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
ALTER TABLE [ IF EXISTS ] name
    ATTACH PARTITION partition_name { FOR
    VALUES partition_bound_spec | DEFAULT }
ALTER TABLE [ IF EXISTS ] name
    DETACH PARTITION partition_name
```

where *action* is one of:

```
    ADD [ COLUMN ] [ IF NOT EXISTS ] column_name data_type
    [ COLLATE collation ] [ column_constraint [ ... ] ]
    DROP [ COLUMN ] [ IF EXISTS ] column_name [ RESTRICT |
CASCADE ]
    ALTER [ COLUMN ] column_name [ SET DATA ] TYPE data_type
    [ COLLATE collation ] [ USING expression ]
    ALTER [ COLUMN ] column_name SET DEFAULT expression
    ALTER [ COLUMN ] column_name DROP DEFAULT
    ALTER [ COLUMN ] column_name { SET | DROP } NOT NULL
    ALTER [ COLUMN ] column_name ADD GENERATED { ALWAYS | BY
DEFAULT } AS IDENTITY [ ( sequence_options ) ]
    ALTER [ COLUMN ] column_name { SET GENERATED { ALWAYS | BY
DEFAULT } | SET sequence_option | RESTART [ [ WITH ] restart ] }
    [...]
    ALTER [ COLUMN ] column_name DROP IDENTITY [ IF EXISTS ]
    ALTER [ COLUMN ] column_name SET STATISTICS integer
    ALTER [ COLUMN ] column_name SET ( attribute_option = value
[, ... ] )
    ALTER [ COLUMN ] column_name RESET ( attribute_option
[, ... ] )
    ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL |
EXTENDED | MAIN }
    ADD table_constraint [ NOT VALID ]
    ADD table_constraint_using_index
    ALTER CONSTRAINT constraint_name [ DEFERRABLE | NOT
DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]
    VALIDATE CONSTRAINT constraint_name
    DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT |
CASCADE ]
```

ALTER TABLE

```
DISABLE TRIGGER [ trigger_name | ALL | USER ]
ENABLE TRIGGER [ trigger_name | ALL | USER ]
ENABLE REPLICA TRIGGER trigger_name
ENABLE ALWAYS TRIGGER trigger_name
DISABLE RULE rewrite_rule_name
ENABLE RULE rewrite_rule_name
ENABLE REPLICA RULE rewrite_rule_name
ENABLE ALWAYS RULE rewrite_rule_name
DISABLE ROW LEVEL SECURITY
ENABLE ROW LEVEL SECURITY
FORCE ROW LEVEL SECURITY
NO FORCE ROW LEVEL SECURITY
CLUSTER ON index_name
SET WITHOUT CLUSTER
SET WITHOUT OIDS
SET TABLESPACE new_tablespace
SET { LOGGED | UNLOGGED }
SET ( storage_parameter = value [, ... ] )
RESET ( storage_parameter [, ... ] )
INHERIT parent_table
NO INHERIT parent_table
OF type_name
NOT OF
OWNER TO { new_owner | CURRENT_USER | SESSION_USER }
REPLICA IDENTITY { DEFAULT | USING INDEX index_name | FULL |
NOTHING }
```

and *partition_bound_spec* is:

```
IN ( partition_bound_expr [, ...] ) |
FROM ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] )
TO ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] ) |
WITH ( MODULUS numeric_literal, REMAINDER numeric_literal )
```

and *column_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL |
NULL |
CHECK ( expression ) [ NO INHERIT ] |
DEFAULT default_expr |
GENERATED ALWAYS AS ( generation_expr ) STORED |
GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY
[ ( sequence_options ) ] |
UNIQUE index_parameters |
PRIMARY KEY index_parameters |
REFERENCES reftable [ ( refcolumn ) ] [ MATCH FULL | MATCH
PARTIAL | MATCH SIMPLE ]
[ ON DELETE referential_action ] [ ON UPDATE referential_action
] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]
```

and *table_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ CHECK ( expression ) [ NO INHERIT ] |
UNIQUE ( column_name [, ... ] ) index_parameters |
```

```

PRIMARY KEY ( column_name [, ... ] ) index_parameters |
EXCLUDE [ USING index_method ] ( exclude_element WITH operator
[, ... ] ) index_parameters [ WHERE ( predicate ) ] |
FOREIGN KEY ( column_name [, ... ] ) REFERENCES reftable
[ ( refcolumn [, ... ] ) ]
    [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON
DELETE referential_action ] [ ON UPDATE referential_action ] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]

```

and *table_constraint_using_index* is:

```

[ CONSTRAINT constraint_name ]
{ UNIQUE | PRIMARY KEY } USING INDEX index_name
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED |
INITIALLY IMMEDIATE ]

```

index_parameters in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

```

[ INCLUDE ( column_name [, ... ] ) ]
[ WITH ( storage_parameter [= value] [, ... ] ) ]
[ USING INDEX TABLESPACE tablespace_name ]

```

exclude_element in an EXCLUDE constraint is:

```

{ column_name | ( expression ) } [ opclass ] [ ASC | DESC ] [ NULLS
{ FIRST | LAST } ]

```

Description

ALTER TABLE changes the definition of an existing table. There are several subforms described below. Note that the lock level required may differ for each subform. An ACCESS EXCLUSIVE lock is held unless explicitly noted. When multiple subcommands are listed, the lock held will be the strictest one required from any subcommand.

ADD COLUMN [IF NOT EXISTS]

This form adds a new column to the table, using the same syntax as CREATE TABLE. If IF NOT EXISTS is specified and a column already exists with this name, no error is thrown.

DROP COLUMN [IF EXISTS]

This form drops a column from a table. Indexes and table constraints involving the column will be automatically dropped as well. Multivariate statistics referencing the dropped column will also be removed if the removal of the column would cause the statistics to contain data for only a single column. You will need to say CASCADE if anything outside the table depends on the column, for example, foreign key references or views. If IF EXISTS is specified and the column does not exist, no error is thrown. In this case a notice is issued instead.

SET DATA TYPE

This form changes the type of a column of a table. Indexes and simple table constraints involving the column will be automatically converted to use the new column type by reparsing the originally supplied expression. The optional COLLATE clause specifies a collation for the new column; if omitted, the collation is the default for the new column type. The optional USING clause specifies how to compute the new column value from the old; if omitted, the default conversion is the same as an assignment cast from old data type to new. A USING clause must be provided if there is no implicit or assignment cast from old to new type.

SET/DROP DEFAULT

These forms set or remove the default value for a column. Default values only apply in subsequent INSERT or UPDATE commands; they do not cause rows already in the table to change.

SET/DROP NOT NULL

These forms change whether a column is marked to allow null values or to reject null values.

SET NOT NULL may only be applied to a column providing none of the records in the table contain a NULL value for the column. Ordinarily this is checked during the ALTER TABLE by scanning the entire table; however, if a valid CHECK constraint is found which proves no NULL can exist, then the table scan is skipped.

If this table is a partition, one cannot perform DROP NOT NULL on a column if it is marked NOT NULL in the parent table. To drop the NOT NULL constraint from all the partitions, perform DROP NOT NULL on the parent table. Even if there is no NOT NULL constraint on the parent, such a constraint can still be added to individual partitions, if desired; that is, the children can disallow nulls even if the parent allows them, but not the other way around.

```
ADD GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY
SET GENERATED { ALWAYS | BY DEFAULT }
DROP IDENTITY [ IF EXISTS ]
```

These forms change whether a column is an identity column or change the generation attribute of an existing identity column. See CREATE TABLE for details.

If DROP IDENTITY IF EXISTS is specified and the column is not an identity column, no error is thrown. In this case a notice is issued instead.

```
SET sequence_option
RESTART
```

These forms alter the sequence that underlies an existing identity column. *sequence_option* is an option supported by ALTER SEQUENCE such as INCREMENT BY.

SET STATISTICS

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations. The target can be set in the range 0 to 10000; alternatively, set it to -1 to revert to using the system default statistics target (*default_statistics_target*). For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

SET STATISTICS acquires a SHARE UPDATE EXCLUSIVE lock.

```
SET ( attribute_option = value [, ... ] )
RESET ( attribute_option [, ... ] )
```

This form sets or resets per-attribute options. Currently, the only defined per-attribute options are *n_distinct* and *n_distinct_inherited*, which override the number-of-distinct-values estimates made by subsequent ANALYZE operations. *n_distinct* affects the statistics for the table itself, while *n_distinct_inherited* affects the statistics gathered for the table plus its inheritance children. When set to a positive value, ANALYZE will assume that the column contains exactly the specified number of distinct nonnull values. When set to a negative value, which must be greater than or equal to -1, ANALYZE will assume that the number of distinct nonnull values in the column is linear in the size of the table; the exact count is to be computed by multiplying the estimated table size by the absolute value of the given number. For example, a value of -1 implies that all values in the column are distinct, while a value of -0.5 implies that each value appears twice on the average. This can be useful when the size of the table changes over time,

since the multiplication by the number of rows in the table is not performed until query planning time. Specify a value of 0 to revert to estimating the number of distinct values normally. For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

Changing per-attribute options acquires a `SHARE UPDATE EXCLUSIVE` lock.

SET STORAGE

This form sets the storage mode for a column. This controls whether this column is held inline or in a secondary TOAST table, and whether the data should be compressed or not. `PLAIN` must be used for fixed-length values such as `integer` and is inline, uncompressed. `MAIN` is for inline, compressible data. `EXTERNAL` is for external, uncompressed data, and `EXTENDED` is for external, compressed data. `EXTENDED` is the default for most data types that support non-`PLAIN` storage. Use of `EXTERNAL` will make substring operations on very large `text` and `bytea` values run faster, at the penalty of increased storage space. Note that `SET STORAGE` doesn't itself change anything in the table, it just sets the strategy to be pursued during future table updates. See Section 68.2 for more information.

ADD *table_constraint* [NOT VALID]

This form adds a new constraint to a table using the same syntax as `CREATE TABLE`, plus the option `NOT VALID`, which is currently only allowed for foreign key and `CHECK` constraints.

Normally, this form will cause a scan of the table to verify that all existing rows in the table satisfy the new constraint. But if the `NOT VALID` option is used, this potentially-lengthy scan is skipped. The constraint will still be enforced against subsequent inserts or updates (that is, they'll fail unless there is a matching row in the referenced table, in the case of foreign keys, or they'll fail unless the new row matches the specified check condition). But the database will not assume that the constraint holds for all rows in the table, until it is validated by using the `VALIDATE CONSTRAINT` option. See Notes below for more information about using the `NOT VALID` option.

Addition of a foreign key constraint requires a `SHARE ROW EXCLUSIVE` lock on the referenced table, in addition to the lock on the table receiving the constraint.

Additional restrictions apply when unique or primary key constraints are added to partitioned tables; see `CREATE TABLE`. Also, foreign key constraints on partitioned tables may not be declared `NOT VALID` at present.

ADD *table_constraint_using_index*

This form adds a new `PRIMARY KEY` or `UNIQUE` constraint to a table based on an existing unique index. All the columns of the index will be included in the constraint.

The index cannot have expression columns nor be a partial index. Also, it must be a b-tree index with default sort ordering. These restrictions ensure that the index is equivalent to one that would be built by a regular `ADD PRIMARY KEY` or `ADD UNIQUE` command.

If `PRIMARY KEY` is specified, and the index's columns are not already marked `NOT NULL`, then this command will attempt to do `ALTER COLUMN SET NOT NULL` against each such column. That requires a full table scan to verify the column(s) contain no nulls. In all other cases, this is a fast operation.

If a constraint name is provided then the index will be renamed to match the constraint name. Otherwise the constraint will be named the same as the index.

After this command is executed, the index is “owned” by the constraint, in the same way as if the index had been built by a regular `ADD PRIMARY KEY` or `ADD UNIQUE` command. In particular, dropping the constraint will make the index disappear too.

This form is not currently supported on partitioned tables.

Note

Adding a constraint using an existing index can be helpful in situations where a new constraint needs to be added without blocking table updates for a long time. To do that, create the index using `CREATE INDEX CONCURRENTLY`, and then install it as an official constraint using this syntax. See the example below.

ALTER CONSTRAINT

This form alters the attributes of a constraint that was previously created. Currently only foreign key constraints may be altered.

VALIDATE CONSTRAINT

This form validates a foreign key or check constraint that was previously created as `NOT VALID`, by scanning the table to ensure there are no rows for which the constraint is not satisfied. Nothing happens if the constraint is already marked valid. (See Notes below for an explanation of the usefulness of this command.)

DROP CONSTRAINT [IF EXISTS]

This form drops the specified constraint on a table, along with any index underlying the constraint. If `IF EXISTS` is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

DISABLE/ENABLE [REPLICA | ALWAYS] TRIGGER

These forms configure the firing of trigger(s) belonging to the table. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. For a deferred trigger, the enable status is checked when the event occurs, not when the trigger function is actually executed. One can disable or enable a single trigger specified by name, or all triggers on the table, or only user triggers (this option excludes internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints). Disabling or enabling internally generated constraint triggers requires superuser privileges; it should be done with caution since of course the integrity of the constraint cannot be guaranteed if the triggers are not executed.

The trigger firing mechanism is also affected by the configuration variable `session_replication_role`. Simply enabled triggers (the default) will fire when the replication role is “origin” (the default) or “local”. Triggers configured as `ENABLE REPLICA` will only fire if the session is in “replica” mode, and triggers configured as `ENABLE ALWAYS` will fire regardless of the current replication role.

The effect of this mechanism is that in the default configuration, triggers do not fire on replicas. This is useful because if a trigger is used on the origin to propagate data between tables, then the replication system will also replicate the propagated data, and the trigger should not fire a second time on the replica, because that would lead to duplication. However, if a trigger is used for another purpose such as creating external alerts, then it might be appropriate to set it to `ENABLE ALWAYS` so that it is also fired on replicas.

This command acquires a `SHARE ROW EXCLUSIVE` lock.

DISABLE/ENABLE [REPLICA | ALWAYS] RULE

These forms configure the firing of rewrite rules belonging to the table. A disabled rule is still known to the system, but is not applied during query rewriting. The semantics are as for dis-

abled/enabled triggers. This configuration is ignored for `ON SELECT` rules, which are always applied in order to keep views working even if the current session is in a non-default replication role.

The rule firing mechanism is also affected by the configuration variable `session_replication_role`, analogous to triggers as described above.

DISABLE/ENABLE ROW LEVEL SECURITY

These forms control the application of row security policies belonging to the table. If enabled and no policies exist for the table, then a default-deny policy is applied. Note that policies can exist for a table even if row level security is disabled - in this case, the policies will NOT be applied and the policies will be ignored. See also `CREATE POLICY`.

NO FORCE/FORCE ROW LEVEL SECURITY

These forms control the application of row security policies belonging to the table when the user is the table owner. If enabled, row level security policies will be applied when the user is the table owner. If disabled (the default) then row level security will not be applied when the user is the table owner. See also `CREATE POLICY`.

CLUSTER ON

This form selects the default index for future `CLUSTER` operations. It does not actually re-cluster the table.

Changing cluster options acquires a `SHARE UPDATE EXCLUSIVE` lock.

SET WITHOUT CLUSTER

This form removes the most recently used `CLUSTER` index specification from the table. This affects future cluster operations that don't specify an index.

Changing cluster options acquires a `SHARE UPDATE EXCLUSIVE` lock.

SET WITHOUT OIDS

Backward-compatible syntax for removing the `oid` system column. As `oid` system columns cannot be added anymore, this never has an effect.

SET TABLESPACE

This form changes the table's tablespace to the specified tablespace and moves the data file(s) associated with the table to the new tablespace. Indexes on the table, if any, are not moved; but they can be moved separately with additional `SET TABLESPACE` commands. When applied to a partitioned table, nothing is moved, but any partitions created afterwards with `CREATE TABLE PARTITION OF` will use that tablespace, unless the `TABLESPACE` clause is used to override it.

All tables in the current database in a tablespace can be moved by using the `ALL IN TABLESPACE` form, which will lock all tables to be moved first and then move each one. This form also supports `OWNED BY`, which will only move tables owned by the roles specified. If the `NOWAIT` option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs are not moved by this command; use `ALTER DATABASE` or explicit `ALTER TABLE` invocations instead if desired. The `information_schema` relations are not considered part of the system catalogs and will be moved. See also `CREATE TABLESPACE`.

SET { LOGGED | UNLOGGED }

This form changes the table from unlogged to logged or vice-versa (see `UNLOGGED`). It cannot be applied to a temporary table.

```
SET ( storage_parameter = value [, ... ] )
```

This form changes one or more storage parameters for the table. See Storage Parameters for details on the available parameters. Note that the table contents will not be modified immediately by this command; depending on the parameter you might need to rewrite the table to get the desired effects. That can be done with VACUUM FULL, CLUSTER or one of the forms of ALTER TABLE that forces a table rewrite. For planner related parameters, changes will take effect from the next time the table is locked so currently executing queries will not be affected.

SHARE UPDATE EXCLUSIVE lock will be taken for fillfactor, toast and autovacuum storage parameters, as well as the following planner related parameters: *effective_io_concurrency*, *parallel_workers*, *seq_page_cost*, *random_page_cost*, *n_distinct* and *n_distinct_inherited*.

```
RESET ( storage_parameter [, ... ] )
```

This form resets one or more storage parameters to their defaults. As with SET, a table rewrite might be needed to update the table entirely.

```
INHERIT parent_table
```

This form adds the target table as a new child of the specified parent table. Subsequently, queries against the parent will include records of the target table. To be added as a child, the target table must already contain all the same columns as the parent (it could have additional columns, too). The columns must have matching data types, and if they have NOT NULL constraints in the parent then they must also have NOT NULL constraints in the child.

There must also be matching child-table constraints for all CHECK constraints of the parent, except those marked non-inheritable (that is, created with ALTER TABLE ... ADD CONSTRAINT ... NO INHERIT) in the parent, which are ignored; all child-table constraints matched must not be marked non-inheritable. Currently UNIQUE, PRIMARY KEY, and FOREIGN KEY constraints are not considered, but this might change in the future.

```
NO INHERIT parent_table
```

This form removes the target table from the list of children of the specified parent table. Queries against the parent table will no longer include records drawn from the target table.

```
OF type_name
```

This form links the table to a composite type as though CREATE TABLE OF had formed it. The table's list of column names and types must precisely match that of the composite type. The table must not inherit from any other table. These restrictions ensure that CREATE TABLE OF would permit an equivalent table definition.

```
NOT OF
```

This form dissociates a typed table from its type.

```
OWNER TO
```

This form changes the owner of the table, sequence, view, materialized view, or foreign table to the specified user.

```
REPLICA IDENTITY
```

This form changes the information which is written to the write-ahead log to identify rows which are updated or deleted. This option has no effect except when logical replication is in use. DEFAULT (the default for non-system tables) records the old values of the columns of the primary key, if any. USING INDEX records the old values of the columns covered by the named index, which must be unique, not partial, not deferrable, and include only columns marked NOT NULL.

FULL records the old values of all columns in the row. NOTHING records no information about the old row. (This is the default for system tables.) In all cases, no old values are logged unless at least one of the columns that would be logged differs between the old and new versions of the row.

RENAME

The RENAME forms change the name of a table (or an index, sequence, view, materialized view, or foreign table), the name of an individual column in a table, or the name of a constraint of the table. When renaming a constraint that has an underlying index, the index is renamed as well. There is no effect on the stored data.

SET SCHEMA

This form moves the table into another schema. Associated indexes, constraints, and sequences owned by table columns are moved as well.

```
ATTACH PARTITION partition_name { FOR VALUES partition_bound_spec |  
DEFAULT }
```

This form attaches an existing table (which might itself be partitioned) as a partition of the target table. The table can be attached as a partition for specific values using FOR VALUES or as a default partition by using DEFAULT. For each index in the target table, a corresponding one will be created in the attached table; or, if an equivalent index already exists, it will be attached to the target table's index, as if ALTER INDEX ATTACH PARTITION had been executed. Note that if the existing table is a foreign table, it is currently not allowed to attach the table as a partition of the target table if there are UNIQUE indexes on the target table. (See also CREATE FOREIGN TABLE.)

A partition using FOR VALUES uses same syntax for *partition_bound_spec* as CREATE TABLE. The partition bound specification must correspond to the partitioning strategy and partition key of the target table. The table to be attached must have all the same columns as the target table and no more; moreover, the column types must also match. Also, it must have all the NOT NULL and CHECK constraints of the target table. Currently FOREIGN KEY constraints are not considered. UNIQUE and PRIMARY KEY constraints from the parent table will be created in the partition, if they don't already exist. If any of the CHECK constraints of the table being attached is marked NO INHERIT, the command will fail; such constraints must be recreated without the NO INHERIT clause.

If the new partition is a regular table, a full table scan is performed to check that existing rows in the table do not violate the partition constraint. It is possible to avoid this scan by adding a valid CHECK constraint to the table that allows only rows satisfying the desired partition constraint before running this command. The CHECK constraint will be used to determine that the table need not be scanned to validate the partition constraint. This does not work, however, if any of the partition keys is an expression and the partition does not accept NULL values. If attaching a list partition that will not accept NULL values, also add NOT NULL constraint to the partition key column, unless it's an expression.

If the new partition is a foreign table, nothing is done to verify that all the rows in the foreign table obey the partition constraint. (See the discussion in CREATE FOREIGN TABLE about constraints on the foreign table.)

When a table has a default partition, defining a new partition changes the partition constraint for the default partition. The default partition can't contain any rows that would need to be moved to the new partition, and will be scanned to verify that none are present. This scan, like the scan of the new partition, can be avoided if an appropriate CHECK constraint is present. Also like the scan of the new partition, it is always skipped when the default partition is a foreign table.

Attaching a partition acquires a SHARE UPDATE EXCLUSIVE lock on the parent table, in addition to ACCESS EXCLUSIVE locks on the table to be attached and on the default partition (if any).

DETACH PARTITION *partition_name*

This form detaches specified partition of the target table. The detached partition continues to exist as a standalone table, but no longer has any ties to the table from which it was detached. Any indexes that were attached to the target table's indexes are detached.

All the forms of ALTER TABLE that act on a single table, except RENAME, SET SCHEMA, ATTACH PARTITION, and DETACH PARTITION can be combined into a list of multiple alterations to be applied together. For example, it is possible to add several columns and/or alter the type of several columns in a single command. This is particularly useful with large tables, since only one pass over the table need be made.

You must own the table to use ALTER TABLE. To change the schema or tablespace of a table, you must also have CREATE privilege on the new schema or tablespace. To add the table as a new child of a parent table, you must own the parent table as well. Also, to attach a table as a new partition of the table, you must own the table being attached. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or alter a column type or use the OF clause, you must also have USAGE privilege on the data type.

Parameters

IF EXISTS

Do not throw an error if the table does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing table to alter. If ONLY is specified before the table name, only that table is altered. If ONLY is not specified, the table and all its descendant tables (if any) are altered. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

column_name

Name of a new or existing column.

new_column_name

New name for an existing column.

new_name

New name for the table.

data_type

Data type of the new column, or new data type for an existing column.

table_constraint

New table constraint for the table.

constraint_name

Name of a new or existing constraint.

CASCADE

Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

trigger_name

Name of a single trigger to disable or enable.

ALL

Disable or enable all triggers belonging to the table. (This requires superuser privilege if any of the triggers are internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints.)

USER

Disable or enable all triggers belonging to the table except for internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints.

index_name

The name of an existing index.

storage_parameter

The name of a table storage parameter.

value

The new value for a table storage parameter. This might be a number or a word depending on the parameter.

parent_table

A parent table to associate or de-associate with this table.

new_owner

The user name of the new owner of the table.

new_tablespace

The name of the tablespace to which the table will be moved.

new_schema

The name of the schema to which the table will be moved.

partition_name

The name of the table to attach as a new partition or to detach from this table.

partition_bound_spec

The partition bound specification for a new partition. Refer to CREATE TABLE for more details on the syntax of the same.

Notes

The key word COLUMN is noise and can be omitted.

When a column is added with `ADD COLUMN` and a non-volatile `DEFAULT` is specified, the default is evaluated at the time of the statement and the result stored in the table's metadata. That value will be used for the column for all existing rows. If no `DEFAULT` is specified, `NULL` is used. In neither case is a rewrite of the table required.

Adding a column with a volatile `DEFAULT` or changing the type of an existing column will require the entire table and its indexes to be rewritten. As an exception, when changing the type of an existing column, if the `USING` clause does not change the column contents and the old type is either binary coercible to the new type or an unconstrained domain over the new type, a table rewrite is not needed; but any indexes on the affected columns must still be rebuilt. Table and/or index rebuilds may take a significant amount of time for a large table; and will temporarily require as much as double the disk space.

Adding a `CHECK` or `NOT NULL` constraint requires scanning the table to verify that existing rows meet the constraint, but does not require a table rewrite.

Similarly, when attaching a new partition it may be scanned to verify that existing rows meet the partition constraint.

The main reason for providing the option to specify multiple changes in a single `ALTER TABLE` is that multiple table scans or rewrites can thereby be combined into a single pass over the table.

Scanning a large table to verify a new foreign key or check constraint can take a long time, and other updates to the table are locked out until the `ALTER TABLE ADD CONSTRAINT` command is committed. The main purpose of the `NOT VALID` constraint option is to reduce the impact of adding a constraint on concurrent updates. With `NOT VALID`, the `ADD CONSTRAINT` command does not scan the table and can be committed immediately. After that, a `VALIDATE CONSTRAINT` command can be issued to verify that existing rows satisfy the constraint. The validation step does not need to lock out concurrent updates, since it knows that other transactions will be enforcing the constraint for rows that they insert or update; only pre-existing rows need to be checked. Hence, validation acquires only a `SHARE UPDATE EXCLUSIVE` lock on the table being altered. (If the constraint is a foreign key then a `ROW SHARE` lock is also required on the table referenced by the constraint.) In addition to improving concurrency, it can be useful to use `NOT VALID` and `VALIDATE CONSTRAINT` in cases where the table is known to contain pre-existing violations. Once the constraint is in place, no new violations can be inserted, and the existing problems can be corrected at leisure until `VALIDATE CONSTRAINT` finally succeeds.

The `DROP COLUMN` form does not physically remove the column, but simply makes it invisible to SQL operations. Subsequent insert and update operations in the table will store a null value for the column. Thus, dropping a column is quick but it will not immediately reduce the on-disk size of your table, as the space occupied by the dropped column is not reclaimed. The space will be reclaimed over time as existing rows are updated.

To force immediate reclamation of space occupied by a dropped column, you can execute one of the forms of `ALTER TABLE` that performs a rewrite of the whole table. This results in reconstructing each row with the dropped column replaced by a null value.

The rewriting forms of `ALTER TABLE` are not MVCC-safe. After a table rewrite, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the rewrite occurred. See Section 13.5 for more details.

The `USING` option of `SET DATA TYPE` can actually specify any expression involving the old values of the row; that is, it can refer to other columns as well as the one being converted. This allows very general conversions to be done with the `SET DATA TYPE` syntax. Because of this flexibility, the `USING` expression is not applied to the column's default value (if any); the result might not be a constant expression as required for a default. This means that when there is no implicit or assignment cast from old to new type, `SET DATA TYPE` might fail to convert the default even though a `USING` clause is supplied. In such cases, drop the default with `DROP DEFAULT`, perform the `ALTER TYPE`, and then use `SET DEFAULT` to add a suitable new default. Similar considerations apply to indexes and constraints involving the column.

If a table has any descendant tables, it is not permitted to add, rename, or change the type of a column in the parent table without doing the same to the descendants. This ensures that the descendants always have columns matching the parent. Similarly, a CHECK constraint cannot be renamed in the parent without also renaming it in all descendants, so that CHECK constraints also match between the parent and its descendants. (That restriction does not apply to index-based constraints, however.) Also, because selecting from the parent also selects from its descendants, a constraint on the parent cannot be marked valid unless it is also marked valid for those descendants. In all of these cases, ALTER TABLE ONLY will be rejected.

A recursive DROP COLUMN operation will remove a descendant table's column only if the descendant does not inherit that column from any other parents and never had an independent definition of the column. A nonrecursive DROP COLUMN (i.e., ALTER TABLE ONLY . . . DROP COLUMN) never removes any descendant columns, but instead marks them as independently defined rather than inherited. A nonrecursive DROP COLUMN command will fail for a partitioned table, because all partitions of a table must have the same columns as the partitioning root.

The actions for identity columns (ADD GENERATED, SET etc., DROP IDENTITY), as well as the actions TRIGGER, CLUSTER, OWNER, and TABLESPACE never recurse to descendant tables; that is, they always act as though ONLY were specified. Adding a constraint recurses only for CHECK constraints that are not marked NO INHERIT.

Changing any part of a system catalog table is not permitted.

Refer to CREATE TABLE for a further description of valid parameters. Chapter 5 has further information on inheritance.

Examples

To add a column of type varchar to a table:

```
ALTER TABLE distributors ADD COLUMN address varchar(30);
```

To drop a column from a table:

```
ALTER TABLE distributors DROP COLUMN address RESTRICT;
```

To change the types of two existing columns in one operation:

```
ALTER TABLE distributors
  ALTER COLUMN address TYPE varchar(80),
  ALTER COLUMN name TYPE varchar(100);
```

To change an integer column containing Unix timestamps to timestamp with time zone via a USING clause:

```
ALTER TABLE foo
  ALTER COLUMN foo_timestamp SET DATA TYPE timestamp with time
  zone
  USING
    timestamp with time zone 'epoch' + foo_timestamp * interval
    '1 second';
```

The same, when the column has a default expression that won't automatically cast to the new data type:

```
ALTER TABLE foo
```

ALTER TABLE

```
ALTER COLUMN foo_timestamp DROP DEFAULT,  
ALTER COLUMN foo_timestamp TYPE timestamp with time zone  
USING  
    timestamp with time zone 'epoch' + foo_timestamp * interval  
'1 second',  
ALTER COLUMN foo_timestamp SET DEFAULT now();
```

To rename an existing column:

```
ALTER TABLE distributors RENAME COLUMN address TO city;
```

To rename an existing table:

```
ALTER TABLE distributors RENAME TO suppliers;
```

To rename an existing constraint:

```
ALTER TABLE distributors RENAME CONSTRAINT zipchk TO zip_check;
```

To add a not-null constraint to a column:

```
ALTER TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To remove a not-null constraint from a column:

```
ALTER TABLE distributors ALTER COLUMN street DROP NOT NULL;
```

To add a check constraint to a table and all its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK  
(char_length(zipcode) = 5);
```

To add a check constraint only to a table and not to its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK  
(char_length(zipcode) = 5) NO INHERIT;
```

(The check constraint will not be inherited by future children, either.)

To remove a check constraint from a table and all its children:

```
ALTER TABLE distributors DROP CONSTRAINT zipchk;
```

To remove a check constraint from one table only:

```
ALTER TABLE ONLY distributors DROP CONSTRAINT zipchk;
```

(The check constraint remains in place for any child tables.)

To add a foreign key constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT distfk FOREIGN KEY
(address) REFERENCES addresses (address);
```

To add a foreign key constraint to a table with the least impact on other work:

```
ALTER TABLE distributors ADD CONSTRAINT distfk FOREIGN KEY
(address) REFERENCES addresses (address) NOT VALID;
ALTER TABLE distributors VALIDATE CONSTRAINT distfk;
```

To add a (multicolumn) unique constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT dist_id_zipcode_key UNIQUE
(dist_id, zipcode);
```

To add an automatically named primary key constraint to a table, noting that a table can only ever have one primary key:

```
ALTER TABLE distributors ADD PRIMARY KEY (dist_id);
```

To move a table to a different tablespace:

```
ALTER TABLE distributors SET TABLESPACE fasttablespace;
```

To move a table to a different schema:

```
ALTER TABLE myschema.distributors SET SCHEMA yourschema;
```

To recreate a primary key constraint, without blocking updates while the index is rebuilt:

```
CREATE UNIQUE INDEX CONCURRENTLY dist_id_temp_idx ON distributors
(dist_id);
ALTER TABLE distributors DROP CONSTRAINT distributors_pkey,
ADD CONSTRAINT distributors_pkey PRIMARY KEY USING INDEX
dist_id_temp_idx;
```

To attach a partition to a range-partitioned table:

```
ALTER TABLE measurement
ATTACH PARTITION measurement_y2016m07 FOR VALUES FROM
('2016-07-01') TO ('2016-08-01');
```

To attach a partition to a list-partitioned table:

```
ALTER TABLE cities
ATTACH PARTITION cities_ab FOR VALUES IN ('a', 'b');
```

To attach a partition to a hash-partitioned table:

```
ALTER TABLE orders
ATTACH PARTITION orders_p4 FOR VALUES WITH (MODULUS 4,
REMAINDER 3);
```

To attach a default partition to a partitioned table:

```
ALTER TABLE cities
    ATTACH PARTITION cities_partdef DEFAULT;
```

To detach a partition from a partitioned table:

```
ALTER TABLE measurement
    DETACH PARTITION measurement_y2015m12;
```

Compatibility

The forms `ADD` (without `USING INDEX`), `DROP [COLUMN]`, `DROP IDENTITY`, `RESTART`, `SET DEFAULT`, `SET DATA TYPE` (without `USING`), `SET GENERATED`, and `SET sequence_option` conform with the SQL standard. The other forms are PostgreSQL extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER TABLE` command is an extension.

`ALTER TABLE DROP COLUMN` can be used to drop the only column of a table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column tables.

See Also

`CREATE TABLE`

ALTER TABLESPACE

ALTER TABLESPACE — change the definition of a tablespace

Synopsis

```
ALTER TABLESPACE name RENAME TO new_name
ALTER TABLESPACE name OWNER TO { new_owner | CURRENT_USER |
SESSION_USER }
ALTER TABLESPACE name SET ( tablespace_option = value [, ... ] )
ALTER TABLESPACE name RESET ( tablespace_option [, ... ] )
```

Description

ALTER TABLESPACE can be used to change the definition of a tablespace.

You must own the tablespace to change the definition of a tablespace. To alter the owner, you must also be a direct or indirect member of the new owning role. (Note that superusers have these privileges automatically.)

Parameters

name

The name of an existing tablespace.

new_name

The new name of the tablespace. The new name cannot begin with `pg_`, as such names are reserved for system tablespaces.

new_owner

The new owner of the tablespace.

tablespace_option

A tablespace parameter to be set or reset. Currently, the only available parameters are `seq_page_cost`, `random_page_cost` and `effective_io_concurrency`. Setting either value for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, as established by the configuration parameters of the same name (see `seq_page_cost`, `random_page_cost`, `effective_io_concurrency`). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

Examples

Rename tablespace `index_space` to `fast_raid`:

```
ALTER TABLESPACE index_space RENAME TO fast_raid;
```

Change the owner of tablespace `index_space`:

```
ALTER TABLESPACE index_space OWNER TO mary;
```

Compatibility

There is no `ALTER TABLESPACE` statement in the SQL standard.

See Also

`CREATE TABLESPACE`, `DROP TABLESPACE`

ALTER TEXT SEARCH CONFIGURATION

ALTER TEXT SEARCH CONFIGURATION — change the definition of a text search configuration

Synopsis

```
ALTER TEXT SEARCH CONFIGURATION name
    ADD MAPPING FOR token_type [, ... ] WITH dictionary_name
    [, ... ]
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING FOR token_type [, ... ] WITH dictionary_name
    [, ... ]
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING REPLACE old_dictionary WITH new_dictionary
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING FOR token_type [, ... ] REPLACE old_dictionary
    WITH new_dictionary
ALTER TEXT SEARCH CONFIGURATION name
    DROP MAPPING [ IF EXISTS ] FOR token_type [, ... ]
ALTER TEXT SEARCH CONFIGURATION name RENAME TO new_name
ALTER TEXT SEARCH CONFIGURATION name OWNER TO { new_owner |
    CURRENT_USER | SESSION_USER }
ALTER TEXT SEARCH CONFIGURATION name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH CONFIGURATION changes the definition of a text search configuration. You can modify its mappings from token types to dictionaries, or change the configuration's name or owner.

You must be the owner of the configuration to use ALTER TEXT SEARCH CONFIGURATION.

Parameters

name

The name (optionally schema-qualified) of an existing text search configuration.

token_type

The name of a token type that is emitted by the configuration's parser.

dictionary_name

The name of a text search dictionary to be consulted for the specified token type(s). If multiple dictionaries are listed, they are consulted in the specified order.

old_dictionary

The name of a text search dictionary to be replaced in the mapping.

new_dictionary

The name of a text search dictionary to be substituted for *old_dictionary*.

new_name

The new name of the text search configuration.

new_owner

The new owner of the text search configuration.

new_schema

The new schema for the text search configuration.

The `ADD MAPPING FOR` form installs a list of dictionaries to be consulted for the specified token type(s); it is an error if there is already a mapping for any of the token types. The `ALTER MAPPING FOR` form does the same, but first removing any existing mapping for those token types. The `ALTER MAPPING REPLACE` forms substitute *new_dictionary* for *old_dictionary* anywhere the latter appears. This is done for only the specified token types when `FOR` appears, or for all mappings of the configuration when it doesn't. The `DROP MAPPING` form removes all dictionaries for the specified token type(s), causing tokens of those types to be ignored by the text search configuration. It is an error if there is no mapping for the token types, unless `IF EXISTS` appears.

Examples

The following example replaces the `english` dictionary with the `swedish` dictionary anywhere that `english` is used within `my_config`.

```
ALTER TEXT SEARCH CONFIGURATION my_config
ALTER MAPPING REPLACE english WITH swedish;
```

Compatibility

There is no `ALTER TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

`CREATE TEXT SEARCH CONFIGURATION`, `DROP TEXT SEARCH CONFIGURATION`

ALTER TEXT SEARCH DICTIONARY

ALTER TEXT SEARCH DICTIONARY — change the definition of a text search dictionary

Synopsis

```
ALTER TEXT SEARCH DICTIONARY name (  
    option [ = value ] [, ... ]  
)  
ALTER TEXT SEARCH DICTIONARY name RENAME TO new_name  
ALTER TEXT SEARCH DICTIONARY name OWNER TO { new_owner |  
    CURRENT_USER | SESSION_USER }  
ALTER TEXT SEARCH DICTIONARY name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH DICTIONARY changes the definition of a text search dictionary. You can change the dictionary's template-specific options, or change the dictionary's name or owner.

You must be the owner of the dictionary to use ALTER TEXT SEARCH DICTIONARY.

Parameters

name

The name (optionally schema-qualified) of an existing text search dictionary.

option

The name of a template-specific option to be set for this dictionary.

value

The new value to use for a template-specific option. If the equal sign and value are omitted, then any previous setting for the option is removed from the dictionary, allowing the default to be used.

new_name

The new name of the text search dictionary.

new_owner

The new owner of the text search dictionary.

new_schema

The new schema for the text search dictionary.

Template-specific options can appear in any order.

Examples

The following example command changes the stopword list for a Snowball-based dictionary. Other parameters remain unchanged.

ALTER TEXT SEARCH DICTIONARY

```
ALTER TEXT SEARCH DICTIONARY my_dict ( StopWords = newrussian );
```

The following example command changes the language option to `dutch`, and removes the stopword option entirely.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( language = dutch,  
StopWords );
```

The following example command “updates” the dictionary's definition without actually changing anything.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( dummy );
```

(The reason this works is that the option removal code doesn't complain if there is no such option.) This trick is useful when changing configuration files for the dictionary: the `ALTER` will force existing database sessions to re-read the configuration files, which otherwise they would never do if they had read them earlier.

Compatibility

There is no `ALTER TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

`CREATE TEXT SEARCH DICTIONARY`, `DROP TEXT SEARCH DICTIONARY`

ALTER TEXT SEARCH PARSER

ALTER TEXT SEARCH PARSER — change the definition of a text search parser

Synopsis

```
ALTER TEXT SEARCH PARSER name RENAME TO new_name
ALTER TEXT SEARCH PARSER name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH PARSER changes the definition of a text search parser. Currently, the only supported functionality is to change the parser's name.

You must be a superuser to use ALTER TEXT SEARCH PARSER.

Parameters

name

The name (optionally schema-qualified) of an existing text search parser.

new_name

The new name of the text search parser.

new_schema

The new schema for the text search parser.

Compatibility

There is no ALTER TEXT SEARCH PARSER statement in the SQL standard.

See Also

CREATE TEXT SEARCH PARSER, DROP TEXT SEARCH PARSER

ALTER TEXT SEARCH TEMPLATE

ALTER TEXT SEARCH TEMPLATE — change the definition of a text search template

Synopsis

```
ALTER TEXT SEARCH TEMPLATE name RENAME TO new_name
ALTER TEXT SEARCH TEMPLATE name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH TEMPLATE changes the definition of a text search template. Currently, the only supported functionality is to change the template's name.

You must be a superuser to use ALTER TEXT SEARCH TEMPLATE.

Parameters

name

The name (optionally schema-qualified) of an existing text search template.

new_name

The new name of the text search template.

new_schema

The new schema for the text search template.

Compatibility

There is no ALTER TEXT SEARCH TEMPLATE statement in the SQL standard.

See Also

CREATE TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

ALTER TRIGGER

ALTER TRIGGER — change the definition of a trigger

Synopsis

```
ALTER TRIGGER name ON table_name RENAME TO new_name
ALTER TRIGGER name ON table_name DEPENDS ON
EXTENSION extension_name
```

Description

ALTER TRIGGER changes properties of an existing trigger. The RENAME clause changes the name of the given trigger without otherwise changing the trigger definition. The DEPENDS ON EXTENSION clause marks the trigger as dependent on an extension, such that if the extension is dropped, the trigger will automatically be dropped as well.

You must own the table on which the trigger acts to be allowed to change its properties.

Parameters

name

The name of an existing trigger to alter.

table_name

The name of the table on which this trigger acts.

new_name

The new name for the trigger.

extension_name

The name of the extension that the trigger is to depend on.

Notes

The ability to temporarily enable or disable a trigger is provided by ALTER TABLE, not by ALTER TRIGGER, because ALTER TRIGGER has no convenient way to express the option of enabling or disabling all of a table's triggers at once.

Examples

To rename an existing trigger:

```
ALTER TRIGGER emp_stamp ON emp RENAME TO emp_track_chgs;
```

To mark a trigger as being dependent on an extension:

```
ALTER TRIGGER emp_stamp ON emp DEPENDS ON EXTENSION emplob;
```

Compatibility

ALTER TRIGGER is a PostgreSQL extension of the SQL standard.

See Also

ALTER TABLE

ALTER TYPE

ALTER TYPE — change the definition of a type

Synopsis

```
ALTER TYPE name action [, ... ]
ALTER TYPE name OWNER TO { new_owner | CURRENT_USER |
    SESSION_USER }
ALTER TYPE name RENAME ATTRIBUTE attribute_name
    TO new_attribute_name [ CASCADE | RESTRICT ]
ALTER TYPE name RENAME TO new_name
ALTER TYPE name SET SCHEMA new_schema
ALTER TYPE name ADD VALUE [ IF NOT EXISTS ] new_enum_value
    [ { BEFORE | AFTER } neighbor_enum_value ]
ALTER TYPE name RENAME VALUE existing_enum_value TO new_enum_value
```

where *action* is one of:

```
    ADD ATTRIBUTE attribute_name data_type [ COLLATE collation ]
    [ CASCADE | RESTRICT ]
    DROP ATTRIBUTE [ IF EXISTS ] attribute_name [ CASCADE |
    RESTRICT ]
    ALTER ATTRIBUTE attribute_name [ SET DATA ] TYPE data_type
    [ COLLATE collation ] [ CASCADE | RESTRICT ]
```

Description

ALTER TYPE changes the definition of an existing type. There are several subforms:

ADD ATTRIBUTE

This form adds a new attribute to a composite type, using the same syntax as CREATE TYPE.

DROP ATTRIBUTE [IF EXISTS]

This form drops an attribute from a composite type. If IF EXISTS is specified and the attribute does not exist, no error is thrown. In this case a notice is issued instead.

SET DATA TYPE

This form changes the type of an attribute of a composite type.

OWNER

This form changes the owner of the type.

RENAME

This form changes the name of the type or the name of an individual attribute of a composite type.

SET SCHEMA

This form moves the type into another schema.

ADD VALUE [IF NOT EXISTS] [BEFORE | AFTER]

This form adds a new value to an enum type. The new value's place in the enum's ordering can be specified as being BEFORE or AFTER one of the existing values. Otherwise, the new item is added at the end of the list of values.

If IF NOT EXISTS is specified, it is not an error if the type already contains the new value: a notice is issued but no other action is taken. Otherwise, an error will occur if the new value is already present.

RENAME VALUE

This form renames a value of an enum type. The value's place in the enum's ordering is not affected. An error will occur if the specified value is not present or the new name is already present.

The ADD ATTRIBUTE, DROP ATTRIBUTE, and ALTER ATTRIBUTE actions can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several attributes and/or alter the type of several attributes in a single command.

You must own the type to use ALTER TYPE. To change the schema of a type, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the type's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the type. However, a superuser can alter ownership of any type anyway.) To add an attribute or alter an attribute type, you must also have USAGE privilege on the data type.

Parameters

name

The name (possibly schema-qualified) of an existing type to alter.

new_name

The new name for the type.

new_owner

The user name of the new owner of the type.

new_schema

The new schema for the type.

attribute_name

The name of the attribute to add, alter, or drop.

new_attribute_name

The new name of the attribute to be renamed.

data_type

The data type of the attribute to add, or the new type of the attribute to alter.

new_enum_value

The new value to be added to an enum type's list of values, or the new name to be given to an existing value. Like all enum literals, it needs to be quoted.

neighbor_enum_value

The existing enum value that the new value should be added immediately before or after in the enum type's sort ordering. Like all enum literals, it needs to be quoted.

existing_enum_value

The existing enum value that should be renamed. Like all enum literals, it needs to be quoted.

CASCADE

Automatically propagate the operation to typed tables of the type being altered, and their descendants.

RESTRICT

Refuse the operation if the type being altered is the type of a typed table. This is the default.

Notes

If `ALTER TYPE ... ADD VALUE` (the form that adds a new value to an enum type) is executed inside a transaction block, the new value cannot be used until after the transaction has been committed.

Comparisons involving an added enum value will sometimes be slower than comparisons involving only original members of the enum type. This will usually only occur if `BEFORE` or `AFTER` is used to set the new value's sort position somewhere other than at the end of the list. However, sometimes it will happen even though the new value is added at the end (this occurs if the OID counter “wrapped around” since the original creation of the enum type). The slowdown is usually insignificant; but if it matters, optimal performance can be regained by dropping and recreating the enum type, or by dumping and reloading the database.

Examples

To rename a data type:

```
ALTER TYPE electronic_mail RENAME TO email;
```

To change the owner of the type `email` to `joe`:

```
ALTER TYPE email OWNER TO joe;
```

To change the schema of the type `email` to `customers`:

```
ALTER TYPE email SET SCHEMA customers;
```

To add a new attribute to a type:

```
ALTER TYPE compfoo ADD ATTRIBUTE f3 int;
```

To add a new value to an enum type in a particular sort position:

```
ALTER TYPE colors ADD VALUE 'orange' AFTER 'red';
```

To rename an enum value:

```
ALTER TYPE colors RENAME VALUE 'purple' TO 'mauve';
```

Compatibility

The variants to add and drop attributes are part of the SQL standard; the other variants are PostgreSQL extensions.

See Also

CREATE TYPE, DROP TYPE

ALTER USER

ALTER USER — change a database role

Synopsis

```
ALTER USER role_specification [ WITH ] option [ ... ]
```

where *option* can be:

```
    SUPERUSER | NOSUPERUSER
  | CREATEDB | NOCREATEDB
  | CREATEROLE | NOCREATEROLE
  | INHERIT | NOINHERIT
  | LOGIN | NOLOGIN
  | REPLICATION | NOREPLICATION
  | BYPASSRLS | NOBYPASSRLS
  | CONNECTION LIMIT connlimit
  | [ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL
  | VALID UNTIL 'timestamp'
```

```
ALTER USER name RENAME TO new_name
```

```
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] SET configuration_parameter { TO | = } { value | DEFAULT }
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] SET configuration_parameter FROM CURRENT
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] RESET configuration_parameter
ALTER USER { role_specification | ALL } [ IN DATABASE database_name
] RESET ALL
```

where *role_specification* can be:

```
    role_name
  | CURRENT_USER
  | SESSION_USER
```

Description

ALTER USER is now an alias for ALTER ROLE.

Compatibility

The ALTER USER statement is a PostgreSQL extension. The SQL standard leaves the definition of users to the implementation.

See Also

ALTER ROLE

ALTER USER MAPPING

ALTER USER MAPPING — change the definition of a user mapping

Synopsis

```
ALTER USER MAPPING FOR { user_name | USER | CURRENT_USER |  
SESSION_USER | PUBLIC }  
SERVER server_name  
OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

Description

ALTER USER MAPPING changes the definition of a user mapping.

The owner of a foreign server can alter user mappings for that server for any user. Also, a user can alter a user mapping for their own user name if USAGE privilege on the server has been granted to the user.

Parameters

user_name

User name of the mapping. CURRENT_USER and USER match the name of the current user. PUBLIC is used to match all present and future user names in the system.

server_name

Server name of the user mapping.

```
OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

Change options for the user mapping. The new options override any previously specified options. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; options are also validated by the server's foreign-data wrapper.

Examples

Change the password for user mapping bob, server foo:

```
ALTER USER MAPPING FOR bob SERVER foo OPTIONS (SET password  
'public');
```

Compatibility

ALTER USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED). There is a subtle syntax issue: The standard omits the FOR key word. Since both CREATE USER MAPPING and DROP USER MAPPING use FOR in analogous positions, and IBM DB2 (being the other major SQL/MED implementation) also requires it for ALTER USER MAPPING, PostgreSQL diverges from the standard here in the interest of consistency and interoperability.

See Also

CREATE USER MAPPING, DROP USER MAPPING

ALTER VIEW

ALTER VIEW — change the definition of a view

Synopsis

```
ALTER VIEW [ IF EXISTS ] name ALTER [ COLUMN ] column_name SET
  DEFAULT expression
ALTER VIEW [ IF EXISTS ] name ALTER [ COLUMN ] column_name DROP
  DEFAULT
ALTER VIEW [ IF EXISTS ] name OWNER TO { new_owner | CURRENT_USER |
  SESSION_USER }
ALTER VIEW [ IF EXISTS ] name RENAME TO new_name
ALTER VIEW [ IF EXISTS ] name SET SCHEMA new_schema
ALTER VIEW [ IF EXISTS ] name SET ( view_option_name
  [= view_option_value] [, ... ] )
ALTER VIEW [ IF EXISTS ] name RESET ( view_option_name [, ... ] )
```

Description

ALTER VIEW changes various auxiliary properties of a view. (If you want to modify the view's defining query, use CREATE OR REPLACE VIEW.)

You must own the view to use ALTER VIEW. To change a view's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the view. However, a superuser can alter ownership of any view anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing view.

IF EXISTS

Do not throw an error if the view does not exist. A notice is issued in this case.

SET/DROP DEFAULT

These forms set or remove the default value for a column. A view column's default value is substituted into any INSERT or UPDATE command whose target is the view, before applying any rules or triggers for the view. The view's default will therefore take precedence over any default values from underlying relations.

new_owner

The user name of the new owner of the view.

new_name

The new name for the view.

new_schema

The new schema for the view.

```
SET ( view_option_name [= view_option_value] [, ... ] )  
RESET ( view_option_name [, ... ] )
```

Sets or resets a view option. Currently supported options are:

`check_option` (string)

Changes the check option of the view. The value must be `local` or `cascaded`.

`security_barrier` (boolean)

Changes the security-barrier property of the view. The value must be Boolean value, such as `true` or `false`.

Notes

For historical reasons, `ALTER TABLE` can be used with views too; but the only variants of `ALTER TABLE` that are allowed with views are equivalent to the ones shown above.

Examples

To rename the view `foo` to `bar`:

```
ALTER VIEW foo RENAME TO bar;
```

To attach a default column value to an updatable view:

```
CREATE TABLE base_table (id int, ts timestamptz);  
CREATE VIEW a_view AS SELECT * FROM base_table;  
ALTER VIEW a_view ALTER COLUMN ts SET DEFAULT now();  
INSERT INTO base_table(id) VALUES(1); -- ts will receive a NULL  
INSERT INTO a_view(id) VALUES(2); -- ts will receive the current  
time
```

Compatibility

`ALTER VIEW` is a PostgreSQL extension of the SQL standard.

See Also

`CREATE VIEW`, `DROP VIEW`

ANALYZE

ANALYZE — collect statistics about a database

Synopsis

```
ANALYZE [ ( option [, ...] ) ] [ table_and_columns [, ...] ]  
ANALYZE [ VERBOSE ] [ table_and_columns [, ...] ]
```

where *option* can be one of:

```
VERBOSE [ boolean ]  
SKIP_LOCKED [ boolean ]
```

and *table_and_columns* is:

```
table_name [ ( column_name [, ...] ) ]
```

Description

ANALYZE collects statistics about the contents of tables in the database, and stores the results in the `pg_statistic` system catalog. Subsequently, the query planner uses these statistics to help determine the most efficient execution plans for queries.

Without a *table_and_columns* list, ANALYZE processes every table and materialized view in the current database that the current user has permission to analyze. With a list, ANALYZE processes only those table(s). It is further possible to give a list of column names for a table, in which case only the statistics for those columns are collected.

When the option list is surrounded by parentheses, the options can be written in any order. The parenthesized syntax was added in PostgreSQL 11; the unparenthesized syntax is deprecated.

Parameters

VERBOSE

Enables display of progress messages.

SKIP_LOCKED

Specifies that ANALYZE should not wait for any conflicting locks to be released when beginning work on a relation: if a relation cannot be locked immediately without waiting, the relation is skipped. Note that even with this option, ANALYZE may still block when opening the relation's indexes or when acquiring sample rows from partitions, table inheritance children, and some types of foreign tables. Also, while ANALYZE ordinarily processes all partitions of specified partitioned tables, this option will cause ANALYZE to skip all partitions if there is a conflicting lock on the partitioned table.

boolean

Specifies whether the selected option should be turned on or off. You can write TRUE, ON, or 1 to enable the option, and FALSE, OFF, or 0 to disable it. The *boolean* value can also be omitted, in which case TRUE is assumed.

table_name

The name (possibly schema-qualified) of a specific table to analyze. If omitted, all regular tables, partitioned tables, and materialized views in the current database are analyzed (but not foreign tables). If the specified table is a partitioned table, both the inheritance statistics of the partitioned table as a whole and statistics of the individual partitions are updated.

column_name

The name of a specific column to analyze. Defaults to all columns.

Outputs

When `VERBOSE` is specified, `ANALYZE` emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

Notes

To analyze a table, one must ordinarily be the table's owner or a superuser. However, database owners are allowed to analyze all tables in their databases, except shared catalogs. (The restriction for shared catalogs means that a true database-wide `ANALYZE` can only be performed by a superuser.) `ANALYZE` will skip over any tables that the calling user does not have permission to analyze.

Foreign tables are analyzed only when explicitly selected. Not all foreign data wrappers support `ANALYZE`. If the table's wrapper does not support `ANALYZE`, the command prints a warning and does nothing.

In the default PostgreSQL configuration, the autovacuum daemon (see Section 24.1.6) takes care of automatic analyzing of tables when they are first loaded with data, and as they change throughout regular operation. When autovacuum is disabled, it is a good idea to run `ANALYZE` periodically, or just after making major changes in the contents of a table. Accurate statistics will help the planner to choose the most appropriate query plan, and thereby improve the speed of query processing. A common strategy for read-mostly databases is to run `VACUUM` and `ANALYZE` once a day during a low-usage time of day. (This will not be sufficient if there is heavy update activity.)

`ANALYZE` requires only a read lock on the target table, so it can run in parallel with other activity on the table.

The statistics collected by `ANALYZE` usually include a list of some of the most common values in each column and a histogram showing the approximate data distribution in each column. One or both of these can be omitted if `ANALYZE` deems them uninteresting (for example, in a unique-key column, there are no common values) or if the column data type does not support the appropriate operators. There is more information about the statistics in Chapter 24.

For large tables, `ANALYZE` takes a random sample of the table contents, rather than examining every row. This allows even very large tables to be analyzed in a small amount of time. Note, however, that the statistics are only approximate, and will change slightly each time `ANALYZE` is run, even if the actual table contents did not change. This might result in small changes in the planner's estimated costs shown by `EXPLAIN`. In rare situations, this non-determinism will cause the planner's choices of query plans to change after `ANALYZE` is run. To avoid this, raise the amount of statistics collected by `ANALYZE`, as described below.

The extent of analysis can be controlled by adjusting the `default_statistics_target` configuration variable, or on a column-by-column basis by setting the per-column statistics target with `ALTER TABLE ... ALTER COLUMN ... SET STATISTICS` (see `ALTER TABLE`). The target value sets the maximum number of entries in the most-common-value list and the maximum number of bins in the histogram. The default target value is 100, but this can be adjusted up or down to trade off accuracy of planner estimates against the time taken for `ANALYZE` and the amount of space occupied in `pg_statistic`. In particular, setting the statistics target to zero disables collection of statistics for

that column. It might be useful to do that for columns that are never used as part of the `WHERE`, `GROUP BY`, or `ORDER BY` clauses of queries, since the planner will have no use for statistics on such columns.

The largest statistics target among the columns being analyzed determines the number of table rows sampled to prepare the statistics. Increasing the target causes a proportional increase in the time and space needed to do `ANALYZE`.

One of the values estimated by `ANALYZE` is the number of distinct values that appear in each column. Because only a subset of the rows are examined, this estimate can sometimes be quite inaccurate, even with the largest possible statistics target. If this inaccuracy leads to bad query plans, a more accurate value can be determined manually and then installed with `ALTER TABLE ... ALTER COLUMN ... SET (n_distinct = ...)` (see `ALTER TABLE`).

If the table being analyzed has one or more children, `ANALYZE` will gather statistics twice: once on the rows of the parent table only, and a second time on the rows of the parent table with all of its children. This second set of statistics is needed when planning queries that traverse the entire inheritance tree. The autovacuum daemon, however, will only consider inserts or updates on the parent table itself when deciding whether to trigger an automatic analyze for that table. If that table is rarely inserted into or updated, the inheritance statistics will not be up to date unless you run `ANALYZE` manually.

If any of the child tables are foreign tables whose foreign data wrappers do not support `ANALYZE`, those child tables are ignored while gathering inheritance statistics.

If the table being analyzed is completely empty, `ANALYZE` will not record new statistics for that table. Any existing statistics will be retained.

Compatibility

There is no `ANALYZE` statement in the SQL standard.

See Also

`VACUUM`, `vacuumdb`, Section 19.4.4, Section 24.1.6

BEGIN

BEGIN — start a transaction block

Synopsis

```
BEGIN [ WORK | TRANSACTION ] [ transaction_mode [, ...] ]
```

where *transaction_mode* is one of:

```
ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ  
COMMITTED | READ UNCOMMITTED }  
READ WRITE | READ ONLY  
[ NOT ] DEFERRABLE
```

Description

BEGIN initiates a transaction block, that is, all statements after a BEGIN command will be executed in a single transaction until an explicit COMMIT or ROLLBACK is given. By default (without BEGIN), PostgreSQL executes transactions in “autocommit” mode, that is, each statement is executed in its own transaction and a commit is implicitly performed at the end of the statement (if execution was successful, otherwise a rollback is done).

Statements are executed more quickly in a transaction block, because transaction start/commit requires significant CPU and disk activity. Execution of multiple statements inside a transaction is also useful to ensure consistency when making several related changes: other sessions will be unable to see the intermediate states wherein not all the related updates have been done.

If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

Refer to SET TRANSACTION for information on the meaning of the other parameters to this statement.

Notes

START TRANSACTION has the same functionality as BEGIN.

Use COMMIT or ROLLBACK to terminate a transaction block.

Issuing BEGIN when already inside a transaction block will provoke a warning message. The state of the transaction is not affected. To nest transactions within a transaction block, use savepoints (see SAVEPOINT).

For reasons of backwards compatibility, the commas between successive *transaction_modes* can be omitted.

Examples

To begin a transaction block:

```
BEGIN;
```

Compatibility

BEGIN is a PostgreSQL language extension. It is equivalent to the SQL-standard command START TRANSACTION, whose reference page contains additional compatibility information.

The DEFERRABLE *transaction_mode* is a PostgreSQL language extension.

Incidentally, the BEGIN key word is used for a different purpose in embedded SQL. You are advised to be careful about the transaction semantics when porting database applications.

See Also

COMMIT, ROLLBACK, START TRANSACTION, SAVEPOINT

CALL

CALL — invoke a procedure

Synopsis

```
CALL name ( [ argument ] [ , ... ] )
```

Description

CALL executes a procedure.

If the procedure has any output parameters, then a result row will be returned, containing the values of those parameters.

Parameters

name

The name (optionally schema-qualified) of the procedure.

argument

An input argument for the procedure call. See Section 4.3 for the full details on function and procedure call syntax, including use of named parameters.

Notes

The user must have EXECUTE privilege on the procedure in order to be allowed to invoke it.

To call a function (not a procedure), use SELECT instead.

If CALL is executed in a transaction block, then the called procedure cannot execute transaction control statements. Transaction control statements are only allowed if CALL is executed in its own transaction.

PL/pgSQL handles output parameters in CALL commands differently; see Section 42.6.3.

Examples

```
CALL do_db_maintenance();
```

Compatibility

CALL conforms to the SQL standard.

See Also

CREATE PROCEDURE

CHECKPOINT

CHECKPOINT — force a write-ahead log checkpoint

Synopsis

CHECKPOINT

Description

A checkpoint is a point in the write-ahead log sequence at which all data files have been updated to reflect the information in the log. All data files will be flushed to disk. Refer to Section 29.4 for more details about what happens during a checkpoint.

The CHECKPOINT command forces an immediate checkpoint when the command is issued, without waiting for a regular checkpoint scheduled by the system (controlled by the settings in Section 19.5.2). CHECKPOINT is not intended for use during normal operation.

If executed during recovery, the CHECKPOINT command will force a restartpoint (see Section 29.4) rather than writing a new checkpoint.

Only superusers can call CHECKPOINT.

Compatibility

The CHECKPOINT command is a PostgreSQL language extension.

CLOSE

CLOSE — close a cursor

Synopsis

```
CLOSE { name | ALL }
```

Description

CLOSE frees the resources associated with an open cursor. After the cursor is closed, no subsequent operations are allowed on it. A cursor should be closed when it is no longer needed.

Every non-holdable open cursor is implicitly closed when a transaction is terminated by COMMIT or ROLLBACK. A holdable cursor is implicitly closed if the transaction that created it aborts via ROLLBACK. If the creating transaction successfully commits, the holdable cursor remains open until an explicit CLOSE is executed, or the client disconnects.

Parameters

name

The name of an open cursor to close.

ALL

Close all open cursors.

Notes

PostgreSQL does not have an explicit OPEN cursor statement; a cursor is considered open when it is declared. Use the DECLARE statement to declare a cursor.

You can see all available cursors by querying the `pg_cursors` system view.

If a cursor is closed after a savepoint which is later rolled back, the CLOSE is not rolled back; that is, the cursor remains closed.

Examples

Close the cursor `liahona`:

```
CLOSE liahona;
```

Compatibility

CLOSE is fully conforming with the SQL standard. CLOSE ALL is a PostgreSQL extension.

See Also

DECLARE, FETCH, MOVE

CLUSTER

CLUSTER — cluster a table according to an index

Synopsis

```
CLUSTER [VERBOSE] table_name [ USING index_name ]  
CLUSTER [VERBOSE]
```

Description

CLUSTER instructs PostgreSQL to cluster the table specified by *table_name* based on the index specified by *index_name*. The index must already have been defined on *table_name*.

When a table is clustered, it is physically reordered based on the index information. Clustering is a one-time operation: when the table is subsequently updated, the changes are not clustered. That is, no attempt is made to store new or updated rows according to their index order. (If one wishes, one can periodically recluster by issuing the command again. Also, setting the table's `fillfactor` storage parameter to less than 100% can aid in preserving cluster ordering during updates, since updated rows are kept on the same page if enough space is available there.)

When a table is clustered, PostgreSQL remembers which index it was clustered by. The form `CLUSTER table_name` reclusters the table using the same index as before. You can also use the `CLUSTER` or `SET WITHOUT CLUSTER` forms of `ALTER TABLE` to set the index to be used for future cluster operations, or to clear any previous setting.

CLUSTER without any parameter reclusters all the previously-clustered tables in the current database that the calling user owns, or all such tables if called by a superuser. This form of CLUSTER cannot be executed inside a transaction block.

When a table is being clustered, an `ACCESS EXCLUSIVE` lock is acquired on it. This prevents any other database operations (both reads and writes) from operating on the table until the CLUSTER is finished.

Parameters

table_name

The name (possibly schema-qualified) of a table.

index_name

The name of an index.

VERBOSE

Prints a progress report as each table is clustered.

Notes

In cases where you are accessing single rows randomly within a table, the actual order of the data in the table is unimportant. However, if you tend to access some data more than others, and there is an index that groups them together, you will benefit from using CLUSTER. If you are requesting a range of indexed values from a table, or a single indexed value that has multiple rows that match, CLUSTER will help because once the index identifies the table page for the first row that matches,

all other rows that match are probably already on the same table page, and so you save disk accesses and speed up the query.

CLUSTER can re-sort the table using either an index scan on the specified index, or (if the index is a b-tree) a sequential scan followed by sorting. It will attempt to choose the method that will be faster, based on planner cost parameters and available statistical information.

When an index scan is used, a temporary copy of the table is created that contains the table data in the index order. Temporary copies of each index on the table are created as well. Therefore, you need free space on disk at least equal to the sum of the table size and the index sizes.

When a sequential scan and sort is used, a temporary sort file is also created, so that the peak temporary space requirement is as much as double the table size, plus the index sizes. This method is often faster than the index scan method, but if the disk space requirement is intolerable, you can disable this choice by temporarily setting `enable_sort` to `off`.

It is advisable to set `maintenance_work_mem` to a reasonably large value (but not more than the amount of RAM you can dedicate to the CLUSTER operation) before clustering.

Because the planner records statistics about the ordering of tables, it is advisable to run ANALYZE on the newly clustered table. Otherwise, the planner might make poor choices of query plans.

Because CLUSTER remembers which indexes are clustered, one can cluster the tables one wants clustered manually the first time, then set up a periodic maintenance script that executes CLUSTER without any parameters, so that the desired tables are periodically reclustered.

Examples

Cluster the table `employees` on the basis of its index `employees_ind`:

```
CLUSTER employees USING employees_ind;
```

Cluster the `employees` table using the same index that was used before:

```
CLUSTER employees;
```

Cluster all tables in the database that have previously been clustered:

```
CLUSTER;
```

Compatibility

There is no CLUSTER statement in the SQL standard.

The syntax

```
CLUSTER index_name ON table_name
```

is also supported for compatibility with pre-8.3 PostgreSQL versions.

See Also

`clusterdb`

COMMENT

COMMENT — define or change the comment of an object

Synopsis

```
COMMENT ON
{
ACCESS METHOD object_name |
AGGREGATE aggregate_name ( aggregate_signature ) |
CAST ( source_type AS target_type ) |
COLLATION object_name |
COLUMN relation_name.column_name |
CONSTRAINT constraint_name ON table_name |
CONSTRAINT constraint_name ON DOMAIN domain_name |
CONVERSION object_name |
DATABASE object_name |
DOMAIN object_name |
EXTENSION object_name |
EVENT TRIGGER object_name |
FOREIGN DATA WRAPPER object_name |
FOREIGN TABLE object_name |
FUNCTION function_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
INDEX object_name |
LARGE OBJECT large_object_oid |
MATERIALIZED VIEW object_name |
OPERATOR operator_name ( left_type, right_type ) |
OPERATOR CLASS object_name USING index_method |
OPERATOR FAMILY object_name USING index_method |
POLICY policy_name ON table_name |
[ PROCEDURAL ] LANGUAGE object_name |
PROCEDURE procedure_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
PUBLICATION object_name |
ROLE object_name |
ROUTINE routine_name [ ( [ [ argmode ] [ argname ] argtype
[ , ... ] ) ) ] |
RULE rule_name ON table_name |
SCHEMA object_name |
SEQUENCE object_name |
SERVER object_name |
STATISTICS object_name |
SUBSCRIPTION object_name |
TABLE object_name |
TABLESPACE object_name |
TEXT SEARCH CONFIGURATION object_name |
TEXT SEARCH DICTIONARY object_name |
TEXT SEARCH PARSER object_name |
TEXT SEARCH TEMPLATE object_name |
TRANSFORM FOR type_name LANGUAGE lang_name |
TRIGGER trigger_name ON table_name |
TYPE object_name |
VIEW object_name
```

```

} IS 'text'

where aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]

```

Description

COMMENT stores a comment about a database object.

Only one comment string is stored for each object, so to modify a comment, issue a new COMMENT command for the same object. To remove a comment, write NULL in place of the text string. Comments are automatically dropped when their object is dropped.

For most kinds of object, only the object's owner can set the comment. Roles don't have owners, so the rule for COMMENT ON ROLE is that you must be superuser to comment on a superuser role, or have the CREATEROLE privilege to comment on non-superuser roles. Likewise, access methods don't have owners either; you must be superuser to comment on an access method. Of course, a superuser can comment on anything.

Comments can be viewed using psql's \d family of commands. Other user interfaces to retrieve comments can be built atop the same built-in functions that psql uses, namely obj_description, col_description, and shobj_description (see Table 9.73).

Parameters

```

object_name
relation_name.column_name
aggregate_name
constraint_name
function_name
operator_name
policy_name
procedure_name
routine_name
rule_name
trigger_name

```

The name of the object to be commented. Names of tables, aggregates, collations, conversions, domains, foreign tables, functions, indexes, operators, operator classes, operator families, procedures, routines, sequences, statistics, text search objects, types, and views can be schema-qualified. When commenting on a column, *relation_name* must refer to a table, view, composite type, or foreign table.

```

table_name
domain_name

```

When creating a comment on a constraint, a trigger, a rule or a policy these parameters specify the name of the table or domain on which that object is defined.

```

source_type

```

The name of the source data type of the cast.

```

target_type

```

The name of the target data type of the cast.

argmode

The mode of a function, procedure, or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that COMMENT does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of a function, procedure, or aggregate argument. Note that COMMENT does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type of a function, procedure, or aggregate argument.

large_object_oid

The OID of the large object.

left_type

right_type

The data type(s) of the operator's arguments (optionally schema-qualified). Write NONE for the missing argument of a prefix or postfix operator.

PROCEDURAL

This is a noise word.

type_name

The name of the data type of the transform.

lang_name

The name of the language of the transform.

text

The new comment, written as a string literal; or NULL to drop the comment.

Notes

There is presently no security mechanism for viewing comments: any user connected to a database can see all the comments for objects in that database. For shared objects such as databases, roles, and tablespaces, comments are stored globally so any user connected to any database in the cluster can see all the comments for shared objects. Therefore, don't put security-critical information in comments.

Examples

Attach a comment to the table mytable:

```
COMMENT ON TABLE mytable IS 'This is my table.';
```

Remove it again:

```
COMMENT ON TABLE mytable IS NULL;
```

Some more examples:

```
COMMENT ON ACCESS METHOD rtree IS 'R-Tree access method';
COMMENT ON AGGREGATE my_aggregate (double precision) IS 'Computes
  sample variance';
COMMENT ON CAST (text AS int4) IS 'Allow casts from text to int4';
COMMENT ON COLLATION "fr_CA" IS 'Canadian French';
COMMENT ON COLUMN my_table.my_column IS 'Employee ID number';
COMMENT ON CONVERSION my_conv IS 'Conversion to UTF8';
COMMENT ON CONSTRAINT bar_col_cons ON bar IS 'Constrains column
  col';
COMMENT ON CONSTRAINT dom_col_constr ON DOMAIN dom IS 'Constrains
  col of domain';
COMMENT ON DATABASE my_database IS 'Development Database';
COMMENT ON DOMAIN my_domain IS 'Email Address Domain';
COMMENT ON EXTENSION hstore IS 'implements the hstore data type';
COMMENT ON FOREIGN DATA WRAPPER mywrapper IS 'my foreign data
  wrapper';
COMMENT ON FOREIGN TABLE my_foreign_table IS 'Employee Information
  in other database';
COMMENT ON FUNCTION my_function (timestamp) IS 'Returns Roman
  Numeral';
COMMENT ON INDEX my_index IS 'Enforces uniqueness on employee ID';
COMMENT ON LANGUAGE plpython IS 'Python support for stored
  procedures';
COMMENT ON LARGE OBJECT 346344 IS 'Planning document';
COMMENT ON MATERIALIZED VIEW my_matview IS 'Summary of order
  history';
COMMENT ON OPERATOR ^ (text, text) IS 'Performs intersection of two
  texts';
COMMENT ON OPERATOR - (NONE, integer) IS 'Unary minus';
COMMENT ON OPERATOR CLASS int4ops USING btree IS '4 byte integer
  operators for btrees';
COMMENT ON OPERATOR FAMILY integer_ops USING btree IS 'all integer
  operators for btrees';
COMMENT ON POLICY my_policy ON mytable IS 'Filter rows by users';
COMMENT ON PROCEDURE my_proc (integer, integer) IS 'Runs a report';
COMMENT ON ROLE my_role IS 'Administration group for finance
  tables';
COMMENT ON RULE my_rule ON my_table IS 'Logs updates of employee
  records';
COMMENT ON SCHEMA my_schema IS 'Departmental data';
COMMENT ON SEQUENCE my_sequence IS 'Used to generate primary keys';
COMMENT ON SERVER myserver IS 'my foreign server';
COMMENT ON STATISTICS my_statistics IS 'Improves planner row
  estimations';
COMMENT ON TABLE my_schema.my_table IS 'Employee Information';
COMMENT ON TABLESPACE my_tablespace IS 'Tablespace for indexes';
COMMENT ON TEXT SEARCH CONFIGURATION my_config IS 'Special word
  filtering';
COMMENT ON TEXT SEARCH DICTIONARY swedish IS 'Snowball stemmer for
  Swedish language';
COMMENT ON TEXT SEARCH PARSER my_parser IS 'Splits text into
  words';
COMMENT ON TEXT SEARCH TEMPLATE snowball IS 'Snowball stemmer';
```

```
COMMENT ON TRANSFORM FOR hstore LANGUAGE plpythonu IS 'Transform
  between hstore and Python dict';
COMMENT ON TRIGGER my_trigger ON my_table IS 'Used for RI';
COMMENT ON TYPE complex IS 'Complex number data type';
COMMENT ON VIEW my_view IS 'View of departmental costs';
```

Compatibility

There is no COMMENT command in the SQL standard.

COMMIT

COMMIT — commit the current transaction

Synopsis

```
COMMIT [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

Description

COMMIT commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use ROLLBACK to abort a transaction.

Issuing COMMIT when not inside a transaction does no harm, but it will provoke a warning message. COMMIT AND CHAIN when not inside a transaction is an error.

Examples

To commit the current transaction and make all changes permanent:

```
COMMIT ;
```

Compatibility

The command COMMIT conforms to the SQL standard. The form COMMIT TRANSACTION is a PostgreSQL extension.

See Also

BEGIN, ROLLBACK

COMMIT PREPARED

COMMIT PREPARED — commit a transaction that was earlier prepared for two-phase commit

Synopsis

```
COMMIT PREPARED transaction_id
```

Description

COMMIT PREPARED commits a transaction that is in prepared state.

Parameters

```
transaction_id
```

The transaction identifier of the transaction that is to be committed.

Notes

To commit a prepared transaction, you must be either the same user that executed the transaction originally, or a superuser. But you do not have to be in the same session that executed the transaction.

This command cannot be executed inside a transaction block. The prepared transaction is committed immediately.

All currently available prepared transactions are listed in the `pg_prepared_xacts` system view.

Examples

Commit the transaction identified by the transaction identifier `foobar`:

```
COMMIT PREPARED 'foobar';
```

Compatibility

COMMIT PREPARED is a PostgreSQL extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

See Also

PREPARE TRANSACTION, ROLLBACK PREPARED

COPY

COPY — copy data between a file and a table

Synopsis

```
COPY table_name [ ( column_name [, ...] ) ]
    FROM { 'filename' | PROGRAM 'command' | STDIN }
    [ [ WITH ] ( option [, ...] ) ]
    [ WHERE condition ]

COPY { table_name [ ( column_name [, ...] ) ] | ( query ) }
    TO { 'filename' | PROGRAM 'command' | STDOUT }
    [ [ WITH ] ( option [, ...] ) ]
```

where *option* can be one of:

```
FORMAT format_name
FREEZE [ boolean ]
DELIMITER 'delimiter_character'
NULL 'null_string'
HEADER [ boolean ]
QUOTE 'quote_character'
ESCAPE 'escape_character'
FORCE_QUOTE { ( column_name [, ...] ) | * }
FORCE_NOT_NULL ( column_name [, ...] )
FORCE_NULL ( column_name [, ...] )
ENCODING 'encoding_name'
```

Description

COPY moves data between PostgreSQL tables and standard file-system files. COPY TO copies the contents of a table *to* a file, while COPY FROM copies data *from* a file to a table (appending the data to whatever is in the table already). COPY TO can also copy the results of a SELECT query.

If a list of columns is specified, COPY will only copy the data in the specified columns to or from the file. If there are any columns in the table that are not in the column list, COPY FROM will insert the default values for those columns.

COPY with a file name instructs the PostgreSQL server to directly read from or write to a file. The file must be accessible by the PostgreSQL user (the user ID the server runs as) and the name must be specified from the viewpoint of the server. When PROGRAM is specified, the server executes the given command and reads from the standard output of the program, or writes to the standard input of the program. The command must be specified from the viewpoint of the server, and be executable by the PostgreSQL user. When STDIN or STDOUT is specified, data is transmitted via the connection between the client and the server.

Parameters

table_name

The name (optionally schema-qualified) of an existing table.

column_name

An optional list of columns to be copied. If no column list is specified, all columns of the table except generated columns will be copied.

query

A SELECT, VALUES, INSERT, UPDATE or DELETE command whose results are to be copied. Note that parentheses are required around the query.

For INSERT, UPDATE and DELETE queries a RETURNING clause must be provided, and the target relation must not have a conditional rule, nor an ALSO rule, nor an INSTEAD rule that expands to multiple statements.

filename

The path name of the input or output file. An input file name can be an absolute or relative path, but an output file name must be an absolute path. Windows users might need to use an E ' ' string and double any backslashes used in the path name.

PROGRAM

A command to execute. In COPY FROM, the input is read from standard output of the command, and in COPY TO, the output is written to the standard input of the command.

Note that the command is invoked by the shell, so if you need to pass any arguments to shell command that come from an untrusted source, you must be careful to strip or escape any special characters that might have a special meaning for the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in it.

STDIN

Specifies that input comes from the client application.

STDOUT

Specifies that output goes to the client application.

boolean

Specifies whether the selected option should be turned on or off. You can write TRUE, ON, or 1 to enable the option, and FALSE, OFF, or 0 to disable it. The *boolean* value can also be omitted, in which case TRUE is assumed.

FORMAT

Selects the data format to be read or written: `text`, `csv` (Comma Separated Values), or `binary`. The default is `text`.

FREEZE

Requests copying the data with rows already frozen, just as they would be after running the VACUUM FREEZE command. This is intended as a performance option for initial data loading. Rows will be frozen only if the table being loaded has been created or truncated in the current subtransaction, there are no cursors open and there are no older snapshots held by this transaction. It is currently not possible to perform a COPY FREEZE on a partitioned table.

Note that all other sessions will immediately be able to see the data once it has been successfully loaded. This violates the normal rules of MVCC visibility and users specifying should be aware of the potential problems this might cause.

DELIMITER

Specifies the character that separates columns within each row (line) of the file. The default is a tab character in text format, a comma in CSV format. This must be a single one-byte character. This option is not allowed when using `binary` format.

NULL

Specifies the string that represents a null value. The default is `\N` (backslash-N) in text format, and an unquoted empty string in CSV format. You might prefer an empty string even in text format for cases where you don't want to distinguish nulls from empty strings. This option is not allowed when using `binary` format.

Note

When using `COPY FROM`, any data item that matches this string will be stored as a null value, so you should make sure that you use the same string as you used with `COPY TO`.

HEADER

Specifies that the file contains a header line with the names of each column in the file. On output, the first line contains the column names from the table, and on input, the first line is ignored. This option is allowed only when using CSV format.

QUOTE

Specifies the quoting character to be used when a data value is quoted. The default is double-quote. This must be a single one-byte character. This option is allowed only when using CSV format.

ESCAPE

Specifies the character that should appear before a data character that matches the `QUOTE` value. The default is the same as the `QUOTE` value (so that the quoting character is doubled if it appears in the data). This must be a single one-byte character. This option is allowed only when using CSV format.

FORCE_QUOTE

Forces quoting to be used for all non-NULL values in each specified column. NULL output is never quoted. If `*` is specified, non-NULL values will be quoted in all columns. This option is allowed only in `COPY TO`, and only when using CSV format.

FORCE_NOT_NULL

Do not match the specified columns' values against the null string. In the default case where the null string is empty, this means that empty values will be read as zero-length strings rather than nulls, even when they are not quoted. This option is allowed only in `COPY FROM`, and only when using CSV format.

FORCE_NULL

Match the specified columns' values against the null string, even if it has been quoted, and if a match is found set the value to NULL. In the default case where the null string is empty, this converts a quoted empty string into NULL. This option is allowed only in `COPY FROM`, and only when using CSV format.

ENCODING

Specifies that the file is encoded in the `encoding_name`. If this option is omitted, the current client encoding is used. See the Notes below for more details.

WHERE

The optional **WHERE** clause has the general form

WHERE *condition*

where *condition* is any expression that evaluates to a result of type `boolean`. Any row that does not satisfy this condition will not be inserted to the table. A row satisfies the condition if it returns true when the actual row values are substituted for any variable references.

Currently, subqueries are not allowed in **WHERE** expressions, and the evaluation does not see any changes made by the **COPY** itself (this matters when the expression contains calls to `VOLATILE` functions).

Outputs

On successful completion, a **COPY** command returns a command tag of the form

COPY *count*

The *count* is the number of rows copied.

Note

psql will print this command tag only if the command was not `COPY ... TO STDOUT`, or the equivalent psql meta-command `\copy ... to stdout`. This is to prevent confusing the command tag with the data that was just printed.

Notes

COPY TO can only be used with plain tables, not with views. However, you can write `COPY (SELECT * FROM viewname) TO ...` to copy the current contents of a view.

COPY FROM can be used with plain, foreign, or partitioned tables or with views that have `INSTEAD OF INSERT` triggers.

COPY only deals with the specific table named; it does not copy data to or from child tables. Thus for example `COPY table TO ...` shows the same data as `SELECT * FROM ONLY table`. But `COPY (SELECT * FROM table) TO ...` can be used to dump all of the data in an inheritance hierarchy.

You must have select privilege on the table whose values are read by **COPY TO**, and insert privilege on the table into which values are inserted by **COPY FROM**. It is sufficient to have column privileges on the column(s) listed in the command.

If row-level security is enabled for the table, the relevant `SELECT` policies will apply to `COPY table TO` statements. Currently, **COPY FROM** is not supported for tables with row-level security. Use equivalent `INSERT` statements instead.

Files named in a **COPY** command are read or written directly by the server, not by the client application. Therefore, they must reside on or be accessible to the database server machine, not the client. They must be accessible to and readable or writable by the PostgreSQL user (the user ID the server runs as), not the client. Similarly, the command specified with `PROGRAM` is executed directly by the server, not by the client application, must be executable by the PostgreSQL user. **COPY** naming a file or command is only allowed to database superusers or users who are granted one of the de-

fault roles `pg_read_server_files`, `pg_write_server_files`, or `pg_execute_server_program`, since it allows reading or writing any file or running a program that the server has privileges to access.

Do not confuse `COPY` with the `psql` instruction `\copy`. `\copy` invokes `COPY FROM STDIN` or `COPY TO STDOUT`, and then fetches/stores the data in a file accessible to the `psql` client. Thus, file accessibility and access rights depend on the client rather than the server when `\copy` is used.

It is recommended that the file name used in `COPY` always be specified as an absolute path. This is enforced by the server in the case of `COPY TO`, but for `COPY FROM` you do have the option of reading from a file specified by a relative path. The path will be interpreted relative to the working directory of the server process (normally the cluster's data directory), not the client's working directory.

Executing a command with `PROGRAM` might be restricted by the operating system's access control mechanisms, such as SELinux.

`COPY FROM` will invoke any triggers and check constraints on the destination table. However, it will not invoke rules.

For identity columns, the `COPY FROM` command will always write the column values provided in the input data, like the `INSERT` option `OVERRIDING SYSTEM VALUE`.

`COPY` input and output is affected by `DateStyle`. To ensure portability to other PostgreSQL installations that might use non-default `DateStyle` settings, `DateStyle` should be set to `ISO` before using `COPY TO`. It is also a good idea to avoid dumping data with `IntervalStyle` set to `sql_standard`, because negative interval values might be misinterpreted by a server that has a different setting for `IntervalStyle`.

Input data is interpreted according to `ENCODING` option or the current client encoding, and output data is encoded in `ENCODING` or the current client encoding, even if the data does not pass through the client but is read from or written to a file directly by the server.

`COPY` stops operation at the first error. This should not lead to problems in the event of a `COPY TO`, but the target table will already have received earlier rows in a `COPY FROM`. These rows will not be visible or accessible, but they still occupy disk space. This might amount to a considerable amount of wasted disk space if the failure happened well into a large copy operation. You might wish to invoke `VACUUM` to recover the wasted space.

`FORCE_NULL` and `FORCE_NOT_NULL` can be used simultaneously on the same column. This results in converting quoted null strings to null values and unquoted null strings to empty strings.

File Formats

Text Format

When the `text` format is used, the data read or written is a text file with one line per table row. Columns in a row are separated by the delimiter character. The column values themselves are strings generated by the output function, or acceptable to the input function, of each attribute's data type. The specified null string is used in place of columns that are null. `COPY FROM` will raise an error if any line of the input file contains more or fewer columns than are expected.

End of data can be represented by a single line containing just backslash-period (`\.`). An end-of-data marker is not necessary when reading from a file, since the end of file serves perfectly well; it is needed only when copying data to or from client applications using pre-3.0 client protocol.

Backslash characters (`\`) can be used in the `COPY` data to quote data characters that might otherwise be taken as row or column delimiters. In particular, the following characters *must* be preceded by a backslash if they appear as part of a column value: backslash itself, newline, carriage return, and the current delimiter character.

The specified null string is sent by `COPY TO` without adding any backslashes; conversely, `COPY FROM` matches the input against the null string before removing backslashes. Therefore, a null string such as `\N` cannot be confused with the actual data value `\N` (which would be represented as `\\N`).

The following special backslash sequences are recognized by `COPY FROM`:

Sequence	Represents
<code>\b</code>	Backspace (ASCII 8)
<code>\f</code>	Form feed (ASCII 12)
<code>\n</code>	Newline (ASCII 10)
<code>\r</code>	Carriage return (ASCII 13)
<code>\t</code>	Tab (ASCII 9)
<code>\v</code>	Vertical tab (ASCII 11)
<code>\digits</code>	Backslash followed by one to three octal digits specifies the character with that numeric code
<code>\xdigits</code>	Backslash <code>x</code> followed by one or two hex digits specifies the character with that numeric code

Presently, `COPY TO` will never emit an octal or hex-digits backslash sequence, but it does use the other sequences listed above for those control characters.

Any other backslashed character that is not mentioned in the above table will be taken to represent itself. However, beware of adding backslashes unnecessarily, since that might accidentally produce a string matching the end-of-data marker (`\.`) or the null string (`\N` by default). These strings will be recognized before any other backslash processing is done.

It is strongly recommended that applications generating `COPY` data convert data newlines and carriage returns to the `\n` and `\r` sequences respectively. At present it is possible to represent a data carriage return by a backslash and carriage return, and to represent a data newline by a backslash and newline. However, these representations might not be accepted in future releases. They are also highly vulnerable to corruption if the `COPY` file is transferred across different machines (for example, from Unix to Windows or vice versa).

`COPY TO` will terminate each row with a Unix-style newline ("`\n`"). Servers running on Microsoft Windows instead output carriage return/newline ("`\r\n`"), but only for `COPY` to a server file; for consistency across platforms, `COPY TO STDOUT` always sends "`\n`" regardless of server platform. `COPY FROM` can handle lines ending with newlines, carriage returns, or carriage return/newlines. To reduce the risk of error due to un-backslashed newlines or carriage returns that were meant as data, `COPY FROM` will complain if the line endings in the input are not all alike.

CSV Format

This format option is used for importing and exporting the Comma Separated Value (CSV) file format used by many other programs, such as spreadsheets. Instead of the escaping rules used by PostgreSQL's standard text format, it produces and recognizes the common CSV escaping mechanism.

The values in each record are separated by the `DELIMITER` character. If the value contains the delimiter character, the `QUOTE` character, the `NULL` string, a carriage return, or line feed character, then the whole value is prefixed and suffixed by the `QUOTE` character, and any occurrence within the value of a `QUOTE` character or the `ESCAPE` character is preceded by the escape character. You can also use `FORCE_QUOTE` to force quotes when outputting non-`NULL` values in specific columns.

The CSV format has no standard way to distinguish a `NULL` value from an empty string. PostgreSQL's `COPY` handles this by quoting. A `NULL` is output as the `NULL` parameter string and is not quoted, while a non-`NULL` value matching the `NULL` parameter string is quoted. For example, with the default settings, a `NULL` is written as an unquoted empty string, while an empty string data value is written

with double quotes (" "). Reading values follows similar rules. You can use `FORCE_NOT_NULL` to prevent `NULL` input comparisons for specific columns. You can also use `FORCE_NULL` to convert quoted null string data values to `NULL`.

Because backslash is not a special character in the CSV format, `\.`, the end-of-data marker, could also appear as a data value. To avoid any misinterpretation, a `\.` data value appearing as a lone entry on a line is automatically quoted on output, and on input, if quoted, is not interpreted as the end-of-data marker. If you are loading a file created by another application that has a single unquoted column and might have a value of `\.`, you might need to quote that value in the input file.

Note

In CSV format, all characters are significant. A quoted value surrounded by white space, or any characters other than `DELIMITER`, will include those characters. This can cause errors if you import data from a system that pads CSV lines with white space out to some fixed width. If such a situation arises you might need to preprocess the CSV file to remove the trailing white space, before importing the data into PostgreSQL.

Note

CSV format will both recognize and produce CSV files with quoted values containing embedded carriage returns and line feeds. Thus the files are not strictly one line per table row like text-format files.

Note

Many programs produce strange and occasionally perverse CSV files, so the file format is more a convention than a standard. Thus you might encounter some files that cannot be imported using this mechanism, and `COPY` might produce files that other programs cannot process.

Binary Format

The `binary` format option causes all data to be stored/read as binary format rather than as text. It is somewhat faster than the text and CSV formats, but a binary-format file is less portable across machine architectures and PostgreSQL versions. Also, the binary format is very data type specific; for example it will not work to output binary data from a `smallint` column and read it into an `integer` column, even though that would work fine in text format.

The `binary` file format consists of a file header, zero or more tuples containing the row data, and a file trailer. Headers and data are in network byte order.

Note

PostgreSQL releases before 7.4 used a different binary file format.

File Header

The file header consists of 15 bytes of fixed fields, followed by a variable-length header extension area. The fixed fields are:

Signature

11-byte sequence `PGCOPY\n\377\r\n\0` — note that the zero byte is a required part of the signature. (The signature is designed to allow easy identification of files that have been munged by a non-8-bit-clean transfer. This signature will be changed by end-of-line-translation filters, dropped zero bytes, dropped high bits, or parity changes.)

Flags field

32-bit integer bit mask to denote important aspects of the file format. Bits are numbered from 0 (LSB) to 31 (MSB). Note that this field is stored in network byte order (most significant byte first), as are all the integer fields used in the file format. Bits 16-31 are reserved to denote critical file format issues; a reader should abort if it finds an unexpected bit set in this range. Bits 0-15 are reserved to signal backwards-compatible format issues; a reader should simply ignore any unexpected bits set in this range. Currently only one flag bit is defined, and the rest must be zero:

Bit 16

If 1, OIDs are included in the data; if 0, not. Oid system columns are not supported in PostgreSQL anymore, but the format still contains the indicator.

Header extension area length

32-bit integer, length in bytes of remainder of header, not including self. Currently, this is zero, and the first tuple follows immediately. Future changes to the format might allow additional data to be present in the header. A reader should silently skip over any header extension data it does not know what to do with.

The header extension area is envisioned to contain a sequence of self-identifying chunks. The flags field is not intended to tell readers what is in the extension area. Specific design of header extension contents is left for a later release.

This design allows for both backwards-compatible header additions (add header extension chunks, or set low-order flag bits) and non-backwards-compatible changes (set high-order flag bits to signal such changes, and add supporting data to the extension area if needed).

Tuples

Each tuple begins with a 16-bit integer count of the number of fields in the tuple. (Presently, all tuples in a table will have the same count, but that might not always be true.) Then, repeated for each field in the tuple, there is a 32-bit length word followed by that many bytes of field data. (The length word does not include itself, and can be zero.) As a special case, -1 indicates a NULL field value. No value bytes follow in the NULL case.

There is no alignment padding or any other extra data between fields.

Presently, all data values in a binary-format file are assumed to be in binary format (format code one). It is anticipated that a future extension might add a header field that allows per-column format codes to be specified.

To determine the appropriate binary format for the actual tuple data you should consult the PostgreSQL source, in particular the `*send` and `*recv` functions for each column's data type (typically these functions are found in the `src/backend/utils/adt/` directory of the source distribution).

If OIDs are included in the file, the OID field immediately follows the field-count word. It is a normal field except that it's not included in the field-count. Note that oid system columns are not supported in current versions of PostgreSQL.

File Trailer

The file trailer consists of a 16-bit integer word containing -1. This is easily distinguished from a tuple's field-count word.

A reader should report an error if a field-count word is neither -1 nor the expected number of columns. This provides an extra check against somehow getting out of sync with the data.

Examples

The following example copies a table to the client using the vertical bar (|) as the field delimiter:

```
COPY country TO STDOUT (DELIMITER '|');
```

To copy data from a file into the country table:

```
COPY country FROM '/usr1/proj/bray/sql/country_data';
```

To copy into a file just the countries whose names start with 'A':

```
COPY (SELECT * FROM country WHERE country_name LIKE 'A%') TO '/usr1/proj/bray/sql/a_list_countries.copy';
```

To copy into a compressed file, you can pipe the output through an external compression program:

```
COPY country TO PROGRAM 'gzip > /usr1/proj/bray/sql/country_data.gz';
```

Here is a sample of data suitable for copying into a table from STDIN:

```
AF      AFGHANISTAN
AL      ALBANIA
DZ      ALGERIA
ZM      ZAMBIA
ZW      ZIMBABWE
```

Note that the white space on each line is actually a tab character.

The following is the same data, output in binary format. The data is shown after filtering through the Unix utility `od -c`. The table has three columns; the first has type `char(2)`, the second has type `text`, and the third has type `integer`. All the rows have a null value in the third column.

```
0000000  P  G  C  O  P  Y  \n 377  \r  \n  \0  \0  \0  \0  \0
 \0
0000020  \0  \0  \0  \0 003  \0  \0  \0 002  A  F  \0  \0  \0 013
 A
0000040  F  G  H  A  N  I  S  T  A  N 377 377 377 377  \0
003
0000060  \0  \0  \0 002  A  L  \0  \0  \0 007  A  L  B  A  N
 I
0000100  A 377 377 377 377  \0 003  \0  \0  \0 002  D  Z  \0  \0
 \0
0000120 007  A  L  G  E  R  I  A 377 377 377 377  \0 003  \0
 \0
0000140  \0 002  Z  M  \0  \0  \0 006  Z  A  M  B  I  A 377
377
0000160 377 377  \0 003  \0  \0  \0 002  Z  W  \0  \0  \0  \b  Z
 I
0000200  M  B  A  B  W  E 377 377 377 377 377 377
```

Compatibility

There is no COPY statement in the SQL standard.

The following syntax was used before PostgreSQL version 9.0 and is still supported:

```
COPY table_name [ ( column_name [, ...] ) ]
FROM { 'filename' | STDIN }
[ [ WITH ]
  [ BINARY ]
  [ DELIMITER [ AS ] 'delimiter_character' ]
  [ NULL [ AS ] 'null_string' ]
  [ CSV [ HEADER ]
    [ QUOTE [ AS ] 'quote_character' ]
    [ ESCAPE [ AS ] 'escape_character' ]
    [ FORCE NOT NULL column_name [, ...] ] ] ] ]

COPY { table_name [ ( column_name [, ...] ) ] | ( query ) }
TO { 'filename' | STDOUT }
[ [ WITH ]
  [ BINARY ]
  [ DELIMITER [ AS ] 'delimiter_character' ]
  [ NULL [ AS ] 'null_string' ]
  [ CSV [ HEADER ]
    [ QUOTE [ AS ] 'quote_character' ]
    [ ESCAPE [ AS ] 'escape_character' ]
    [ FORCE QUOTE { column_name [, ...] | * } ] ] ] ]
```

Note that in this syntax, BINARY and CSV are treated as independent keywords, not as arguments of a FORMAT option.

The following syntax was used before PostgreSQL version 7.3 and is still supported:

```
COPY [ BINARY ] table_name
FROM { 'filename' | STDIN }
[ [USING] DELIMITERS 'delimiter_character' ]
[ WITH NULL AS 'null_string' ]

COPY [ BINARY ] table_name
TO { 'filename' | STDOUT }
[ [USING] DELIMITERS 'delimiter_character' ]
[ WITH NULL AS 'null_string' ]
```

CREATE ACCESS METHOD

CREATE ACCESS METHOD — define a new access method

Synopsis

```
CREATE ACCESS METHOD name
    TYPE access_method_type
    HANDLER handler_function
```

Description

CREATE ACCESS METHOD creates a new access method.

The access method name must be unique within the database.

Only superusers can define new access methods.

Parameters

name

The name of the access method to be created.

access_method_type

This clause specifies the type of access method to define. Only TABLE and INDEX are supported at present.

handler_function

handler_function is the name (possibly schema-qualified) of a previously registered function that represents the access method. The handler function must be declared to take a single argument of type `internal`, and its return type depends on the type of access method; for TABLE access methods, it must be `table_am_handler` and for INDEX access methods, it must be `index_am_handler`. The C-level API that the handler function must implement varies depending on the type of access method. The table access method API is described in Chapter 60 and the index access method API is described in Chapter 61.

Examples

Create an index access method `heptree` with handler function `heptree_handler`:

```
CREATE ACCESS METHOD heptree TYPE INDEX HANDLER heptree_handler;
```

Compatibility

CREATE ACCESS METHOD is a PostgreSQL extension.

See Also

DROP ACCESS METHOD, CREATE OPERATOR CLASS, CREATE OPERATOR FAMILY

CREATE AGGREGATE

CREATE AGGREGATE — define a new aggregate function

Synopsis

```
CREATE [ OR REPLACE ] AGGREGATE name ( [ argmode ] [ argname
] arg_data_type [ , ... ] ) (
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = combinefunc ]
    [ , SERIALFUNC = serialfunc ]
    [ , DESERIALFUNC = deserialfunc ]
    [ , INITCOND = initial_condition ]
    [ , MSFUNC = msfunc ]
    [ , MINVFUNC = minvfunc ]
    [ , MSTYPE = mstate_data_type ]
    [ , MSSPACE = mstate_data_size ]
    [ , MFINALFUNC = mffunc ]
    [ , MFINALFUNC_EXTRA ]
    [ , MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE |
READ_WRITE } ]
    [ , MINITCOND = minitial_condition ]
    [ , SORTOP = sort_operator ]
    [ , PARALLEL = { SAFE | RESTRICTED | UNSAFE } ]
)
```

```
CREATE [ OR REPLACE ] AGGREGATE name ( [ [ argmode ] [ argname
] arg_data_type [ , ... ] ]
                                ORDER BY [ argmode ] [ argname
] arg_data_type [ , ... ] ) (
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , INITCOND = initial_condition ]
    [ , PARALLEL = { SAFE | RESTRICTED | UNSAFE } ]
    [ , HYPOTHETICAL ]
)
```

or the old syntax

```
CREATE [ OR REPLACE ] AGGREGATE name (
    BASETYPE = base_type,
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
```

```

    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = combinefunc ]
    [ , SERIALFUNC = serialfunc ]
    [ , DESERIALFUNC = deserialfunc ]
    [ , INITCOND = initial_condition ]
    [ , MSFUNC = msfunc ]
    [ , MINVFUNC = minvfunc ]
    [ , MSTYPE = mstate_data_type ]
    [ , MSSPACE = mstate_data_size ]
    [ , MFINALFUNC = mfunc ]
    [ , MFINALFUNC_EXTRA ]
    [ , MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE |
READ_WRITE } ]
    [ , MINITCOND = minitial_condition ]
    [ , SORTOP = sort_operator ]
)

```

Description

CREATE AGGREGATE defines a new aggregate function. CREATE OR REPLACE AGGREGATE will either define a new aggregate function or replace an existing definition. Some basic and commonly-used aggregate functions are included with the distribution; they are documented in Section 9.20. If one defines new types or needs an aggregate function not already provided, then CREATE AGGREGATE can be used to provide the desired features.

When replacing an existing definition, the argument types, result type, and number of direct arguments may not be changed. Also, the new definition must be of the same kind (ordinary aggregate, ordered-set aggregate, or hypothetical-set aggregate) as the old one.

If a schema name is given (for example, CREATE AGGREGATE *myschema.myagg* . . .) then the aggregate function is created in the specified schema. Otherwise it is created in the current schema.

An aggregate function is identified by its name and input data type(s). Two aggregates in the same schema can have the same name if they operate on different input types. The name and input data type(s) of an aggregate must also be distinct from the name and input data type(s) of every ordinary function in the same schema. This behavior is identical to overloading of ordinary function names (see CREATE FUNCTION).

A simple aggregate function is made from one or two ordinary functions: a state transition function *sfunc*, and an optional final calculation function *ffunc*. These are used as follows:

```

sfunc( internal-state, next-data-values ) ---> next-internal-state
ffunc( internal-state ) ---> aggregate-value

```

PostgreSQL creates a temporary variable of data type *stype* to hold the current internal state of the aggregate. At each input row, the aggregate argument value(s) are calculated and the state transition function is invoked with the current state value and the new argument value(s) to calculate a new internal state value. After all the rows have been processed, the final function is invoked once to calculate the aggregate's return value. If there is no final function then the ending state value is returned as-is.

An aggregate function can provide an initial condition, that is, an initial value for the internal state value. This is specified and stored in the database as a value of type `text`, but it must be a valid external representation of a constant of the state value data type. If it is not supplied then the state value starts out null.

If the state transition function is declared “strict”, then it cannot be called with null inputs. With such a transition function, aggregate execution behaves as follows. Rows with any null input values are

ignored (the function is not called and the previous state value is retained). If the initial state value is null, then at the first row with all-nonnull input values, the first argument value replaces the state value, and the transition function is invoked at each subsequent row with all-nonnull input values. This is handy for implementing aggregates like `max`. Note that this behavior is only available when `state_data_type` is the same as the first `arg_data_type`. When these types are different, you must supply a nonnull initial condition or use a nonstrict transition function.

If the state transition function is not strict, then it will be called unconditionally at each input row, and must deal with null inputs and null state values for itself. This allows the aggregate author to have full control over the aggregate's handling of null values.

If the final function is declared “strict”, then it will not be called when the ending state value is null; instead a null result will be returned automatically. (Of course this is just the normal behavior of strict functions.) In any case the final function has the option of returning a null value. For example, the final function for `avg` returns null when it sees there were zero input rows.

Sometimes it is useful to declare the final function as taking not just the state value, but extra parameters corresponding to the aggregate's input values. The main reason for doing this is if the final function is polymorphic and the state value's data type would be inadequate to pin down the result type. These extra parameters are always passed as NULL (and so the final function must not be strict when the `FINALFUNC_EXTRA` option is used), but nonetheless they are valid parameters. The final function could for example make use of `get_fn_expr_argtype` to identify the actual argument type in the current call.

An aggregate can optionally support *moving-aggregate mode*, as described in Section 37.12.1. This requires specifying the `MSFUNC`, `MINVFUNC`, and `MSTYPE` parameters, and optionally the `MSSPACE`, `MFINALFUNC`, `MFINALFUNC_EXTRA`, `MFINALFUNC_MODIFY`, and `MINITCOND` parameters. Except for `MINVFUNC`, these parameters work like the corresponding simple-aggregate parameters without `M`; they define a separate implementation of the aggregate that includes an inverse transition function.

The syntax with `ORDER BY` in the parameter list creates a special type of aggregate called an *ordered-set aggregate*; or if `HYPOTHETICAL` is specified, then a *hypothetical-set aggregate* is created. These aggregates operate over groups of sorted values in order-dependent ways, so that specification of an input sort order is an essential part of a call. Also, they can have *direct* arguments, which are arguments that are evaluated only once per aggregation rather than once per input row. Hypothetical-set aggregates are a subclass of ordered-set aggregates in which some of the direct arguments are required to match, in number and data types, the aggregated argument columns. This allows the values of those direct arguments to be added to the collection of aggregate-input rows as an additional “hypothetical” row.

An aggregate can optionally support *partial aggregation*, as described in Section 37.12.4. This requires specifying the `COMBINEFUNC` parameter. If the `state_data_type` is `internal`, it's usually also appropriate to provide the `SERIALFUNC` and `DESERIALFUNC` parameters so that parallel aggregation is possible. Note that the aggregate must also be marked `PARALLEL SAFE` to enable parallel aggregation.

Aggregates that behave like `MIN` or `MAX` can sometimes be optimized by looking into an index instead of scanning every input row. If this aggregate can be so optimized, indicate it by specifying a *sort operator*. The basic requirement is that the aggregate must yield the first element in the sort ordering induced by the operator; in other words:

```
SELECT agg(col) FROM tab;
```

must be equivalent to:

```
SELECT col FROM tab ORDER BY col USING sortop LIMIT 1;
```

Further assumptions are that the aggregate ignores null inputs, and that it delivers a null result if and only if there were no non-null inputs. Ordinarily, a data type's < operator is the proper sort operator for MIN, and > is the proper sort operator for MAX. Note that the optimization will never actually take effect unless the specified operator is the "less than" or "greater than" strategy member of a B-tree index operator class.

To be able to create an aggregate function, you must have USAGE privilege on the argument types, the state type(s), and the return type, as well as EXECUTE privilege on the supporting functions.

Parameters

name

The name (optionally schema-qualified) of the aggregate function to create.

argmode

The mode of an argument: IN or VARIADIC. (Aggregate functions do not support OUT arguments.) If omitted, the default is IN. Only the last argument can be marked VARIADIC.

argname

The name of an argument. This is currently only useful for documentation purposes. If omitted, the argument has no name.

arg_data_type

An input data type on which this aggregate function operates. To create a zero-argument aggregate function, write * in place of the list of argument specifications. (An example of such an aggregate is count (*).)

base_type

In the old syntax for CREATE AGGREGATE, the input data type is specified by a basetype parameter rather than being written next to the aggregate name. Note that this syntax allows only one input parameter. To define a zero-argument aggregate function with this syntax, specify the basetype as "ANY" (not *). Ordered-set aggregates cannot be defined with the old syntax.

sfunc

The name of the state transition function to be called for each input row. For a normal *N*-argument aggregate function, the *sfunc* must take *N*+1 arguments, the first being of type *state_data_type* and the rest matching the declared input data type(s) of the aggregate. The function must return a value of type *state_data_type*. This function takes the current state value and the current input data value(s), and returns the next state value.

For ordered-set (including hypothetical-set) aggregates, the state transition function receives only the current state value and the aggregated arguments, not the direct arguments. Otherwise it is the same.

state_data_type

The data type for the aggregate's state value.

state_data_size

The approximate average size (in bytes) of the aggregate's state value. If this parameter is omitted or is zero, a default estimate is used based on the *state_data_type*. The planner uses this value to estimate the memory required for a grouped aggregate query. The planner will consider

using hash aggregation for such a query only if the hash table is estimated to fit in `work_mem`; therefore, large values of this parameter discourage use of hash aggregation.

ffunc

The name of the final function called to compute the aggregate's result after all input rows have been traversed. For a normal aggregate, this function must take a single argument of type `state_data_type`. The return data type of the aggregate is defined as the return type of this function. If *ffunc* is not specified, then the ending state value is used as the aggregate's result, and the return type is `state_data_type`.

For ordered-set (including hypothetical-set) aggregates, the final function receives not only the final state value, but also the values of all the direct arguments.

If `FINALFUNC_EXTRA` is specified, then in addition to the final state value and any direct arguments, the final function receives extra NULL values corresponding to the aggregate's regular (aggregated) arguments. This is mainly useful to allow correct resolution of the aggregate result type when a polymorphic aggregate is being defined.

`FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE }`

This option specifies whether the final function is a pure function that does not modify its arguments. `READ_ONLY` indicates it does not; the other two values indicate that it may change the transition state value. See Notes below for more detail. The default is `READ_ONLY`, except for ordered-set aggregates, for which the default is `READ_WRITE`.

combinefunc

The *combinefunc* function may optionally be specified to allow the aggregate function to support partial aggregation. If provided, the *combinefunc* must combine two `state_data_type` values, each containing the result of aggregation over some subset of the input values, to produce a new `state_data_type` that represents the result of aggregating over both sets of inputs. This function can be thought of as an *sfunc*, where instead of acting upon an individual input row and adding it to the running aggregate state, it adds another aggregate state to the running state.

The *combinefunc* must be declared as taking two arguments of the `state_data_type` and returning a value of the `state_data_type`. Optionally this function may be “strict”. In this case the function will not be called when either of the input states are null; the other state will be taken as the correct result.

For aggregate functions whose `state_data_type` is `internal`, the *combinefunc* must not be strict. In this case the *combinefunc* must ensure that null states are handled correctly and that the state being returned is properly stored in the aggregate memory context.

serialfunc

An aggregate function whose `state_data_type` is `internal` can participate in parallel aggregation only if it has a *serialfunc* function, which must serialize the aggregate state into a `bytea` value for transmission to another process. This function must take a single argument of type `internal` and return type `bytea`. A corresponding *deserialfunc* is also required.

deserialfunc

Deserialize a previously serialized aggregate state back into `state_data_type`. This function must take two arguments of types `bytea` and `internal`, and produce a result of type `internal`. (Note: the second, `internal` argument is unused, but is required for type safety reasons.)

initial_condition

The initial setting for the state value. This must be a string constant in the form accepted for the data type `state_data_type`. If not specified, the state value starts out null.

msfunc

The name of the forward state transition function to be called for each input row in moving-aggregate mode. This is exactly like the regular transition function, except that its first argument and result are of type *mstate_data_type*, which might be different from *state_data_type*.

minvfunc

The name of the inverse state transition function to be used in moving-aggregate mode. This function has the same argument and result types as *msfunc*, but it is used to remove a value from the current aggregate state, rather than add a value to it. The inverse transition function must have the same strictness attribute as the forward state transition function.

mstate_data_type

The data type for the aggregate's state value, when using moving-aggregate mode.

mstate_data_size

The approximate average size (in bytes) of the aggregate's state value, when using moving-aggregate mode. This works the same as *state_data_size*.

mffunc

The name of the final function called to compute the aggregate's result after all input rows have been traversed, when using moving-aggregate mode. This works the same as *ffunc*, except that its first argument's type is *mstate_data_type* and extra dummy arguments are specified by writing `MFINALFUNC_EXTRA`. The aggregate result type determined by *mffunc* or *mstate_data_type* must match that determined by the aggregate's regular implementation.

`MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE }`

This option is like `FINALFUNC_MODIFY`, but it describes the behavior of the moving-aggregate final function.

initial_condition

The initial setting for the state value, when using moving-aggregate mode. This works the same as *initial_condition*.

sort_operator

The associated sort operator for a MIN- or MAX-like aggregate. This is just an operator name (possibly schema-qualified). The operator is assumed to have the same input data types as the aggregate (which must be a single-argument normal aggregate).

`PARALLEL = { SAFE | RESTRICTED | UNSAFE }`

The meanings of `PARALLEL SAFE`, `PARALLEL RESTRICTED`, and `PARALLEL UNSAFE` are the same as in `CREATE FUNCTION`. An aggregate will not be considered for parallelization if it is marked `PARALLEL UNSAFE` (which is the default!) or `PARALLEL RESTRICTED`. Note that the parallel-safety markings of the aggregate's support functions are not consulted by the planner, only the marking of the aggregate itself.

HYPOTHETICAL

For ordered-set aggregates only, this flag specifies that the aggregate arguments are to be processed according to the requirements for hypothetical-set aggregates: that is, the last few direct arguments must match the data types of the aggregated (`WITHIN GROUP`) arguments. The `HYPOTHETICAL` flag has no effect on run-time behavior, only on parse-time resolution of the data types and collations of the aggregate's arguments.

The parameters of `CREATE AGGREGATE` can be written in any order, not just the order illustrated above.

Notes

In parameters that specify support function names, you can write a schema name if needed, for example `SFUNC = public.sum`. Do not write argument types there, however — the argument types of the support functions are determined from other parameters.

Ordinarily, PostgreSQL functions are expected to be true functions that do not modify their input values. However, an aggregate transition function, *when used in the context of an aggregate*, is allowed to cheat and modify its transition-state argument in place. This can provide substantial performance benefits compared to making a fresh copy of the transition state each time.

Likewise, while an aggregate final function is normally expected not to modify its input values, sometimes it is impractical to avoid modifying the transition-state argument. Such behavior must be declared using the `FINALFUNC_MODIFY` parameter. The `READ_WRITE` value indicates that the final function modifies the transition state in unspecified ways. This value prevents use of the aggregate as a window function, and it also prevents merging of transition states for aggregate calls that share the same input values and transition functions. The `SHAREABLE` value indicates that the transition function cannot be applied after the final function, but multiple final-function calls can be performed on the ending transition state value. This value prevents use of the aggregate as a window function, but it allows merging of transition states. (That is, the optimization of interest here is not applying the same final function repeatedly, but applying different final functions to the same ending transition state value. This is allowed as long as none of the final functions are marked `READ_WRITE`.)

If an aggregate supports moving-aggregate mode, it will improve calculation efficiency when the aggregate is used as a window function for a window with moving frame start (that is, a frame start mode other than `UNBOUNDED PRECEDING`). Conceptually, the forward transition function adds input values to the aggregate's state when they enter the window frame from the bottom, and the inverse transition function removes them again when they leave the frame at the top. So, when values are removed, they are always removed in the same order they were added. Whenever the inverse transition function is invoked, it will thus receive the earliest added but not yet removed argument value(s). The inverse transition function can assume that at least one row will remain in the current state after it removes the oldest row. (When this would not be the case, the window function mechanism simply starts a fresh aggregation, rather than using the inverse transition function.)

The forward transition function for moving-aggregate mode is not allowed to return `NULL` as the new state value. If the inverse transition function returns `NULL`, this is taken as an indication that the inverse function cannot reverse the state calculation for this particular input, and so the aggregate calculation will be redone from scratch for the current frame starting position. This convention allows moving-aggregate mode to be used in situations where there are some infrequent cases that are impractical to reverse out of the running state value.

If no moving-aggregate implementation is supplied, the aggregate can still be used with moving frames, but PostgreSQL will recompute the whole aggregation whenever the start of the frame moves. Note that whether or not the aggregate supports moving-aggregate mode, PostgreSQL can handle a moving frame end without recalculation; this is done by continuing to add new values to the aggregate's state. This is why use of an aggregate as a window function requires that the final function be read-only: it must not damage the aggregate's state value, so that the aggregation can be continued even after an aggregate result value has been obtained for one set of frame boundaries.

The syntax for ordered-set aggregates allows `VARIADIC` to be specified for both the last direct parameter and the last aggregated (`WITHIN GROUP`) parameter. However, the current implementation restricts use of `VARIADIC` in two ways. First, ordered-set aggregates can only use `VARIADIC "any"`, not other variadic array types. Second, if the last direct parameter is `VARIADIC "any"`, then there can be only one aggregated parameter and it must also be `VARIADIC "any"`. (In the representation used in the system catalogs, these two parameters are merged into a single `VARIADIC "any"` item, since `pg_proc` cannot represent functions with more than one `VARIADIC` parameter.) If the

aggregate is a hypothetical-set aggregate, the direct arguments that match the `VARIADIC` "any" parameter are the hypothetical ones; any preceding parameters represent additional direct arguments that are not constrained to match the aggregated arguments.

Currently, ordered-set aggregates do not need to support moving-aggregate mode, since they cannot be used as window functions.

Partial (including parallel) aggregation is currently not supported for ordered-set aggregates. Also, it will never be used for aggregate calls that include `DISTINCT` or `ORDER BY` clauses, since those semantics cannot be supported during partial aggregation.

Examples

See Section 37.12.

Compatibility

`CREATE AGGREGATE` is a PostgreSQL language extension. The SQL standard does not provide for user-defined aggregate functions.

See Also

`ALTER AGGREGATE`, `DROP AGGREGATE`

CREATE CAST

CREATE CAST — define a new cast

Synopsis

```
CREATE CAST (source_type AS target_type)
  WITH FUNCTION function_name [ (argument_type [, ...]) ]
  [ AS ASSIGNMENT | AS IMPLICIT ]
```

```
CREATE CAST (source_type AS target_type)
  WITHOUT FUNCTION
  [ AS ASSIGNMENT | AS IMPLICIT ]
```

```
CREATE CAST (source_type AS target_type)
  WITH INOUT
  [ AS ASSIGNMENT | AS IMPLICIT ]
```

Description

CREATE CAST defines a new cast. A cast specifies how to perform a conversion between two data types. For example,

```
SELECT CAST(42 AS float8);
```

converts the integer constant 42 to type float8 by invoking a previously specified function, in this case float8(int4). (If no suitable cast has been defined, the conversion fails.)

Two types can be *binary coercible*, which means that the conversion can be performed “for free” without invoking any function. This requires that corresponding values use the same internal representation. For instance, the types text and varchar are binary coercible both ways. Binary coercibility is not necessarily a symmetric relationship. For example, the cast from xml to text can be performed for free in the present implementation, but the reverse direction requires a function that performs at least a syntax check. (Two types that are binary coercible both ways are also referred to as binary compatible.)

You can define a cast as an *I/O conversion cast* by using the WITH INOUT syntax. An I/O conversion cast is performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type. In many common cases, this feature avoids the need to write a separate cast function for conversion. An I/O conversion cast acts the same as a regular function-based cast; only the implementation is different.

By default, a cast can be invoked only by an explicit cast request, that is an explicit CAST(*x* AS *typename*) or *x* : *typename* construct.

If the cast is marked AS ASSIGNMENT then it can be invoked implicitly when assigning a value to a column of the target data type. For example, supposing that foo.f1 is a column of type text, then:

```
INSERT INTO foo (f1) VALUES (42);
```

will be allowed if the cast from type integer to type text is marked AS ASSIGNMENT, otherwise not. (We generally use the term *assignment cast* to describe this kind of cast.)

If the cast is marked `AS IMPLICIT` then it can be invoked implicitly in any context, whether assignment or internally in an expression. (We generally use the term *implicit cast* to describe this kind of cast.) For example, consider this query:

```
SELECT 2 + 4.0;
```

The parser initially marks the constants as being of type `integer` and `numeric` respectively. There is no `integer + numeric` operator in the system catalogs, but there is a `numeric + numeric` operator. The query will therefore succeed if a cast from `integer` to `numeric` is available and is marked `AS IMPLICIT` — which in fact it is. The parser will apply the implicit cast and resolve the query as if it had been written

```
SELECT CAST ( 2 AS numeric ) + 4.0;
```

Now, the catalogs also provide a cast from `numeric` to `integer`. If that cast were marked `AS IMPLICIT` — which it is not — then the parser would be faced with choosing between the above interpretation and the alternative of casting the `numeric` constant to `integer` and applying the `integer + integer` operator. Lacking any knowledge of which choice to prefer, it would give up and declare the query ambiguous. The fact that only one of the two casts is implicit is the way in which we teach the parser to prefer resolution of a mixed `numeric-and-integer` expression as `numeric`; there is no built-in knowledge about that.

It is wise to be conservative about marking casts as implicit. An overabundance of implicit casting paths can cause PostgreSQL to choose surprising interpretations of commands, or to be unable to resolve commands at all because there are multiple possible interpretations. A good rule of thumb is to make a cast implicitly invocable only for information-preserving transformations between types in the same general type category. For example, the cast from `int2` to `int4` can reasonably be implicit, but the cast from `float8` to `int4` should probably be assignment-only. Cross-type-category casts, such as `text` to `int4`, are best made explicit-only.

Note

Sometimes it is necessary for usability or standards-compliance reasons to provide multiple implicit casts among a set of types, resulting in ambiguity that cannot be avoided as above. The parser has a fallback heuristic based on *type categories* and *preferred types* that can help to provide desired behavior in such cases. See `CREATE TYPE` for more information.

To be able to create a cast, you must own the source or the target data type and have `USAGE` privilege on the other type. To create a binary-coercible cast, you must be superuser. (This restriction is made because an erroneous binary-coercible cast conversion can easily crash the server.)

Parameters

source_type

The name of the source data type of the cast.

target_type

The name of the target data type of the cast.

function_name[(*argument_type* [, ...])]

The function used to perform the cast. The function name can be schema-qualified. If it is not, the function will be looked up in the schema search path. The function's result data type must match

the target type of the cast. Its arguments are discussed below. If no argument list is specified, the function name must be unique in its schema.

WITHOUT FUNCTION

Indicates that the source type is binary-coercible to the target type, so no function is required to perform the cast.

WITH INOUT

Indicates that the cast is an I/O conversion cast, performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type.

AS ASSIGNMENT

Indicates that the cast can be invoked implicitly in assignment contexts.

AS IMPLICIT

Indicates that the cast can be invoked implicitly in any context.

Cast implementation functions can have one to three arguments. The first argument type must be identical to or binary-coercible from the cast's source type. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or `-1` if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise. (Bizarrely, the SQL standard demands different behaviors for explicit and implicit casts in some cases. This argument is supplied for functions that must implement such casts. It is not recommended that you design your own data types so that this matters.)

The return type of a cast function must be identical to or binary-coercible to the cast's target type.

Ordinarily a cast must have different source and target data types. However, it is allowed to declare a cast with identical source and target types if it has a cast implementation function with more than one argument. This is used to represent type-specific length coercion functions in the system catalogs. The named function is used to coerce a value of the type to the type modifier value given by its second argument.

When a cast has different source and target types and a function that takes more than one argument, it supports converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two cast steps, one to convert between data types and a second to apply the modifier.

A cast to or from a domain type currently has no effect. Casting to or from a domain uses the casts associated with its underlying type.

Notes

Use `DROP CAST` to remove user-defined casts.

Remember that if you want to be able to convert types both ways you need to declare casts both ways explicitly.

It is normally not necessary to create casts between user-defined types and the standard string types (`text`, `varchar`, and `char(n)`), as well as user-defined types that are defined to be in the string category). PostgreSQL provides automatic I/O conversion casts for that. The automatic casts to string types are treated as assignment casts, while the automatic casts from string types are explicit-only. You can override this behavior by declaring your own cast to replace an automatic cast, but usually the only reason to do so is if you want the conversion to be more easily invocable than the standard assignment-only or explicit-only setting. Another possible reason is that you want the conversion to

behave differently from the type's I/O function; but that is sufficiently surprising that you should think twice about whether it's a good idea. (A small number of the built-in types do indeed have different behaviors for conversions, mostly because of requirements of the SQL standard.)

While not required, it is recommended that you continue to follow this old convention of naming cast implementation functions after the target data type. Many users are used to being able to cast data types using a function-style notation, that is *typename(x)*. This notation is in fact nothing more nor less than a call of the cast implementation function; it is not specially treated as a cast. If your conversion functions are not named to support this convention then you will have surprised users. Since PostgreSQL allows overloading of the same function name with different argument types, there is no difficulty in having multiple conversion functions from different types that all use the target type's name.

Note

Actually the preceding paragraph is an oversimplification: there are two cases in which a function-call construct will be treated as a cast request without having matched it to an actual function. If a function call *name(x)* does not exactly match any existing function, but *name* is the name of a data type and `pg_cast` provides a binary-coercible cast to this type from the type of *x*, then the call will be construed as a binary-coercible cast. This exception is made so that binary-coercible casts can be invoked using functional syntax, even though they lack any function. Likewise, if there is no `pg_cast` entry but the cast would be to or from a string type, the call will be construed as an I/O conversion cast. This exception allows I/O conversion casts to be invoked using functional syntax.

Note

There is also an exception to the exception: I/O conversion casts from composite types to string types cannot be invoked using functional syntax, but must be written in explicit cast syntax (either `CAST` or `::` notation). This exception was added because after the introduction of automatically-provided I/O conversion casts, it was found too easy to accidentally invoke such a cast when a function or column reference was intended.

Examples

To create an assignment cast from type `bigint` to type `int4` using the function `int4(bigint)`:

```
CREATE CAST (bigint AS int4) WITH FUNCTION int4(bigint) AS
ASSIGNMENT;
```

(This cast is already predefined in the system.)

Compatibility

The `CREATE CAST` command conforms to the SQL standard, except that SQL does not make provisions for binary-coercible types or extra arguments to implementation functions. `AS IMPLICIT` is a PostgreSQL extension, too.

See Also

`CREATE FUNCTION`, `CREATE TYPE`, `DROP CAST`

CREATE COLLATION

CREATE COLLATION — define a new collation

Synopsis

```
CREATE COLLATION [ IF NOT EXISTS ] name (  
    [ LOCALE = locale, ]  
    [ LC_COLLATE = lc_collate, ]  
    [ LC_CTYPE = lc_ctype, ]  
    [ PROVIDER = provider, ]  
    [ DETERMINISTIC = boolean, ]  
    [ VERSION = version ]  
)  
CREATE COLLATION [ IF NOT EXISTS ] name FROM existing_collation
```

Description

CREATE COLLATION defines a new collation using the specified operating system locale settings, or by copying an existing collation.

To be able to create a collation, you must have CREATE privilege on the destination schema.

Parameters

IF NOT EXISTS

Do not throw an error if a collation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing collation is anything like the one that would have been created.

name

The name of the collation. The collation name can be schema-qualified. If it is not, the collation is defined in the current schema. The collation name must be unique within that schema. (The system catalogs can contain collations with the same name for other encodings, but these are ignored if the database encoding does not match.)

locale

This is a shortcut for setting LC_COLLATE and LC_CTYPE at once. If you specify this, you cannot specify either of those parameters.

lc_collate

Use the specified operating system locale for the LC_COLLATE locale category.

lc_ctype

Use the specified operating system locale for the LC_CTYPE locale category.

provider

Specifies the provider to use for locale services associated with this collation. Possible values are: *icu*, *libc*. *libc* is the default. The available choices depend on the operating system and build options.

DETERMINISTIC

Specifies whether the collation should use deterministic comparisons. The default is true. A deterministic comparison considers strings that are not byte-wise equal to be unequal even if they are considered logically equal by the comparison. PostgreSQL breaks ties using a byte-wise comparison. Comparison that is not deterministic can make the collation be, say, case- or accent-insensitive. For that, you need to choose an appropriate `LC_COLLATE` setting *and* set the collation to not deterministic here.

Nondeterministic collations are only supported with the ICU provider.

version

Specifies the version string to store with the collation. Normally, this should be omitted, which will cause the version to be computed from the actual version of the collation as provided by the operating system. This option is intended to be used by `pg_upgrade` for copying the version from an existing installation.

See also `ALTER COLLATION` for how to handle collation version mismatches.

existing_collation

The name of an existing collation to copy. The new collation will have the same properties as the existing one, but it will be an independent object.

Notes

`CREATE COLLATION` takes a `SHARE ROW EXCLUSIVE` lock, which is self-conflicting, on the `pg_collation` system catalog, so only one `CREATE COLLATION` command can run at a time.

Use `DROP COLLATION` to remove user-defined collations.

See Section 23.2.2.3 for more information on how to create collations.

When using the `libc` collation provider, the locale must be applicable to the current database encoding. See `CREATE DATABASE` for the precise rules.

Examples

To create a collation from the operating system locale `fr_FR.utf8` (assuming the current database encoding is UTF8):

```
CREATE COLLATION french (locale = 'fr_FR.utf8');
```

To create a collation using the ICU provider using German phone book sort order:

```
CREATE COLLATION german_phonebook (provider = icu, locale = 'de-u-co-phonebk');
```

To create a collation from an existing collation:

```
CREATE COLLATION german FROM "de_DE";
```

This can be convenient to be able to use operating-system-independent collation names in applications.

Compatibility

There is a `CREATE COLLATION` statement in the SQL standard, but it is limited to copying an existing collation. The syntax to create a new collation is a PostgreSQL extension.

See Also

ALTER COLLATION, DROP COLLATION

CREATE CONVERSION

CREATE CONVERSION — define a new encoding conversion

Synopsis

```
CREATE [ DEFAULT ] CONVERSION name
    FOR source_encoding TO dest_encoding FROM function_name
```

Description

CREATE CONVERSION defines a new conversion between character set encodings. Also, conversions that are marked DEFAULT can be used for automatic encoding conversion between client and server. For this purpose, two conversions, from encoding A to B *and* from encoding B to A, must be defined.

To be able to create a conversion, you must have EXECUTE privilege on the function and CREATE privilege on the destination schema.

Parameters

DEFAULT

The DEFAULT clause indicates that this conversion is the default for this particular source to destination encoding. There should be only one default encoding in a schema for the encoding pair.

name

The name of the conversion. The conversion name can be schema-qualified. If it is not, the conversion is defined in the current schema. The conversion name must be unique within a schema.

source_encoding

The source encoding name.

dest_encoding

The destination encoding name.

function_name

The function used to perform the conversion. The function name can be schema-qualified. If it is not, the function will be looked up in the path.

The function must have the following signature:

```
conv_proc(
    integer, -- source encoding ID
    integer, -- destination encoding ID
    cstring, -- source string (null terminated C string)
    internal, -- destination (fill with a null terminated C
string)
    integer -- source string length
) RETURNS void;
```

Notes

Use `DROP CONVERSION` to remove user-defined conversions.

The privileges required to create a conversion might be changed in a future release.

Examples

To create a conversion from encoding UTF8 to LATIN1 using myfunc:

```
CREATE CONVERSION myconv FOR 'UTF8' TO 'LATIN1' FROM myfunc;
```

Compatibility

`CREATE CONVERSION` is a PostgreSQL extension. There is no `CREATE CONVERSION` statement in the SQL standard, but a `CREATE TRANSLATION` statement that is very similar in purpose and syntax.

See Also

`ALTER CONVERSION`, `CREATE FUNCTION`, `DROP CONVERSION`

CREATE DATABASE

CREATE DATABASE — create a new database

Synopsis

```
CREATE DATABASE name
    [ [ WITH ] [ OWNER [=] user_name ]
      [ TEMPLATE [=] template ]
      [ ENCODING [=] encoding ]
      [ LC_COLLATE [=] lc_collate ]
      [ LC_CTYPE [=] lc_ctype ]
      [ TABLESPACE [=] tablespace_name ]
      [ ALLOW_CONNECTIONS [=] allowconn ]
      [ CONNECTION LIMIT [=] connlimit ]
      [ IS_TEMPLATE [=] istemplate ] ]
```

Description

CREATE DATABASE creates a new PostgreSQL database.

To create a database, you must be a superuser or have the special CREATEDB privilege. See CREATE ROLE.

By default, the new database will be created by cloning the standard system database `template1`. A different template can be specified by writing `TEMPLATE name`. In particular, by writing `TEMPLATE template0`, you can create a virgin database containing only the standard objects predefined by your version of PostgreSQL. This is useful if you wish to avoid copying any installation-local objects that might have been added to `template1`.

Parameters

name

The name of a database to create.

user_name

The role name of the user who will own the new database, or `DEFAULT` to use the default (namely, the user executing the command). To create a database owned by another role, you must be a direct or indirect member of that role, or be a superuser.

template

The name of the template from which to create the new database, or `DEFAULT` to use the default template (`template1`).

encoding

Character set encoding to use in the new database. Specify a string constant (e.g., `'SQL_ASCII'`), or an integer encoding number, or `DEFAULT` to use the default encoding (namely, the encoding of the template database). The character sets supported by the PostgreSQL server are described in Section 23.3.1. See below for additional restrictions.

lc_collate

Collation order (`LC_COLLATE`) to use in the new database. This affects the sort order applied to strings, e.g. in queries with `ORDER BY`, as well as the order used in indexes on text columns. The default is to use the collation order of the template database. See below for additional restrictions.

lc_ctype

Character classification (`LC_CTYPE`) to use in the new database. This affects the categorization of characters, e.g. lower, upper and digit. The default is to use the character classification of the template database. See below for additional restrictions.

tablespace_name

The name of the tablespace that will be associated with the new database, or `DEFAULT` to use the template database's tablespace. This tablespace will be the default tablespace used for objects created in this database. See `CREATE TABLESPACE` for more information.

allowconn

If false then no one can connect to this database. The default is true, allowing connections (except as restricted by other mechanisms, such as `GRANT/REVOKE CONNECT`).

conlimit

How many concurrent connections can be made to this database. -1 (the default) means no limit.

istemplate

If true, then this database can be cloned by any user with `CREATEDB` privileges; if false (the default), then only superusers or the owner of the database can clone it.

Optional parameters can be written in any order, not only the order illustrated above.

Notes

`CREATE DATABASE` cannot be executed inside a transaction block.

Errors along the line of “could not initialize database directory” are most likely related to insufficient permissions on the data directory, a full disk, or other file system problems.

Use `DROP DATABASE` to remove a database.

The program `createdb` is a wrapper program around this command, provided for convenience.

Database-level configuration parameters (set via `ALTER DATABASE`) are not copied from the template database.

Although it is possible to copy a database other than `template1` by specifying its name as the template, this is not (yet) intended as a general-purpose “`COPY DATABASE`” facility. The principal limitation is that no other sessions can be connected to the template database while it is being copied. `CREATE DATABASE` will fail if any other connection exists when it starts; otherwise, new connections to the template database are locked out until `CREATE DATABASE` completes. See Section 22.3 for more information.

The character set encoding specified for the new database must be compatible with the chosen locale settings (`LC_COLLATE` and `LC_CTYPE`). If the locale is `C` (or equivalently `POSIX`), then all encodings are allowed, but for other locale settings there is only one encoding that will work properly. (On Windows, however, UTF-8 encoding can be used with any locale.) `CREATE DATABASE` will allow superusers to specify `SQL_ASCII` encoding regardless of the locale settings, but this choice is dep-

recated and may result in misbehavior of character-string functions if data that is not encoding-compatible with the locale is stored in the database.

The encoding and locale settings must match those of the template database, except when `template0` is used as template. This is because other databases might contain data that does not match the specified encoding, or might contain indexes whose sort ordering is affected by `LC_COLLATE` and `LC_CTYPE`. Copying such data would result in a database that is corrupt according to the new settings. `template0`, however, is known to not contain any data or indexes that would be affected.

The `CONNECTION LIMIT` option is only enforced approximately; if two new sessions start at about the same time when just one connection “slot” remains for the database, it is possible that both will fail. Also, the limit is not enforced against superusers or background worker processes.

Examples

To create a new database:

```
CREATE DATABASE lusiadas;
```

To create a database `sales` owned by user `salesapp` with a default tablespace of `salesspace`:

```
CREATE DATABASE sales OWNER salesapp TABLESPACE salesspace;
```

To create a database `music` with a different locale:

```
CREATE DATABASE music
  LC_COLLATE 'sv_SE.utf8' LC_CTYPE 'sv_SE.utf8'
  TEMPLATE template0;
```

In this example, the `TEMPLATE template0` clause is required if the specified locale is different from the one in `template1`. (If it is not, then specifying the locale explicitly is redundant.)

To create a database `music2` with a different locale and a different character set encoding:

```
CREATE DATABASE music2
  LC_COLLATE 'sv_SE.iso885915' LC_CTYPE 'sv_SE.iso885915'
  ENCODING LATIN9
  TEMPLATE template0;
```

The specified locale and encoding settings must match, or an error will be reported.

Note that locale names are specific to the operating system, so that the above commands might not work in the same way everywhere.

Compatibility

There is no `CREATE DATABASE` statement in the SQL standard. Databases are equivalent to catalogs, whose creation is implementation-defined.

See Also

`ALTER DATABASE`, `DROP DATABASE`

CREATE DOMAIN

CREATE DOMAIN — define a new domain

Synopsis

```
CREATE DOMAIN name [ AS ] data_type
    [ COLLATE collation ]
    [ DEFAULT expression ]
    [ constraint [ ... ] ]
```

where *constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL | NULL | CHECK (expression) }
```

Description

CREATE DOMAIN creates a new domain. A domain is essentially a data type with optional constraints (restrictions on the allowed set of values). The user who defines a domain becomes its owner.

If a schema name is given (for example, CREATE DOMAIN *myschema.mydomain* ...) then the domain is created in the specified schema. Otherwise it is created in the current schema. The domain name must be unique among the types and domains existing in its schema.

Domains are useful for abstracting common constraints on fields into a single location for maintenance. For example, several tables might contain email address columns, all requiring the same CHECK constraint to verify the address syntax. Define a domain rather than setting up each table's constraint individually.

To be able to create a domain, you must have USAGE privilege on the underlying type.

Parameters

name

The name (optionally schema-qualified) of a domain to be created.

data_type

The underlying data type of the domain. This can include array specifiers.

collation

An optional collation for the domain. If no collation is specified, the underlying data type's default collation is used. The underlying type must be collatable if COLLATE is specified.

DEFAULT *expression*

The DEFAULT clause specifies a default value for columns of the domain data type. The value is any variable-free expression (but subqueries are not allowed). The data type of the default expression must match the data type of the domain. If no default value is specified, then the default value is the null value.

The default expression will be used in any insert operation that does not specify a value for the column. If a default value is defined for a particular column, it overrides any default associated

with the domain. In turn, the domain default overrides any default value associated with the underlying data type.

CONSTRAINT *constraint_name*

An optional name for a constraint. If not specified, the system generates a name.

NOT NULL

Values of this domain are prevented from being null (but see notes below).

NULL

Values of this domain are allowed to be null. This is the default.

This clause is only intended for compatibility with nonstandard SQL databases. Its use is discouraged in new applications.

CHECK (*expression*)

CHECK clauses specify integrity constraints or tests which values of the domain must satisfy. Each constraint must be an expression producing a Boolean result. It should use the key word `VALUE` to refer to the value being tested. Expressions evaluating to `TRUE` or `UNKNOWN` succeed. If the expression produces a `FALSE` result, an error is reported and the value is not allowed to be converted to the domain type.

Currently, CHECK expressions cannot contain subqueries nor refer to variables other than `VALUE`.

When a domain has multiple CHECK constraints, they will be tested in alphabetical order by name. (PostgreSQL versions before 9.5 did not honor any particular firing order for CHECK constraints.)

Notes

Domain constraints, particularly `NOT NULL`, are checked when converting a value to the domain type. It is possible for a column that is nominally of the domain type to read as null despite there being such a constraint. For example, this can happen in an outer-join query, if the domain column is on the nullable side of the outer join. A more subtle example is

```
INSERT INTO tab (domcol) VALUES ((SELECT domcol FROM tab WHERE
false));
```

The empty scalar sub-SELECT will produce a null value that is considered to be of the domain type, so no further constraint checking is applied to it, and the insertion will succeed.

It is very difficult to avoid such problems, because of SQL's general assumption that a null value is a valid value of every data type. Best practice therefore is to design a domain's constraints so that a null value is allowed, and then to apply column `NOT NULL` constraints to columns of the domain type as needed, rather than directly to the domain type.

PostgreSQL assumes that CHECK constraints' conditions are immutable, that is, they will always give the same result for the same input value. This assumption is what justifies examining CHECK constraints only when a value is first converted to be of a domain type, and not at other times. (This is essentially the same as the treatment of table CHECK constraints, as described in Section 5.4.1.)

An example of a common way to break this assumption is to reference a user-defined function in a CHECK expression, and then change the behavior of that function. PostgreSQL does not disallow that, but it will not notice if there are stored values of the domain type that now violate the CHECK constraint. That would cause a subsequent database dump and reload to fail. The recommended way to handle such a change is to drop the constraint (using `ALTER DOMAIN`), adjust the function definition, and re-add the constraint, thereby rechecking it against stored data.

Examples

This example creates the `us_postal_code` data type and then uses the type in a table definition. A regular expression test is used to verify that the value looks like a valid US postal code:

```
CREATE DOMAIN us_postal_code AS TEXT
CHECK(
    VALUE ~ '^\\d{5}$'
OR VALUE ~ '^\\d{5}-\\d{4}$'
);
```

```
CREATE TABLE us_snail_addy (
    address_id SERIAL PRIMARY KEY,
    street1 TEXT NOT NULL,
    street2 TEXT,
    street3 TEXT,
    city TEXT NOT NULL,
    postal us_postal_code NOT NULL
);
```

Compatibility

The command `CREATE DOMAIN` conforms to the SQL standard.

See Also

`ALTER DOMAIN`, `DROP DOMAIN`

CREATE EVENT TRIGGER

CREATE EVENT TRIGGER — define a new event trigger

Synopsis

```
CREATE EVENT TRIGGER name
  ON event
  [ WHEN filter_variable IN (filter_value [, ... ]) [ AND ... ] ]
  EXECUTE { FUNCTION | PROCEDURE } function_name()
```

Description

CREATE EVENT TRIGGER creates a new event trigger. Whenever the designated event occurs and the WHEN condition associated with the trigger, if any, is satisfied, the trigger function will be executed. For a general introduction to event triggers, see Chapter 39. The user who creates an event trigger becomes its owner.

Parameters

name

The name to give the new trigger. This name must be unique within the database.

event

The name of the event that triggers a call to the given function. See Section 39.1 for more information on event names.

filter_variable

The name of a variable used to filter events. This makes it possible to restrict the firing of the trigger to a subset of the cases in which it is supported. Currently the only supported *filter_variable* is TAG.

filter_value

A list of values for the associated *filter_variable* for which the trigger should fire. For TAG, this means a list of command tags (e.g. 'DROP FUNCTION').

function_name

A user-supplied function that is declared as taking no argument and returning type `event_trigger`.

In the syntax of CREATE EVENT TRIGGER, the keywords FUNCTION and PROCEDURE are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword PROCEDURE here is historical and deprecated.

Notes

Only superusers can create event triggers.

Event triggers are disabled in single-user mode (see `postgres`). If an erroneous event trigger disables the database so much that you can't even drop the trigger, restart in single-user mode and you'll be able to do that.

Examples

Forbid the execution of any DDL command:

```
CREATE OR REPLACE FUNCTION abort_any_command()  
  RETURNS event_trigger  
  LANGUAGE plpgsql  
  AS $$  
BEGIN  
  RAISE EXCEPTION 'command % is disabled', tg_tag;  
END;  
$$;  
  
CREATE EVENT TRIGGER abort_ddl ON ddl_command_start  
  EXECUTE FUNCTION abort_any_command();
```

Compatibility

There is no CREATE EVENT TRIGGER statement in the SQL standard.

See Also

ALTER EVENT TRIGGER, DROP EVENT TRIGGER, CREATE FUNCTION

CREATE EXTENSION

CREATE EXTENSION — install an extension

Synopsis

```
CREATE EXTENSION [ IF NOT EXISTS ] extension_name
    [ WITH ] [ SCHEMA schema_name ]
        [ VERSION version ]
        [ FROM old_version ]
        [ CASCADE ]
```

Description

CREATE EXTENSION loads a new extension into the current database. There must not be an extension of the same name already loaded.

Loading an extension essentially amounts to running the extension's script file. The script will typically create new SQL objects such as functions, data types, operators and index support methods. CREATE EXTENSION additionally records the identities of all the created objects, so that they can be dropped again if DROP EXTENSION is issued.

Loading an extension requires the same privileges that would be required to create its component objects. For most extensions this means superuser or database owner privileges are needed. The user who runs CREATE EXTENSION becomes the owner of the extension for purposes of later privilege checks, as well as the owner of any objects created by the extension's script.

Parameters

IF NOT EXISTS

Do not throw an error if an extension with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing extension is anything like the one that would have been created from the currently-available script file.

extension_name

The name of the extension to be installed. PostgreSQL will create the extension using details from the file SHAREDIR/extension/*extension_name*.control.

schema_name

The name of the schema in which to install the extension's objects, given that the extension allows its contents to be relocated. The named schema must already exist. If not specified, and the extension's control file does not specify a schema either, the current default object creation schema is used.

If the extension specifies a *schema* parameter in its control file, then that schema cannot be overridden with a SCHEMA clause. Normally, an error will be raised if a SCHEMA clause is given and it conflicts with the extension's *schema* parameter. However, if the CASCADE clause is also given, then *schema_name* is ignored when it conflicts. The given *schema_name* will be used for installation of any needed extensions that do not specify *schema* in their control files.

Remember that the extension itself is not considered to be within any schema: extensions have unqualified names that must be unique database-wide. But objects belonging to the extension can be within schemas.

version

The version of the extension to install. This can be written as either an identifier or a string literal. The default version is whatever is specified in the extension's control file.

old_version

FROM *old_version* must be specified when, and only when, you are attempting to install an extension that replaces an “old style” module that is just a collection of objects not packaged into an extension. This option causes CREATE EXTENSION to run an alternative installation script that absorbs the existing objects into the extension, instead of creating new objects. Be careful that SCHEMA specifies the schema containing these pre-existing objects.

The value to use for *old_version* is determined by the extension's author, and might vary if there is more than one version of the old-style module that can be upgraded into an extension. For the standard additional modules supplied with pre-9.1 PostgreSQL, use `unpackaged` for *old_version* when updating a module to extension style.

CASCADE

Automatically install any extensions that this extension depends on that are not already installed. Their dependencies are likewise automatically installed, recursively. The SCHEMA clause, if given, applies to all extensions that get installed this way. Other options of the statement are not applied to automatically-installed extensions; in particular, their default versions are always selected.

Notes

Before you can use CREATE EXTENSION to load an extension into a database, the extension's supporting files must be installed. Information about installing the extensions supplied with PostgreSQL can be found in Additional Supplied Modules.

The extensions currently available for loading can be identified from the `pg_available_extensions` or `pg_available_extension_versions` system views.

For information about writing new extensions, see Section 37.17.

Examples

Install the `hstore` extension into the current database:

```
CREATE EXTENSION hstore;
```

Update a pre-9.1 installation of `hstore` into extension style:

```
CREATE EXTENSION hstore SCHEMA public FROM unpackaged;
```

Be careful to specify the schema in which you installed the existing `hstore` objects.

Compatibility

CREATE EXTENSION is a PostgreSQL extension.

See Also

ALTER EXTENSION, DROP EXTENSION

CREATE FOREIGN DATA WRAPPER

CREATE FOREIGN DATA WRAPPER — define a new foreign-data wrapper

Synopsis

```
CREATE FOREIGN DATA WRAPPER name
    [ HANDLER handler_function | NO HANDLER ]
    [ VALIDATOR validator_function | NO VALIDATOR ]
    [ OPTIONS ( option 'value' [, ... ] ) ]
```

Description

CREATE FOREIGN DATA WRAPPER creates a new foreign-data wrapper. The user who defines a foreign-data wrapper becomes its owner.

The foreign-data wrapper name must be unique within the database.

Only superusers can create foreign-data wrappers.

Parameters

name

The name of the foreign-data wrapper to be created.

HANDLER *handler_function*

handler_function is the name of a previously registered function that will be called to retrieve the execution functions for foreign tables. The handler function must take no arguments, and its return type must be `fdw_handler`.

It is possible to create a foreign-data wrapper with no handler function, but foreign tables using such a wrapper can only be declared, not accessed.

VALIDATOR *validator_function*

validator_function is the name of a previously registered function that will be called to check the generic options given to the foreign-data wrapper, as well as options for foreign servers, user mappings and foreign tables using the foreign-data wrapper. If no validator function or NO VALIDATOR is specified, then options will not be checked at creation time. (Foreign-data wrappers will possibly ignore or reject invalid option specifications at run time, depending on the implementation.) The validator function must take two arguments: one of type `text[]`, which will contain the array of options as stored in the system catalogs, and one of type `oid`, which will be the OID of the system catalog containing the options. The return type is ignored; the function should report invalid options using the `ereport(ERROR)` function.

OPTIONS (*option* '*value*' [, ...])

This clause specifies options for the new foreign-data wrapper. The allowed option names and values are specific to each foreign data wrapper and are validated using the foreign-data wrapper's validator function. Option names must be unique.

Notes

PostgreSQL's foreign-data functionality is still under active development. Optimization of queries is primitive (and mostly left to the wrapper, too). Thus, there is considerable room for future performance improvements.

Examples

Create a useless foreign-data wrapper dummy:

```
CREATE FOREIGN DATA WRAPPER dummy;
```

Create a foreign-data wrapper `file` with handler function `file_fdw_handler`:

```
CREATE FOREIGN DATA WRAPPER file HANDLER file_fdw_handler;
```

Create a foreign-data wrapper `mywrapper` with some options:

```
CREATE FOREIGN DATA WRAPPER mywrapper  
    OPTIONS (debug 'true');
```

Compatibility

`CREATE FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), with the exception that the `HANDLER` and `VALIDATOR` clauses are extensions and the standard clauses `LIBRARY` and `LANGUAGE` are not implemented in PostgreSQL.

Note, however, that the SQL/MED functionality as a whole is not yet conforming.

See Also

`ALTER FOREIGN DATA WRAPPER`, `DROP FOREIGN DATA WRAPPER`, `CREATE SERVER`,
`CREATE USER MAPPING`, `CREATE FOREIGN TABLE`

CREATE FOREIGN TABLE

CREATE FOREIGN TABLE — define a new foreign table

Synopsis

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name ( [
  { column_name data_type [ OPTIONS ( option 'value' [, ... ] ) ]
  [ COLLATE collation ] [ column_constraint [ ... ] ]
    | table_constraint }
  [, ... ]
] )
[ INHERITS ( parent_table [, ... ] ) ]
  SERVER server_name
[ OPTIONS ( option 'value' [, ... ] ) ]
```

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name
  PARTITION OF parent_table [ (
    { column_name [ WITH OPTIONS ] [ column_constraint [ ... ] ]
      | table_constraint }
    [, ... ]
  ) ] partition_bound_spec
  SERVER server_name
[ OPTIONS ( option 'value' [, ... ] ) ]
```

where *column_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL |
  NULL |
  CHECK ( expression ) [ NO INHERIT ] |
  DEFAULT default_expr |
  GENERATED ALWAYS AS ( generation_expr ) STORED }
```

and *table_constraint* is:

```
[ CONSTRAINT constraint_name ]
CHECK ( expression ) [ NO INHERIT ]
```

Description

CREATE FOREIGN TABLE creates a new foreign table in the current database. The table will be owned by the user issuing the command.

If a schema name is given (for example, CREATE FOREIGN TABLE myschema.mytable ...) then the table is created in the specified schema. Otherwise it is created in the current schema. The name of the foreign table must be distinct from the name of any other foreign table, table, sequence, index, view, or materialized view in the same schema.

CREATE FOREIGN TABLE also automatically creates a data type that represents the composite type corresponding to one row of the foreign table. Therefore, foreign tables cannot have the same name as any existing data type in the same schema.

If PARTITION OF clause is specified then the table is created as a partition of *parent_table* with specified bounds.

To be able to create a foreign table, you must have `USAGE` privilege on the foreign server, as well as `USAGE` privilege on all column types used in the table.

Parameters

`IF NOT EXISTS`

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

table_name

The name (optionally schema-qualified) of the table to be created.

column_name

The name of a column to be created in the new table.

data_type

The data type of the column. This can include array specifiers. For more information on the data types supported by PostgreSQL, refer to Chapter 8.

`COLLATE collation`

The `COLLATE` clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

`INHERITS (parent_table [, ...])`

The optional `INHERITS` clause specifies a list of tables from which the new foreign table automatically inherits all columns. Parent tables can be plain tables or foreign tables. See the similar form of `CREATE TABLE` for more details.

`PARTITION OF parent_table FOR VALUES partition_bound_spec`

This form can be used to create the foreign table as partition of the given parent table with specified partition bound values. See the similar form of `CREATE TABLE` for more details. Note that it is currently not allowed to create the foreign table as a partition of the parent table if there are `UNIQUE` indexes on the parent table. (See also `ALTER TABLE ATTACH PARTITION`.)

`CONSTRAINT constraint_name`

An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `col must be positive` can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

`NOT NULL`

The column is not allowed to contain null values.

`NULL`

The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

```
CHECK ( expression ) [ NO INHERIT ]
```

The CHECK clause specifies an expression producing a Boolean result which each row in the foreign table is expected to satisfy; that is, the expression should produce TRUE or UNKNOWN, never FALSE, for all rows in the foreign table. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns.

Currently, CHECK expressions cannot contain subqueries nor refer to variables other than columns of the current row. The system column `tableoid` may be referenced, but not any other system column.

A constraint marked with NO INHERIT will not propagate to child tables.

```
DEFAULT default_expr
```

The DEFAULT clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (subqueries and cross-references to other columns in the current table are not allowed). The data type of the default expression must match the data type of the column.

The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

```
GENERATED ALWAYS AS ( generation_expr ) STORED
```

This clause creates the column as a *generated column*. The column cannot be written to, and when read the result of the specified expression will be returned.

The keyword STORED is required to signify that the column will be computed on write. (The computed value will be presented to the foreign-data wrapper for storage and must be returned on reading.)

The generation expression can refer to other columns in the table, but not other generated columns. Any functions and operators used must be immutable. References to other tables are not allowed.

```
server_name
```

The name of an existing foreign server to use for the foreign table. For details on defining a server, see CREATE SERVER.

```
OPTIONS ( option 'value' [, ...] )
```

Options to be associated with the new foreign table or one of its columns. The allowed option names and values are specific to each foreign data wrapper and are validated using the foreign-data wrapper's validator function. Duplicate option names are not allowed (although it's OK for a table option and a column option to have the same name).

Notes

Constraints on foreign tables (such as CHECK or NOT NULL clauses) are not enforced by the core PostgreSQL system, and most foreign data wrappers do not attempt to enforce them either; that is, the constraint is simply assumed to hold true. There would be little point in such enforcement since it would only apply to rows inserted or updated via the foreign table, and not to rows modified by other means, such as directly on the remote server. Instead, a constraint attached to a foreign table should represent a constraint that is being enforced by the remote server.

Some special-purpose foreign data wrappers might be the only access mechanism for the data they access, and in that case it might be appropriate for the foreign data wrapper itself to perform constraint enforcement. But you should not assume that a wrapper does that unless its documentation says so.

Although PostgreSQL does not attempt to enforce constraints on foreign tables, it does assume that they are correct for purposes of query optimization. If there are rows visible in the foreign table that do not satisfy a declared constraint, queries on the table might produce incorrect answers. It is the user's responsibility to ensure that the constraint definition matches reality.

Similar considerations apply to generated columns. Stored generated columns are computed on insert or update on the local PostgreSQL server and handed to the foreign-data wrapper for writing out to the foreign data store, but it is not enforced that a query of the foreign table returns values for stored generated columns that are consistent with the generation expression. Again, this might result in incorrect query results.

While rows can be moved from local partitions to a foreign-table partition (provided the foreign data wrapper supports tuple routing), they cannot be moved from a foreign-table partition to another partition.

Examples

Create foreign table `films`, which will be accessed through the server `film_server`:

```
CREATE FOREIGN TABLE films (  
    code          char(5) NOT NULL,  
    title         varchar(40) NOT NULL,  
    did           integer NOT NULL,  
    date_prod    date,  
    kind          varchar(10),  
    len          interval hour to minute  
)  
SERVER film_server;
```

Create foreign table `measurement_y2016m07`, which will be accessed through the server `server_07`, as a partition of the range partitioned table `measurement`:

```
CREATE FOREIGN TABLE measurement_y2016m07  
    PARTITION OF measurement FOR VALUES FROM ('2016-07-01') TO  
    ('2016-08-01')  
    SERVER server_07;
```

Compatibility

The `CREATE FOREIGN TABLE` command largely conforms to the SQL standard; however, much as with `CREATE TABLE`, `NULL` constraints and zero-column foreign tables are permitted. The ability to specify column default values is also a PostgreSQL extension. Table inheritance, in the form defined by PostgreSQL, is nonstandard.

See Also

`ALTER FOREIGN TABLE`, `DROP FOREIGN TABLE`, `CREATE TABLE`, `CREATE SERVER`, `IMPORT FOREIGN SCHEMA`

CREATE FUNCTION

CREATE FUNCTION — define a new function

Synopsis

```
CREATE [ OR REPLACE ] FUNCTION
  name ( [ [ argmode ] [ argname ] argtype [ { DEFAULT |
= } default_expr ] [, ...] ] )
  [ RETURNS rettype
  | RETURNS TABLE ( column_name column_type [, ...] ) ]
  { LANGUAGE lang_name
  | TRANSFORM { FOR TYPE type_name } [, ... ]
  | WINDOW
  | IMMUTABLE | STABLE | VOLATILE | [ NOT ] LEAKPROOF
  | CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
  | [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
  | PARALLEL { UNSAFE | RESTRICTED | SAFE }
  | COST execution_cost
  | ROWS result_rows
  | SUPPORT support_function
  | SET configuration_parameter { TO value | = value | FROM
CURRENT }
  | AS 'definition'
  | AS 'obj_file', 'link_symbol'
} ...
```

Description

CREATE FUNCTION defines a new function. CREATE OR REPLACE FUNCTION will either create a new function, or replace an existing definition. To be able to define a function, the user must have the USAGE privilege on the language.

If a schema name is included, then the function is created in the specified schema. Otherwise it is created in the current schema. The name of the new function must not match any existing function or procedure with the same input argument types in the same schema. However, functions and procedures of different argument types can share a name (this is called *overloading*).

To replace the current definition of an existing function, use CREATE OR REPLACE FUNCTION. It is not possible to change the name or argument types of a function this way (if you tried, you would actually be creating a new, distinct function). Also, CREATE OR REPLACE FUNCTION will not let you change the return type of an existing function. To do that, you must drop and recreate the function. (When using OUT parameters, that means you cannot change the types of any OUT parameters except by dropping the function.)

When CREATE OR REPLACE FUNCTION is used to replace an existing function, the ownership and permissions of the function do not change. All other function properties are assigned the values specified or implied in the command. You must own the function to replace it (this includes being a member of the owning role).

If you drop and then recreate a function, the new function is not the same entity as the old; you will have to drop existing rules, views, triggers, etc. that refer to the old function. Use CREATE OR REPLACE FUNCTION to change a function definition without breaking objects that refer to the function. Also, ALTER FUNCTION can be used to change most of the auxiliary properties of an existing function.

The user that creates the function becomes the owner of the function.

To be able to create a function, you must have `USAGE` privilege on the argument types and the return type.

Parameters

name

The name (optionally schema-qualified) of the function to create.

argmode

The mode of an argument: `IN`, `OUT`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. Only `OUT` arguments can follow a `VARIADIC` one. Also, `OUT` and `INOUT` arguments cannot be used together with the `RETURNS TABLE` notation.

argname

The name of an argument. Some languages (including `SQL` and `PL/pgSQL`) let you use the name in the function body. For other languages the name of an input argument is just extra documentation, so far as the function itself is concerned; but you can use input argument names when calling a function to improve readability (see Section 4.3). In any case, the name of an output argument is significant, because it defines the column name in the result row type. (If you omit the name for an output argument, the system will choose a default column name.)

argtype

The data type(s) of the function's arguments (optionally schema-qualified), if any. The argument types can be base, composite, or domain types, or can reference the type of a table column.

Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. Pseudo-types indicate that the actual argument type is either incompletely specified, or outside the set of ordinary `SQL` data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a function independent of changes to the definition of a table.

default_expr

An expression to be used as default value if the parameter is not specified. The expression has to be coercible to the argument type of the parameter. Only input (including `INOUT`) parameters can have a default value. All input parameters following a parameter with a default value must have default values as well.

rettype

The return data type (optionally schema-qualified). The return type can be a base, composite, or domain type, or can reference the type of a table column. Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. If the function is not supposed to return a value, specify `void` as the return type.

When there are `OUT` or `INOUT` parameters, the `RETURNS` clause can be omitted. If present, it must agree with the result type implied by the output parameters: `RECORD` if there are multiple output parameters, or the same type as the single output parameter.

The `SETOF` modifier indicates that the function will return a set of items, rather than a single item.

The type of a column is referenced by writing `table_name.column_name%TYPE`.

column_name

The name of an output column in the RETURNS TABLE syntax. This is effectively another way of declaring a named OUT parameter, except that RETURNS TABLE also implies RETURNS SETOF.

column_type

The data type of an output column in the RETURNS TABLE syntax.

lang_name

The name of the language that the function is implemented in. It can be `sql`, `c`, `internal`, or the name of a user-defined procedural language, e.g. `plpgsql`. Enclosing the name in single quotes is deprecated and requires matching case.

TRANSFORM { FOR TYPE *type_name* } [, ...] }

Lists which transforms a call to the function should apply. Transforms convert between SQL types and language-specific data types; see CREATE TRANSFORM. Procedural language implementations usually have hardcoded knowledge of the built-in types, so those don't need to be listed here. If a procedural language implementation does not know how to handle a type and no transform is supplied, it will fall back to a default behavior for converting data types, but this depends on the implementation.

WINDOW

WINDOW indicates that the function is a *window function* rather than a plain function. This is currently only useful for functions written in C. The WINDOW attribute cannot be changed when replacing an existing function definition.

IMMUTABLE

STABLE

VOLATILE

These attributes inform the query optimizer about the behavior of the function. At most one choice can be specified. If none of these appear, VOLATILE is the default assumption.

IMMUTABLE indicates that the function cannot modify the database and always returns the same result when given the same argument values; that is, it does not do database lookups or otherwise use information not directly present in its argument list. If this option is given, any call of the function with all-constant arguments can be immediately replaced with the function value.

STABLE indicates that the function cannot modify the database, and that within a single table scan it will consistently return the same result for the same argument values, but that its result could change across SQL statements. This is the appropriate selection for functions whose results depend on database lookups, parameter variables (such as the current time zone), etc. (It is inappropriate for AFTER triggers that wish to query rows modified by the current command.) Also note that the `current_timestamp` family of functions qualify as stable, since their values do not change within a transaction.

VOLATILE indicates that the function value can change even within a single table scan, so no optimizations can be made. Relatively few database functions are volatile in this sense; some examples are `random()`, `curval()`, `timeofday()`. But note that any function that has side-effects must be classified volatile, even if its result is quite predictable, to prevent calls from being optimized away; an example is `setval()`.

For additional details see Section 37.7.

LEAKPROOF

LEAKPROOF indicates that the function has no side effects. It reveals no information about its arguments other than by its return value. For example, a function which throws an error message

for some argument values but not others, or which includes the argument values in any error message, is not leakproof. This affects how the system executes queries against views created with the `security_barrier` option or tables with row level security enabled. The system will enforce conditions from security policies and security barrier views before any user-supplied conditions from the query itself that contain non-leakproof functions, in order to prevent the inadvertent exposure of data. Functions and operators marked as leakproof are assumed to be trustworthy, and may be executed before conditions from security policies and security barrier views. In addition, functions which do not take arguments or which are not passed any arguments from the security barrier view or table do not have to be marked as leakproof to be executed before security conditions. See `CREATE VIEW` and Section 40.5. This option can only be set by the superuser.

`CALLED ON NULL INPUT`
`RETURNS NULL ON NULL INPUT`
`STRICT`

`CALLED ON NULL INPUT` (the default) indicates that the function will be called normally when some of its arguments are null. It is then the function author's responsibility to check for null values if necessary and respond appropriately.

`RETURNS NULL ON NULL INPUT` or `STRICT` indicates that the function always returns null whenever any of its arguments are null. If this parameter is specified, the function is not executed when there are null arguments; instead a null result is assumed automatically.

`[EXTERNAL] SECURITY INVOKER`
`[EXTERNAL] SECURITY DEFINER`

`SECURITY INVOKER` indicates that the function is to be executed with the privileges of the user that calls it. That is the default. `SECURITY DEFINER` specifies that the function is to be executed with the privileges of the user that owns it.

The key word `EXTERNAL` is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all functions not only external ones.

`PARALLEL`

`PARALLEL UNSAFE` indicates that the function can't be executed in parallel mode and the presence of such a function in an SQL statement forces a serial execution plan. This is the default. `PARALLEL RESTRICTED` indicates that the function can be executed in parallel mode, but the execution is restricted to parallel group leader. `PARALLEL SAFE` indicates that the function is safe to run in parallel mode without restriction.

Functions should be labeled parallel unsafe if they modify any database state, or if they make changes to the transaction such as using sub-transactions, or if they access sequences or attempt to make persistent changes to settings (e.g. `setval`). They should be labeled as parallel restricted if they access temporary tables, client connection state, cursors, prepared statements, or miscellaneous backend-local state which the system cannot synchronize in parallel mode (e.g. `setseed` cannot be executed other than by the group leader because a change made by another process would not be reflected in the leader). In general, if a function is labeled as being safe when it is restricted or unsafe, or if it is labeled as being restricted when it is in fact unsafe, it may throw errors or produce wrong answers when used in a parallel query. C-language functions could in theory exhibit totally undefined behavior if mislabeled, since there is no way for the system to protect itself against arbitrary C code, but in most likely cases the result will be no worse than for any other function. If in doubt, functions should be labeled as `UNSAFE`, which is the default.

`COST execution_cost`

A positive number giving the estimated execution cost for the function, in units of `cpu_operator_cost`. If the function returns a set, this is the cost per returned row. If the cost is not specified, 1 unit is assumed for C-language and internal functions, and 100 units for functions in all other languages. Larger values cause the planner to try to avoid evaluating the function more often than necessary.

ROWS *result_rows*

A positive number giving the estimated number of rows that the planner should expect the function to return. This is only allowed when the function is declared to return a set. The default assumption is 1000 rows.

SUPPORT *support_function*

The name (optionally schema-qualified) of a *planner support function* to use for this function. See Section 37.11 for details. You must be superuser to use this option.

configuration_parameter
value

The SET clause causes the specified configuration parameter to be set to the specified value when the function is entered, and then restored to its prior value when the function exits. SET FROM CURRENT saves the value of the parameter that is current when CREATE FUNCTION is executed as the value to be applied when the function is entered.

If a SET clause is attached to a function, then the effects of a SET LOCAL command executed inside the function for the same variable are restricted to the function: the configuration parameter's prior value is still restored at function exit. However, an ordinary SET command (without LOCAL) overrides the SET clause, much as it would do for a previous SET LOCAL command: the effects of such a command will persist after function exit, unless the current transaction is rolled back.

See SET and Chapter 19 for more information about allowed parameter names and values.

definition

A string constant defining the function; the meaning depends on the language. It can be an internal function name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the function definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function definition must be escaped by doubling them.

obj_file, link_symbol

This form of the AS clause is used for dynamically loadable C language functions when the function name in the C language source code is not the same as the name of the SQL function. The string *obj_file* is the name of the shared library file containing the compiled C function, and is interpreted as for the LOAD command. The string *link_symbol* is the function's link symbol, that is, the name of the function in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL function being defined. The C names of all functions must be different, so you must give overloaded C functions different C names (for example, use the argument types as part of the C names).

When repeated CREATE FUNCTION calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session.

Refer to Section 37.3 for further information on writing functions.

Overloading

PostgreSQL allows function *overloading*; that is, the same name can be used for several different functions so long as they have distinct input argument types. Whether or not you use it, this capability entails security precautions when calling functions in databases where some users mistrust other users; see Section 10.3.

Two functions are considered the same if they have the same names and *input* argument types, ignoring any OUT parameters. Thus for example these declarations conflict:

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, out text) ...
```

Functions that have different argument type lists will not be considered to conflict at creation time, but if defaults are provided they might conflict in use. For example, consider

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, int default 42) ...
```

A call `foo(10)` will fail due to the ambiguity about which function should be called.

Notes

The full SQL type syntax is allowed for declaring a function's arguments and return value. However, parenthesized type modifiers (e.g., the precision field for type `numeric`) are discarded by `CREATE FUNCTION`. Thus for example `CREATE FUNCTION foo (varchar(10)) ...` is exactly the same as `CREATE FUNCTION foo (varchar) ...`

When replacing an existing function with `CREATE OR REPLACE FUNCTION`, there are restrictions on changing parameter names. You cannot change the name already assigned to any input parameter (although you can add names to parameters that had none before). If there is more than one output parameter, you cannot change the names of the output parameters, because that would change the column names of the anonymous composite type that describes the function's result. These restrictions are made to ensure that existing calls of the function do not stop working when it is replaced.

If a function is declared `STRICT` with a `VARIADIC` argument, the strictness check tests that the variadic array *as a whole* is non-null. The function will still be called if the array has null elements.

Examples

Here are some trivial examples to help you get started. For more information and examples, see Section 37.3.

```
CREATE FUNCTION add(integer, integer) RETURNS integer
  AS 'select $1 + $2;'
  LANGUAGE SQL
  IMMUTABLE
  RETURNS NULL ON NULL INPUT;
```

Increment an integer, making use of an argument name, in PL/pgSQL:

```
CREATE OR REPLACE FUNCTION increment(i integer) RETURNS integer AS
  $$
    BEGIN
      RETURN i + 1;
    END;
  $$ LANGUAGE plpgsql;
```

Return a record containing multiple output parameters:

```
CREATE FUNCTION dup(in int, out f1 int, out f2 text)
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;
```

```
SELECT * FROM dup(42);
```

You can do the same thing more verbosely with an explicitly named composite type:

```
CREATE TYPE dup_result AS (f1 int, f2 text);
```

```
CREATE FUNCTION dup(int) RETURNS dup_result
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;
```

```
SELECT * FROM dup(42);
```

Another way to return multiple columns is to use a TABLE function:

```
CREATE FUNCTION dup(int) RETURNS TABLE(f1 int, f2 text)
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;
```

```
SELECT * FROM dup(42);
```

However, a TABLE function is different from the preceding examples, because it actually returns a *set* of records, not just one record.

Writing SECURITY DEFINER Functions Safely

Because a SECURITY DEFINER function is executed with the privileges of the user that owns it, care is needed to ensure that the function cannot be misused. For security, search_path should be set to exclude any schemas writable by untrusted users. This prevents malicious users from creating objects (e.g., tables, functions, and operators) that mask objects intended to be used by the function. Particularly important in this regard is the temporary-table schema, which is searched first by default, and is normally writable by anyone. A secure arrangement can be obtained by forcing the temporary schema to be searched last. To do this, write pg_temp as the last entry in search_path. This function illustrates safe usage:

```
CREATE FUNCTION check_password(uname TEXT, pass TEXT)
  RETURNS BOOLEAN AS $$
  DECLARE passed BOOLEAN;
  BEGIN
    SELECT (pwd = $2) INTO passed
    FROM   pwds
    WHERE  username = $1;

    RETURN passed;
  END;
  $$ LANGUAGE plpgsql
  SECURITY DEFINER
  -- Set a secure search_path: trusted schema(s), then 'pg_temp'.
  SET search_path = admin, pg_temp;
```

This function's intention is to access a table admin.pwds. But without the SET clause, or with a SET clause mentioning only admin, the function could be subverted by creating a temporary table named pwds.

Before PostgreSQL version 8.3, the `SET` clause was not available, and so older functions may contain rather complicated logic to save, set, and restore `search_path`. The `SET` clause is far easier to use for this purpose.

Another point to keep in mind is that by default, execute privilege is granted to `PUBLIC` for newly created functions (see Section 5.7 for more information). Frequently you will wish to restrict use of a security definer function to only some users. To do that, you must revoke the default `PUBLIC` privileges and then grant execute privilege selectively. To avoid having a window where the new function is accessible to all, create it and set the privileges within a single transaction. For example:

```
BEGIN;  
CREATE FUNCTION check_password(uname TEXT, pass TEXT) ... SECURITY  
  DEFINER;  
REVOKE ALL ON FUNCTION check_password(uname TEXT, pass TEXT) FROM  
  PUBLIC;  
GRANT EXECUTE ON FUNCTION check_password(uname TEXT, pass TEXT) TO  
  admins;  
COMMIT;
```

Compatibility

A `CREATE FUNCTION` command is defined in the SQL standard. The PostgreSQL version is similar but not fully compatible. The attributes are not portable, neither are the different available languages.

For compatibility with some other database systems, *argmode* can be written either before or after *argname*. But only the first way is standard-compliant.

For parameter defaults, the SQL standard specifies only the syntax with the `DEFAULT` key word. The syntax with `=` is used in T-SQL and Firebird.

See Also

ALTER FUNCTION, DROP FUNCTION, GRANT, LOAD, REVOKE

CREATE GROUP

CREATE GROUP — define a new database role

Synopsis

```
CREATE GROUP name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
SUPERUSER | NOSUPERUSER  
| CREATEDB | NOCREATEDB  
| CREATEROLE | NOCREATEROLE  
| INHERIT | NOINHERIT  
| LOGIN | NOLOGIN  
| [ ENCRYPTED ] PASSWORD 'password'  
| VALID UNTIL 'timestamp'  
| IN ROLE role_name [ , ... ]  
| IN GROUP role_name [ , ... ]  
| ROLE role_name [ , ... ]  
| ADMIN role_name [ , ... ]  
| USER role_name [ , ... ]  
| SYSID uid
```

Description

CREATE GROUP is now an alias for CREATE ROLE.

Compatibility

There is no CREATE GROUP statement in the SQL standard.

See Also

CREATE ROLE

CREATE INDEX

CREATE INDEX — define a new index

Synopsis

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ [ IF NOT EXISTS ] name ]
ON [ ONLY ] table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ]
  [ opclass ] [ ASC | DESC ] [ NULLS { FIRST | LAST } ] [, ...] )
  [ INCLUDE ( column_name [, ...] ) ]
  [ WITH ( storage_parameter = value [, ... ] ) ]
  [ TABLESPACE tablespace_name ]
  [ WHERE predicate ]
```

Description

`CREATE INDEX` constructs an index on the specified column(s) of the specified relation, which can be a table or a materialized view. Indexes are primarily used to enhance database performance (though inappropriate use can result in slower performance).

The key field(s) for the index are specified as column names, or alternatively as expressions written in parentheses. Multiple fields can be specified if the index method supports multicolumn indexes.

An index field can be an expression computed from the values of one or more columns of the table row. This feature can be used to obtain fast access to data based on some transformation of the basic data. For example, an index computed on `upper(col)` would allow the clause `WHERE upper(col) = 'JIM'` to use an index.

PostgreSQL provides the index methods B-tree, hash, GiST, SP-GiST, GIN, and BRIN. Users can also define their own index methods, but that is fairly complicated.

When the `WHERE` clause is present, a *partial index* is created. A partial index is an index that contains entries for only a portion of a table, usually a portion that is more useful for indexing than the rest of the table. For example, if you have a table that contains both billed and unbilled orders where the unbilled orders take up a small fraction of the total table and yet that is an often used section, you can improve performance by creating an index on just that portion. Another possible application is to use `WHERE` with `UNIQUE` to enforce uniqueness over a subset of a table. See Section 11.8 for more discussion.

The expression used in the `WHERE` clause can refer only to columns of the underlying table, but it can use all columns, not just the ones being indexed. Presently, subqueries and aggregate expressions are also forbidden in `WHERE`. The same restrictions apply to index fields that are expressions.

All functions and operators used in an index definition must be “immutable”, that is, their results must depend only on their arguments and never on any outside influence (such as the contents of another table or the current time). This restriction ensures that the behavior of the index is well-defined. To use a user-defined function in an index expression or `WHERE` clause, remember to mark the function immutable when you create it.

Parameters

`UNIQUE`

Causes the system to check for duplicate values in the table when the index is created (if data already exist) and each time data is added. Attempts to insert or update data which would result in duplicate entries will generate an error.

Additional restrictions apply when unique indexes are applied to partitioned tables; see CREATE TABLE.

CONCURRENTLY

When this option is used, PostgreSQL will build the index without taking any locks that prevent concurrent inserts, updates, or deletes on the table; whereas a standard index build locks out writes (but not reads) on the table until it's done. There are several caveats to be aware of when using this option — see Building Indexes Concurrently.

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing index is anything like the one that would have been created. Index name is required when IF NOT EXISTS is specified.

INCLUDE

The optional INCLUDE clause specifies a list of columns which will be included in the index as *non-key* columns. A non-key column cannot be used in an index scan search qualification, and it is disregarded for purposes of any uniqueness or exclusion constraint enforced by the index. However, an index-only scan can return the contents of non-key columns without having to visit the index's table, since they are available directly from the index entry. Thus, addition of non-key columns allows index-only scans to be used for queries that otherwise could not use them.

It's wise to be conservative about adding non-key columns to an index, especially wide columns. If an index tuple exceeds the maximum size allowed for the index type, data insertion will fail. In any case, non-key columns duplicate data from the index's table and bloat the size of the index, thus potentially slowing searches.

Columns listed in the INCLUDE clause don't need appropriate operator classes; the clause can include columns whose data types don't have operator classes defined for a given access method.

Expressions are not supported as included columns since they cannot be used in index-only scans.

Currently, the B-tree and the GiST index access methods support this feature. In B-tree and the GiST indexes, the values of columns listed in the INCLUDE clause are included in leaf tuples which correspond to heap tuples, but are not included in upper-level index entries used for tree navigation.

name

The name of the index to be created. No schema name can be included here; the index is always created in the same schema as its parent table. If the name is omitted, PostgreSQL chooses a suitable name based on the parent table's name and the indexed column name(s).

ONLY

Indicates not to recurse creating indexes on partitions, if the table is partitioned. The default is to recurse.

table_name

The name (possibly schema-qualified) of the table to be indexed.

method

The name of the index method to be used. Choices are `btree`, `hash`, `gist`, `spgist`, `gin`, and `brin`. The default method is `btree`.

column_name

The name of a column of the table.

expression

An expression based on one or more columns of the table. The expression usually must be written with surrounding parentheses, as shown in the syntax. However, the parentheses can be omitted if the expression has the form of a function call.

collation

The name of the collation to use for the index. By default, the index uses the collation declared for the column to be indexed or the result collation of the expression to be indexed. Indexes with non-default collations can be useful for queries that involve expressions using non-default collations.

opclass

The name of an operator class. See below for details.

ASC

Specifies ascending sort order (which is the default).

DESC

Specifies descending sort order.

NULLS FIRST

Specifies that nulls sort before non-nulls. This is the default when DESC is specified.

NULLS LAST

Specifies that nulls sort after non-nulls. This is the default when DESC is not specified.

storage_parameter

The name of an index-method-specific storage parameter. See Index Storage Parameters for details.

tablespace_name

The tablespace in which to create the index. If not specified, `default_tablespace` is consulted, or `temp_tablespaces` for indexes on temporary tables.

predicate

The constraint expression for a partial index.

Index Storage Parameters

The optional `WITH` clause specifies *storage parameters* for the index. Each index method has its own set of allowed storage parameters. The B-tree, hash, GiST and SP-GiST index methods all accept this parameter:

fillfactor

The fillfactor for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (adding new largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency. B-trees use a default fillfactor of 90, but any integer value from 10 to 100 can be selected. If the table is static then fillfactor 100 is best to minimize the index's physical size, but

for heavily updated tables a smaller fillfactor is better to minimize the need for page splits. The other index methods use fillfactor in different but roughly analogous ways; the default fillfactor varies between methods.

B-tree indexes additionally accept this parameter:

`vacuum_cleanup_index_scale_factor`

Per-index value for `vacuum_cleanup_index_scale_factor`.

GiST indexes additionally accept this parameter:

`buffering`

Determines whether the buffering build technique described in Section 64.4.1 is used to build the index. With `OFF` it is disabled, with `ON` it is enabled, and with `AUTO` it is initially disabled, but turned on on-the-fly once the index size reaches `effective_cache_size`. The default is `AUTO`.

GIN indexes accept different parameters:

`fastupdate`

This setting controls usage of the fast update technique described in Section 66.4.1. It is a Boolean parameter: `ON` enables fast update, `OFF` disables it. (Alternative spellings of `ON` and `OFF` are allowed as described in Section 19.1.) The default is `ON`.

Note

Turning `fastupdate` off via `ALTER INDEX` prevents future insertions from going into the list of pending index entries, but does not in itself flush previous entries. You might want to `VACUUM` the table or call `gin_clean_pending_list` function afterward to ensure the pending list is emptied.

`gin_pending_list_limit`

Custom `gin_pending_list_limit` parameter. This value is specified in kilobytes.

BRIN indexes accept different parameters:

`pages_per_range`

Defines the number of table blocks that make up one block range for each entry of a BRIN index (see Section 67.1 for more details). The default is 128.

`autosummarize`

Defines whether a summarization run is invoked for the previous page range whenever an insertion is detected on the next one.

Building Indexes Concurrently

Creating an index can interfere with regular operation of a database. Normally PostgreSQL locks the table to be indexed against writes and performs the entire index build with a single scan of the table. Other transactions can still read the table, but if they try to insert, update, or delete rows in the table they will block until the index build is finished. This could have a severe effect if the system is a live production database. Very large tables can take many hours to be indexed, and even for smaller tables, an index build can lock out writers for periods that are unacceptably long for a production system.

PostgreSQL supports building indexes without locking out writes. This method is invoked by specifying the `CONCURRENTLY` option of `CREATE INDEX`. When this option is used, PostgreSQL must perform two scans of the table, and in addition it must wait for all existing transactions that could potentially modify or use the index to terminate. Thus this method requires more total work than a standard index build and takes significantly longer to complete. However, since it allows normal operations to continue while the index is built, this method is useful for adding new indexes in a production environment. Of course, the extra CPU and I/O load imposed by the index creation might slow other operations.

In a concurrent index build, the index is actually entered into the system catalogs in one transaction, then two table scans occur in two more transactions. Before each table scan, the index build must wait for existing transactions that have modified the table to terminate. After the second scan, the index build must wait for any transactions that have a snapshot (see Chapter 13) predating the second scan to terminate. Then finally the index can be marked ready for use, and the `CREATE INDEX` command terminates. Even then, however, the index may not be immediately usable for queries: in the worst case, it cannot be used as long as transactions exist that predate the start of the index build.

If a problem arises while scanning the table, such as a deadlock or a uniqueness violation in a unique index, the `CREATE INDEX` command will fail but leave behind an “invalid” index. This index will be ignored for querying purposes because it might be incomplete; however it will still consume update overhead. The `psql \d` command will report such an index as `INVALID`:

```
postgres=# \d tab
          Table "public.tab"
  Column | Type      | Collation | Nullable | Default
-----+-----+-----+-----+-----
  col    | integer   |           |          |
Indexes:
    "idx" btree (col) INVALID
```

The recommended recovery method in such cases is to drop the index and try again to perform `CREATE INDEX CONCURRENTLY`. (Another possibility is to rebuild the index with `REINDEX INDEX CONCURRENTLY`).

Another caveat when building a unique index concurrently is that the uniqueness constraint is already being enforced against other transactions when the second table scan begins. This means that constraint violations could be reported in other queries prior to the index becoming available for use, or even in cases where the index build eventually fails. Also, if a failure does occur in the second scan, the “invalid” index continues to enforce its uniqueness constraint afterwards.

Concurrent builds of expression indexes and partial indexes are supported. Errors occurring in the evaluation of these expressions could cause behavior similar to that described above for unique constraint violations.

Regular index builds permit other regular index builds on the same table to occur simultaneously, but only one concurrent index build can occur on a table at a time. In either case, schema modification of the table is not allowed while the index is being built. Another difference is that a regular `CREATE INDEX` command can be performed within a transaction block, but `CREATE INDEX CONCURRENTLY` cannot.

Concurrent builds for indexes on partitioned tables are currently not supported. However, you may concurrently build the index on each partition individually and then finally create the partitioned index non-concurrently in order to reduce the time where writes to the partitioned table will be locked out. In this case, building the partitioned index is a metadata only operation.

Notes

See Chapter 11 for information about when indexes can be used, when they are not used, and in which particular situations they can be useful.

Currently, only the B-tree, GiST, GIN, and BRIN index methods support multicolumn indexes. Up to 32 fields can be specified by default. (This limit can be altered when building PostgreSQL.) Only B-tree currently supports unique indexes.

An *operator class* can be specified for each column of an index. The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on four-byte integers would use the `int4_ops` class; this operator class includes comparison functions for four-byte integers. In practice the default operator class for the column's data type is usually sufficient. The main point of having operator classes is that for some data types, there could be more than one meaningful ordering. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when creating an index. More information about operator classes is in Section 11.10 and in Section 37.16.

When `CREATE INDEX` is invoked on a partitioned table, the default behavior is to recurse to all partitions to ensure they all have matching indexes. Each partition is first checked to determine whether an equivalent index already exists, and if so, that index will become attached as a partition index to the index being created, which will become its parent index. If no matching index exists, a new index will be created and automatically attached; the name of the new index in each partition will be determined as if no index name had been specified in the command. If the `ONLY` option is specified, no recursion is done, and the index is marked invalid. (`ALTER INDEX ... ATTACH PARTITION` marks the index valid, once all partitions acquire matching indexes.) Note, however, that any partition that is created in the future using `CREATE TABLE ... PARTITION OF` will automatically have a matching index, regardless of whether `ONLY` is specified.

For index methods that support ordered scans (currently, only B-tree), the optional clauses `ASC`, `DESC`, `NULLS FIRST`, and/or `NULLS LAST` can be specified to modify the sort ordering of the index. Since an ordered index can be scanned either forward or backward, it is not normally useful to create a single-column `DESC` index — that sort ordering is already available with a regular index. The value of these options is that multicolumn indexes can be created that match the sort ordering requested by a mixed-ordering query, such as `SELECT ... ORDER BY x ASC, y DESC`. The `NULLS` options are useful if you need to support “nulls sort low” behavior, rather than the default “nulls sort high”, in queries that depend on indexes to avoid sorting steps.

For most index methods, the speed of creating an index is dependent on the setting of `maintenance_work_mem`. Larger values will reduce the time needed for index creation, so long as you don't make it larger than the amount of memory really available, which would drive the machine into swapping.

PostgreSQL can build indexes while leveraging multiple CPUs in order to process the table rows faster. This feature is known as *parallel index build*. For index methods that support building indexes in parallel (currently, only B-tree), `maintenance_work_mem` specifies the maximum amount of memory that can be used by each index build operation as a whole, regardless of how many worker processes were started. Generally, a cost model automatically determines how many worker processes should be requested, if any.

Parallel index builds may benefit from increasing `maintenance_work_mem` where an equivalent serial index build will see little or no benefit. Note that `maintenance_work_mem` may influence the number of worker processes requested, since parallel workers must have at least a 32MB share of the total `maintenance_work_mem` budget. There must also be a remaining 32MB share for the leader process. Increasing `max_parallel_maintenance_workers` may allow more workers to be used, which will reduce the time needed for index creation, so long as the index build is not already I/O bound. Of course, there should also be sufficient CPU capacity that would otherwise lie idle.

Setting a value for `parallel_workers` via `ALTER TABLE` directly controls how many parallel worker processes will be requested by a `CREATE INDEX` against the table. This bypasses the cost model completely, and prevents `maintenance_work_mem` from affecting how many parallel workers are requested. Setting `parallel_workers` to 0 via `ALTER TABLE` will disable parallel index builds on the table in all cases.

Tip

You might want to reset `parallel_workers` after setting it as part of tuning an index build. This avoids inadvertent changes to query plans, since `parallel_workers` affects *all* parallel table scans.

While `CREATE INDEX` with the `CONCURRENTLY` option supports parallel builds without special restrictions, only the first table scan is actually performed in parallel.

Use `DROP INDEX` to remove an index.

Prior releases of PostgreSQL also had an R-tree index method. This method has been removed because it had no significant advantages over the GiST method. If `USING rtree` is specified, `CREATE INDEX` will interpret it as `USING gist`, to simplify conversion of old databases to GiST.

Examples

To create a unique B-tree index on the column `title` in the table `films`:

```
CREATE UNIQUE INDEX title_idx ON films (title);
```

To create a unique B-tree index on the column `title` with included columns `director` and `rating` in the table `films`:

```
CREATE UNIQUE INDEX title_idx ON films (title) INCLUDE (director, rating);
```

To create an index on the expression `lower(title)`, allowing efficient case-insensitive searches:

```
CREATE INDEX ON films ((lower(title)));
```

(In this example we have chosen to omit the index name, so the system will choose a name, typically `films_lower_idx`.)

To create an index with non-default collation:

```
CREATE INDEX title_idx_german ON films (title COLLATE "de_DE");
```

To create an index with non-default sort ordering of nulls:

```
CREATE INDEX title_idx_nulls_low ON films (title NULLS FIRST);
```

To create an index with non-default fill factor:

```
CREATE UNIQUE INDEX title_idx ON films (title) WITH (fillfactor = 70);
```

To create a GIN index with fast updates disabled:

```
CREATE INDEX gin_idx ON documents_table USING GIN (locations) WITH (fastupdate = off);
```

To create an index on the column `code` in the table `films` and have the index reside in the tablespace `indexspace`:

```
CREATE INDEX code_idx ON films (code) TABLESPACE indexspace;
```

To create a GiST index on a point attribute so that we can efficiently use box operators on the result of the conversion function:

```
CREATE INDEX pointloc
  ON points USING gist (box(location,location));
SELECT * FROM points
  WHERE box(location,location) && '(0,0),(1,1)::box;
```

To create an index without locking out writes to the table:

```
CREATE INDEX CONCURRENTLY sales_quantity_index ON sales_table
  (quantity);
```

Compatibility

`CREATE INDEX` is a PostgreSQL language extension. There are no provisions for indexes in the SQL standard.

See Also

`ALTER INDEX`, `DROP INDEX`, `REINDEX`

CREATE LANGUAGE

CREATE LANGUAGE — define a new procedural language

Synopsis

```
CREATE [ OR REPLACE ] [ PROCEDURAL ] LANGUAGE name
CREATE [ OR REPLACE ] [ TRUSTED ] [ PROCEDURAL ] LANGUAGE name
    HANDLER call_handler [ INLINE inline_handler ]
    [ VALIDATOR valfunction ]
```

Description

CREATE LANGUAGE registers a new procedural language with a PostgreSQL database. Subsequently, functions and procedures can be defined in this new language.

Note

As of PostgreSQL 9.1, most procedural languages have been made into “extensions”, and should therefore be installed with CREATE EXTENSION not CREATE LANGUAGE. Direct use of CREATE LANGUAGE should now be confined to extension installation scripts. If you have a “bare” language in your database, perhaps as a result of an upgrade, you can convert it to an extension using CREATE EXTENSION *lang-name* FROM unpackaged.

CREATE LANGUAGE effectively associates the language name with handler function(s) that are responsible for executing functions written in the language. Refer to Chapter 55 for more information about language handlers.

There are two forms of the CREATE LANGUAGE command. In the first form, the user supplies just the name of the desired language, and the PostgreSQL server consults the `pg_pltemplate` system catalog to determine the correct parameters. In the second form, the user supplies the language parameters along with the language name. The second form can be used to create a language that is not defined in `pg_pltemplate`, but this approach is considered obsolescent.

When the server finds an entry in the `pg_pltemplate` catalog for the given language name, it will use the catalog data even if the command includes language parameters. This behavior simplifies loading of old dump files, which are likely to contain out-of-date information about language support functions.

Ordinarily, the user must have the PostgreSQL superuser privilege to register a new language. However, the owner of a database can register a new language within that database if the language is listed in the `pg_pltemplate` catalog and is marked as allowed to be created by database owners (`tmpldbacreate` is true). The default is that trusted languages can be created by database owners, but this can be adjusted by superusers by modifying the contents of `pg_pltemplate`. The creator of a language becomes its owner and can later drop it, rename it, or assign it to a new owner.

CREATE OR REPLACE LANGUAGE will either create a new language, or replace an existing definition. If the language already exists, its parameters are updated according to the values specified or taken from `pg_pltemplate`, but the language's ownership and permissions settings do not change, and any existing functions written in the language are assumed to still be valid. In addition to the normal privilege requirements for creating a language, the user must be superuser or owner of the existing language. The REPLACE case is mainly meant to be used to ensure that the language exists. If the

language has a `pg_pltemplate` entry then `REPLACE` will not actually change anything about an existing definition, except in the unusual case where the `pg_pltemplate` entry has been modified since the language was created.

Parameters

`TRUSTED`

`TRUSTED` specifies that the language does not grant access to data that the user would not otherwise have. If this key word is omitted when registering the language, only users with the PostgreSQL superuser privilege can use this language to create new functions.

`PROCEDURAL`

This is a noise word.

name

The name of the new procedural language. The name must be unique among the languages in the database.

For backward compatibility, the name can be enclosed by single quotes.

`HANDLER` *call_handler*

call_handler is the name of a previously registered function that will be called to execute the procedural language's functions. The call handler for a procedural language must be written in a compiled language such as C with version 1 call convention and registered with PostgreSQL as a function taking no arguments and returning the `language_handler` type, a placeholder type that is simply used to identify the function as a call handler.

`INLINE` *inline_handler*

inline_handler is the name of a previously registered function that will be called to execute an anonymous code block (`DO` command) in this language. If no *inline_handler* function is specified, the language does not support anonymous code blocks. The handler function must take one argument of type `internal`, which will be the `DO` command's internal representation, and it will typically return `void`. The return value of the handler is ignored.

`VALIDATOR` *valfunction*

valfunction is the name of a previously registered function that will be called when a new function in the language is created, to validate the new function. If no validator function is specified, then a new function will not be checked when it is created. The validator function must take one argument of type `oid`, which will be the OID of the to-be-created function, and will typically return `void`.

A validator function would typically inspect the function body for syntactical correctness, but it can also look at other properties of the function, for example if the language cannot handle certain argument types. To signal an error, the validator function should use the `ereport()` function. The return value of the function is ignored.

The `TRUSTED` option and the support function name(s) are ignored if the server has an entry for the specified language name in `pg_pltemplate`.

Notes

Use `DROP LANGUAGE` to drop procedural languages.

The system catalog `pg_language` (see Section 51.29) records information about the currently installed languages. Also, the `psql` command `\dL` lists the installed languages.

To create functions in a procedural language, a user must have the `USAGE` privilege for the language. By default, `USAGE` is granted to `PUBLIC` (i.e., everyone) for trusted languages. This can be revoked if desired.

Procedural languages are local to individual databases. However, a language can be installed into the `template1` database, which will cause it to be available automatically in all subsequently-created databases.

The call handler function, the inline handler function (if any), and the validator function (if any) must already exist if the server does not have an entry for the language in `pg_pltemplate`. But when there is an entry, the functions need not already exist; they will be automatically defined if not present in the database. (This might result in `CREATE LANGUAGE` failing, if the shared library that implements the language is not available in the installation.)

In PostgreSQL versions before 7.3, it was necessary to declare handler functions as returning the placeholder type `opaque`, rather than `language_handler`. To support loading of old dump files, `CREATE LANGUAGE` will accept a function declared as returning `opaque`, but it will issue a notice and change the function's declared return type to `language_handler`.

Examples

The preferred way of creating any of the standard procedural languages is just:

```
CREATE LANGUAGE plperl;
```

For a language not known in the `pg_pltemplate` catalog, a sequence such as this is needed:

```
CREATE FUNCTION plsample_call_handler() RETURNS language_handler
AS '$libdir/plsample'
LANGUAGE C;
CREATE LANGUAGE plsample
HANDLER plsample_call_handler;
```

Compatibility

`CREATE LANGUAGE` is a PostgreSQL extension.

See Also

`ALTER LANGUAGE`, `CREATE FUNCTION`, `DROP LANGUAGE`, `GRANT`, `REVOKE`

CREATE MATERIALIZED VIEW

CREATE MATERIALIZED VIEW — define a new materialized view

Synopsis

```
CREATE MATERIALIZED VIEW [ IF NOT EXISTS ] table_name
  [ (column_name [, ...] ) ]
  [ USING method ]
  [ WITH ( storage_parameter [= value] [, ... ] ) ]
  [ TABLESPACE tablespace_name ]
  AS query
  [ WITH [ NO ] DATA ]
```

Description

CREATE MATERIALIZED VIEW defines a materialized view of a query. The query is executed and used to populate the view at the time the command is issued (unless WITH NO DATA is used) and may be refreshed later using REFRESH MATERIALIZED VIEW.

CREATE MATERIALIZED VIEW is similar to CREATE TABLE AS, except that it also remembers the query used to initialize the view, so that it can be refreshed later upon demand. A materialized view has many of the same properties as a table, but there is no support for temporary materialized views.

Parameters

IF NOT EXISTS

Do not throw an error if a materialized view with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing materialized view is anything like the one that would have been created.

table_name

The name (optionally schema-qualified) of the materialized view to be created.

column_name

The name of a column in the new materialized view. If column names are not provided, they are taken from the output column names of the query.

USING *method*

This optional clause specifies the table access method to use to store the contents for the new materialized view; the method needs be an access method of type TABLE. See Chapter 60 for more information. If this option is not specified, the default table access method is chosen for the new materialized view. See `default_table_access_method` for more information.

WITH (*storage_parameter* [= *value*] [, ...])

This clause specifies optional storage parameters for the new materialized view; see Storage Parameters for more information. All parameters supported for CREATE TABLE are also supported for CREATE MATERIALIZED VIEW. See CREATE TABLE for more information.

TABLESPACE *tablespace_name*

The *tablespace_name* is the name of the tablespace in which the new materialized view is to be created. If not specified, `default_tablespace` is consulted.

query

A `SELECT`, `TABLE`, or `VALUES` command. This query will run within a security-restricted operation; in particular, calls to functions that themselves create temporary tables will fail.

`WITH [NO] DATA`

This clause specifies whether or not the materialized view should be populated at creation time. If not, the materialized view will be flagged as unscannable and cannot be queried until `REFRESH MATERIALIZED VIEW` is used.

Compatibility

`CREATE MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

`ALTER MATERIALIZED VIEW`, `CREATE TABLE AS`, `CREATE VIEW`, `DROP MATERIALIZED VIEW`, `REFRESH MATERIALIZED VIEW`

CREATE OPERATOR

CREATE OPERATOR — define a new operator

Synopsis

```
CREATE OPERATOR name (  
    {FUNCTION|PROCEDURE} = function_name  
    [, LEFTARG = left_type ] [, RIGHTARG = right_type ]  
    [, COMMUTATOR = com_op ] [, NEGATOR = neg_op ]  
    [, RESTRICT = res_proc ] [, JOIN = join_proc ]  
    [, HASHES ] [, MERGES ]  
)
```

Description

CREATE OPERATOR defines a new operator, *name*. The user who defines an operator becomes its owner. If a schema name is given then the operator is created in the specified schema. Otherwise it is created in the current schema.

The operator name is a sequence of up to NAMEDATALEN-1 (63 by default) characters from the following list:

```
+ - * / < > = ~ ! @ # % ^ & | ` ?
```

There are a few restrictions on your choice of name:

- -- and /* cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multicharacter operator name cannot end in + or -, unless the name also contains at least one of these characters:

```
~ ! @ # % ^ & | ` ?
```

For example, @- is an allowed operator name, but *- is not. This restriction allows PostgreSQL to parse SQL-compliant commands without requiring spaces between tokens.

- The use of => as an operator name is deprecated. It may be disallowed altogether in a future release.

The operator != is mapped to <> on input, so these two names are always equivalent.

At least one of LEFTARG and RIGHTARG must be defined. For binary operators, both must be defined. For right unary operators, only LEFTARG should be defined, while for left unary operators only RIGHTARG should be defined.

The *function_name* function must have been previously defined using CREATE FUNCTION and must be defined to accept the correct number of arguments (either one or two) of the indicated types.

In the syntax of CREATE OPERATOR, the keywords FUNCTION and PROCEDURE are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword PROCEDURE here is historical and deprecated.

The other clauses specify optional operator optimization clauses. Their meaning is detailed in Section 37.15.

To be able to create an operator, you must have `USAGE` privilege on the argument types and the return type, as well as `EXECUTE` privilege on the underlying function. If a commutator or negator operator is specified, you must own these operators.

Parameters

name

The name of the operator to be defined. See above for allowable characters. The name can be schema-qualified, for example `CREATE OPERATOR myschema.+ (...)`. If not, then the operator is created in the current schema. Two operators in the same schema can have the same name if they operate on different data types. This is called *overloading*.

function_name

The function used to implement this operator.

left_type

The data type of the operator's left operand, if any. This option would be omitted for a left-unity operator.

right_type

The data type of the operator's right operand, if any. This option would be omitted for a right-unity operator.

com_op

The commutator of this operator.

neg_op

The negator of this operator.

res_proc

The restriction selectivity estimator function for this operator.

join_proc

The join selectivity estimator function for this operator.

`HASHES`

Indicates this operator can support a hash join.

`MERGES`

Indicates this operator can support a merge join.

To give a schema-qualified operator name in *com_op* or the other optional arguments, use the `OPERATOR()` syntax, for example:

```
COMMUTATOR = OPERATOR(myschema.===) ,
```

Notes

Refer to Section 37.14 for further information.

It is not possible to specify an operator's lexical precedence in `CREATE OPERATOR`, because the parser's precedence behavior is hard-wired. See Section 4.1.6 for precedence details.

The obsolete options `SORT1`, `SORT2`, `LTCMP`, and `GTCMP` were formerly used to specify the names of sort operators associated with a merge-joinable operator. This is no longer necessary, since information about associated operators is found by looking at B-tree operator families instead. If one of these options is given, it is ignored except for implicitly setting `MERGES` true.

Use `DROP OPERATOR` to delete user-defined operators from a database. Use `ALTER OPERATOR` to modify operators in a database.

Examples

The following command defines a new operator, area-equality, for the data type `box`:

```
CREATE OPERATOR === (  
    LEFTARG = box,  
    RIGHTARG = box,  
    FUNCTION = area_equal_function,  
    COMMUTATOR = ===,  
    NEGATOR = !==,  
    RESTRICT = area_restriction_function,  
    JOIN = area_join_function,  
    HASHES, MERGES  
);
```

Compatibility

`CREATE OPERATOR` is a PostgreSQL extension. There are no provisions for user-defined operators in the SQL standard.

See Also

`ALTER OPERATOR`, `CREATE OPERATOR CLASS`, `DROP OPERATOR`

CREATE OPERATOR CLASS

CREATE OPERATOR CLASS — define a new operator class

Synopsis

```
CREATE OPERATOR CLASS name [ DEFAULT ] FOR TYPE data_type
  USING index_method [ FAMILY family_name ] AS
  { OPERATOR strategy_number operator_name [ ( op_type, op_type
) ] [ FOR SEARCH | FOR ORDER BY sort_family_name ]
  | FUNCTION support_number [ ( op_type [ , op_type
] ) ] function_name ( argument_type [ , ... ] )
  | STORAGE storage_type
} [ , ... ]
```

Description

CREATE OPERATOR CLASS creates a new operator class. An operator class defines how a particular data type can be used with an index. The operator class specifies that certain operators will fill particular roles or “strategies” for this data type and this index method. The operator class also specifies the support functions to be used by the index method when the operator class is selected for an index column. All the operators and functions used by an operator class must be defined before the operator class can be created.

If a schema name is given then the operator class is created in the specified schema. Otherwise it is created in the current schema. Two operator classes in the same schema can have the same name only if they are for different index methods.

The user who defines an operator class becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator class definition could confuse or even crash the server.)

CREATE OPERATOR CLASS does not presently check whether the operator class definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator class.

Related operator classes can be grouped into *operator families*. To add a new operator class to an existing family, specify the FAMILY option in CREATE OPERATOR CLASS. Without this option, the new class is placed into a family named the same as the new class (creating that family if it doesn't already exist).

Refer to Section 37.16 for further information.

Parameters

name

The name of the operator class to be created. The name can be schema-qualified.

DEFAULT

If present, the operator class will become the default operator class for its data type. At most one operator class can be the default for a specific data type and index method.

data_type

The column data type that this operator class is for.

index_method

The name of the index method this operator class is for.

family_name

The name of the existing operator family to add this operator class to. If not specified, a family named the same as the operator class is used (creating it, if it doesn't already exist).

strategy_number

The index method's strategy number for an operator associated with the operator class.

operator_name

The name (optionally schema-qualified) of an operator associated with the operator class.

op_type

In an OPERATOR clause, the operand data type(s) of the operator, or NONE to signify a left-unary or right-unary operator. The operand data types can be omitted in the normal case where they are the same as the operator class's data type.

In a FUNCTION clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function (for B-tree comparison functions and hash functions) or the class's data type (for B-tree sort support functions and all functions in GiST, SP-GiST, GIN and BRIN operator classes). These defaults are correct, and so *op_type* need not be specified in FUNCTION clauses, except for the case of a B-tree sort support function that is meant to support cross-data-type comparisons.

sort_family_name

The name (optionally schema-qualified) of an existing *btree* operator family that describes the sort ordering associated with an ordering operator.

If neither FOR SEARCH nor FOR ORDER BY is specified, FOR SEARCH is the default.

support_number

The index method's support function number for a function associated with the operator class.

function_name

The name (optionally schema-qualified) of a function that is an index method support function for the operator class.

argument_type

The parameter data type(s) of the function.

storage_type

The data type actually stored in the index. Normally this is the same as the column data type, but some index methods (currently GiST, GIN and BRIN) allow it to be different. The STORAGE clause must be omitted unless the index method allows a different type to be used. If the column *data_type* is specified as *anyarray*, the *storage_type* can be declared as *anyelement* to indicate that the index entries are members of the element type belonging to the actual array type that each particular index is created for.

The OPERATOR, FUNCTION, and STORAGE clauses can appear in any order.

Notes

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator class is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator class.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before PostgreSQL 8.4, the `OPERATOR` clause could include a `RECHECK` option. This is no longer supported because whether an index operator is “lossy” is now determined on-the-fly at run time. This allows efficient handling of cases where an operator might or might not be lossy.

Examples

The following example command defines a GiST index operator class for the data type `_int4` (array of `int4`). See the `intarray` module for the complete example.

```
CREATE OPERATOR CLASS gist__int_ops
  DEFAULT FOR TYPE _int4 USING gist AS
  OPERATOR          3      &&,
  OPERATOR          6      = (anyarray, anyarray),
  OPERATOR          7      @>,
  OPERATOR          8      <@,
  OPERATOR          20     @@ (_int4, query_int),
  FUNCTION          1      g_int_consistent (internal, _int4,
smallint, oid, internal),
  FUNCTION          2      g_int_union (internal, internal),
  FUNCTION          3      g_int_compress (internal),
  FUNCTION          4      g_int_decompress (internal),
  FUNCTION          5      g_int_penalty (internal, internal,
internal),
  FUNCTION          6      g_int_picksplit (internal,
internal),
  FUNCTION          7      g_int_same (_int4, _int4,
internal);
```

Compatibility

`CREATE OPERATOR CLASS` is a PostgreSQL extension. There is no `CREATE OPERATOR CLASS` statement in the SQL standard.

See Also

`ALTER OPERATOR CLASS`, `DROP OPERATOR CLASS`, `CREATE OPERATOR FAMILY`, `ALTER OPERATOR FAMILY`

CREATE OPERATOR FAMILY

CREATE OPERATOR FAMILY — define a new operator family

Synopsis

```
CREATE OPERATOR FAMILY name USING index_method
```

Description

CREATE OPERATOR FAMILY creates a new operator family. An operator family defines a collection of related operator classes, and perhaps some additional operators and support functions that are compatible with these operator classes but not essential for the functioning of any individual index. (Operators and functions that are essential to indexes should be grouped within the relevant operator class, rather than being “loose” in the operator family. Typically, single-data-type operators are bound to operator classes, while cross-data-type operators can be loose in an operator family containing operator classes for both data types.)

The new operator family is initially empty. It should be populated by issuing subsequent CREATE OPERATOR CLASS commands to add contained operator classes, and optionally ALTER OPERATOR FAMILY commands to add “loose” operators and their corresponding support functions.

If a schema name is given then the operator family is created in the specified schema. Otherwise it is created in the current schema. Two operator families in the same schema can have the same name only if they are for different index methods.

The user who defines an operator family becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

Refer to Section 37.16 for further information.

Parameters

name

The name of the operator family to be created. The name can be schema-qualified.

index_method

The name of the index method this operator family is for.

Compatibility

CREATE OPERATOR FAMILY is a PostgreSQL extension. There is no CREATE OPERATOR FAMILY statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, DROP OPERATOR FAMILY, CREATE OPERATOR CLASS, ALTER OPERATOR CLASS, DROP OPERATOR CLASS

CREATE POLICY

CREATE POLICY — define a new row level security policy for a table

Synopsis

```
CREATE POLICY name ON table_name
  [ AS { PERMISSIVE | RESTRICTIVE } ]
  [ FOR { ALL | SELECT | INSERT | UPDATE | DELETE } ]
  [ TO { role_name | PUBLIC | CURRENT_USER | SESSION_USER }
  [, ...] ]
  [ USING ( using_expression ) ]
  [ WITH CHECK ( check_expression ) ]
```

Description

The CREATE POLICY command defines a new row-level security policy for a table. Note that row-level security must be enabled on the table (using ALTER TABLE ... ENABLE ROW LEVEL SECURITY) in order for created policies to be applied.

A policy grants the permission to select, insert, update, or delete rows that match the relevant policy expression. Existing table rows are checked against the expression specified in USING, while new rows that would be created via INSERT or UPDATE are checked against the expression specified in WITH CHECK. When a USING expression returns true for a given row then that row is visible to the user, while if false or null is returned then the row is not visible. When a WITH CHECK expression returns true for a row then that row is inserted or updated, while if false or null is returned then an error occurs.

For INSERT and UPDATE statements, WITH CHECK expressions are enforced after BEFORE triggers are fired, and before any actual data modifications are made. Thus a BEFORE ROW trigger may modify the data to be inserted, affecting the result of the security policy check. WITH CHECK expressions are enforced before any other constraints.

Policy names are per-table. Therefore, one policy name can be used for many different tables and have a definition for each table which is appropriate to that table.

Policies can be applied for specific commands or for specific roles. The default for newly created policies is that they apply for all commands and roles, unless otherwise specified. Multiple policies may apply to a single command; see below for more details. Table 256 summarizes how the different types of policy apply to specific commands.

For policies that can have both USING and WITH CHECK expressions (ALL and UPDATE), if no WITH CHECK expression is defined, then the USING expression will be used both to determine which rows are visible (normal USING case) and which new rows will be allowed to be added (WITH CHECK case).

If row-level security is enabled for a table, but no applicable policies exist, a “default deny” policy is assumed, so that no rows will be visible or updatable.

Parameters

name

The name of the policy to be created. This must be distinct from the name of any other policy for the table.

table_name

The name (optionally schema-qualified) of the table the policy applies to.

PERMISSIVE

Specify that the policy is to be created as a permissive policy. All permissive policies which are applicable to a given query will be combined together using the Boolean “OR” operator. By creating permissive policies, administrators can add to the set of records which can be accessed. Policies are permissive by default.

RESTRICTIVE

Specify that the policy is to be created as a restrictive policy. All restrictive policies which are applicable to a given query will be combined together using the Boolean “AND” operator. By creating restrictive policies, administrators can reduce the set of records which can be accessed as all restrictive policies must be passed for each record.

Note that there needs to be at least one permissive policy to grant access to records before restrictive policies can be usefully used to reduce that access. If only restrictive policies exist, then no records will be accessible. When a mix of permissive and restrictive policies are present, a record is only accessible if at least one of the permissive policies passes, in addition to all the restrictive policies.

command

The command to which the policy applies. Valid options are ALL, SELECT, INSERT, UPDATE, and DELETE. ALL is the default. See below for specifics regarding how these are applied.

role_name

The role(s) to which the policy is to be applied. The default is PUBLIC, which will apply the policy to all roles.

using_expression

Any SQL conditional expression (returning boolean). The conditional expression cannot contain any aggregate or window functions. This expression will be added to queries that refer to the table if row level security is enabled. Rows for which the expression returns true will be visible. Any rows for which the expression returns false or null will not be visible to the user (in a SELECT), and will not be available for modification (in an UPDATE or DELETE). Such rows are silently suppressed; no error is reported.

check_expression

Any SQL conditional expression (returning boolean). The conditional expression cannot contain any aggregate or window functions. This expression will be used in INSERT and UPDATE queries against the table if row level security is enabled. Only rows for which the expression evaluates to true will be allowed. An error will be thrown if the expression evaluates to false or null for any of the records inserted or any of the records that result from the update. Note that the *check_expression* is evaluated against the proposed new contents of the row, not the original contents.

Per-Command Policies

ALL

Using ALL for a policy means that it will apply to all commands, regardless of the type of command. If an ALL policy exists and more specific policies exist, then both the ALL policy and the more specific policy (or policies) will be applied. Additionally, ALL policies will be applied to

both the selection side of a query and the modification side, using the `USING` expression for both cases if only a `USING` expression has been defined.

As an example, if an `UPDATE` is issued, then the `ALL` policy will be applicable both to what the `UPDATE` will be able to select as rows to be updated (applying the `USING` expression), and to the resulting updated rows, to check if they are permitted to be added to the table (applying the `WITH CHECK` expression, if defined, and the `USING` expression otherwise). If an `INSERT` or `UPDATE` command attempts to add rows to the table that do not pass the `ALL` policy's `WITH CHECK` expression, the entire command will be aborted.

SELECT

Using `SELECT` for a policy means that it will apply to `SELECT` queries and whenever `SELECT` permissions are required on the relation the policy is defined for. The result is that only those records from the relation that pass the `SELECT` policy will be returned during a `SELECT` query, and that queries that require `SELECT` permissions, such as `UPDATE`, will also only see those records that are allowed by the `SELECT` policy. A `SELECT` policy cannot have a `WITH CHECK` expression, as it only applies in cases where records are being retrieved from the relation.

INSERT

Using `INSERT` for a policy means that it will apply to `INSERT` commands. Rows being inserted that do not pass this policy will result in a policy violation error, and the entire `INSERT` command will be aborted. An `INSERT` policy cannot have a `USING` expression, as it only applies in cases where records are being added to the relation.

Note that `INSERT` with `ON CONFLICT DO UPDATE` checks `INSERT` policies' `WITH CHECK` expressions only for rows appended to the relation by the `INSERT` path.

UPDATE

Using `UPDATE` for a policy means that it will apply to `UPDATE`, `SELECT FOR UPDATE` and `SELECT FOR SHARE` commands, as well as auxiliary `ON CONFLICT DO UPDATE` clauses of `INSERT` commands. Since `UPDATE` involves pulling an existing record and replacing it with a new modified record, `UPDATE` policies accept both a `USING` expression and a `WITH CHECK` expression. The `USING` expression determines which records the `UPDATE` command will see to operate against, while the `WITH CHECK` expression defines which modified rows are allowed to be stored back into the relation.

Any rows whose updated values do not pass the `WITH CHECK` expression will cause an error, and the entire command will be aborted. If only a `USING` clause is specified, then that clause will be used for both `USING` and `WITH CHECK` cases.

Typically an `UPDATE` command also needs to read data from columns in the relation being updated (e.g., in a `WHERE` clause or a `RETURNING` clause, or in an expression on the right hand side of the `SET` clause). In this case, `SELECT` rights are also required on the relation being updated, and the appropriate `SELECT` or `ALL` policies will be applied in addition to the `UPDATE` policies. Thus the user must have access to the row(s) being updated through a `SELECT` or `ALL` policy in addition to being granted permission to update the row(s) via an `UPDATE` or `ALL` policy.

When an `INSERT` command has an auxiliary `ON CONFLICT DO UPDATE` clause, if the `UPDATE` path is taken, the row to be updated is first checked against the `USING` expressions of any `UPDATE` policies, and then the new updated row is checked against the `WITH CHECK` expressions. Note, however, that unlike a standalone `UPDATE` command, if the existing row does not pass the `USING` expressions, an error will be thrown (the `UPDATE` path will *never* be silently avoided).

DELETE

Using `DELETE` for a policy means that it will apply to `DELETE` commands. Only rows that pass this policy will be seen by a `DELETE` command. There can be rows that are visible through a

SELECT that are not available for deletion, if they do not pass the USING expression for the DELETE policy.

In most cases a DELETE command also needs to read data from columns in the relation that it is deleting from (e.g., in a WHERE clause or a RETURNING clause). In this case, SELECT rights are also required on the relation, and the appropriate SELECT or ALL policies will be applied in addition to the DELETE policies. Thus the user must have access to the row(s) being deleted through a SELECT or ALL policy in addition to being granted permission to delete the row(s) via a DELETE or ALL policy.

A DELETE policy cannot have a WITH CHECK expression, as it only applies in cases where records are being deleted from the relation, so that there is no new row to check.

Table 256. Policies Applied by Command Type

Command	SELECT/ALL policy	INSERT/ALL policy	UPDATE/ALL policy		DELETE/ALL policy
	USING expression	WITH CHECK expression	USING expression	WITH CHECK expression	USING expression
SELECT	Existing row	—	—	—	—
SELECT FOR UP-DATE / SHARE	Existing row	—	Existing row	—	—
INSERT	—	New row	—	—	—
INSERT . . . RETURNING	New row ^a	New row	—	—	—
UPDATE	Existing & new rows ^a	—	Existing row	New row	—
DELETE	Existing row ^a	—	—	—	Existing row
ON CONFLICT DO UPDATE	Existing & new rows	—	Existing row	New row	—

^a If read access is required to the existing or new row (for example, a WHERE or RETURNING clause that refers to columns from the relation).

Application of Multiple Policies

When multiple policies of different command types apply to the same command (for example, SELECT and UPDATE policies applied to an UPDATE command), then the user must have both types of permissions (for example, permission to select rows from the relation as well as permission to update them). Thus the expressions for one type of policy are combined with the expressions for the other type of policy using the AND operator.

When multiple policies of the same command type apply to the same command, then there must be at least one PERMISSIVE policy granting access to the relation, and all of the RESTRICTIVE policies must pass. Thus all the PERMISSIVE policy expressions are combined using OR, all the RESTRICTIVE policy expressions are combined using AND, and the results are combined using AND. If there are no PERMISSIVE policies, then access is denied.

Note that, for the purposes of combining multiple policies, ALL policies are treated as having the same type as whichever other type of policy is being applied.

For example, in an UPDATE command requiring both SELECT and UPDATE permissions, if there are multiple applicable policies of each type, they will be combined as follows:

```
expression from RESTRICTIVE SELECT/ALL policy 1
AND
expression from RESTRICTIVE SELECT/ALL policy 2
AND
...
AND
(
  expression from PERMISSIVE SELECT/ALL policy 1
  OR
  expression from PERMISSIVE SELECT/ALL policy 2
  OR
  ...
)
AND
expression from RESTRICTIVE UPDATE/ALL policy 1
AND
expression from RESTRICTIVE UPDATE/ALL policy 2
AND
...
AND
(
  expression from PERMISSIVE UPDATE/ALL policy 1
  OR
  expression from PERMISSIVE UPDATE/ALL policy 2
  OR
  ...
)
```

Notes

You must be the owner of a table to create or change policies for it.

While policies will be applied for explicit queries against tables in the database, they are not applied when the system is performing internal referential integrity checks or validating constraints. This means there are indirect ways to determine that a given value exists. An example of this is attempting to insert a duplicate value into a column that is a primary key or has a unique constraint. If the insert fails then the user can infer that the value already exists. (This example assumes that the user is permitted by policy to insert records which they are not allowed to see.) Another example is where a user is allowed to insert into a table which references another, otherwise hidden table. Existence can be determined by the user inserting values into the referencing table, where success would indicate that the value exists in the referenced table. These issues can be addressed by carefully crafting policies to prevent users from being able to insert, delete, or update records at all which might possibly indicate a value they are not otherwise able to see, or by using generated values (e.g., surrogate keys) instead of keys with external meanings.

Generally, the system will enforce filter conditions imposed using security policies prior to qualifications that appear in user queries, in order to prevent inadvertent exposure of the protected data to user-defined functions which might not be trustworthy. However, functions and operators marked by the system (or the system administrator) as LEAKPROOF may be evaluated before policy expressions, as they are assumed to be trustworthy.

Since policy expressions are added to the user's query directly, they will be run with the rights of the user running the overall query. Therefore, users who are using a given policy must be able to access any tables or functions referenced in the expression or they will simply receive a permission denied error when attempting to query the table that has row-level security enabled. This does not change how views work, however. As with normal queries and views, permission checks and policies for the tables which are referenced by a view will use the view owner's rights and any policies which apply to the view owner.

Additional discussion and practical examples can be found in Section 5.8.

Compatibility

`CREATE POLICY` is a PostgreSQL extension.

See Also

`ALTER POLICY`, `DROP POLICY`, `ALTER TABLE`

CREATE PROCEDURE

CREATE PROCEDURE — define a new procedure

Synopsis

```
CREATE [ OR REPLACE ] PROCEDURE
    name ( [ [ argmode ] [ argname ] argtype [ { DEFAULT |
= } default_expr ] [, ...] ] )
    { LANGUAGE lang_name
      | TRANSFORM { FOR TYPE type_name } [, ... ]
      | [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
      | SET configuration_parameter { TO value | = value | FROM
CURRENT }
      | AS 'definition'
      | AS 'obj_file', 'link_symbol'
    } ...
```

Description

CREATE PROCEDURE defines a new procedure. CREATE OR REPLACE PROCEDURE will either create a new procedure, or replace an existing definition. To be able to define a procedure, the user must have the USAGE privilege on the language.

If a schema name is included, then the procedure is created in the specified schema. Otherwise it is created in the current schema. The name of the new procedure must not match any existing procedure or function with the same input argument types in the same schema. However, procedures and functions of different argument types can share a name (this is called *overloading*).

To replace the current definition of an existing procedure, use CREATE OR REPLACE PROCEDURE. It is not possible to change the name or argument types of a procedure this way (if you tried, you would actually be creating a new, distinct procedure).

When CREATE OR REPLACE PROCEDURE is used to replace an existing procedure, the ownership and permissions of the procedure do not change. All other procedure properties are assigned the values specified or implied in the command. You must own the procedure to replace it (this includes being a member of the owning role).

The user that creates the procedure becomes the owner of the procedure.

To be able to create a procedure, you must have USAGE privilege on the argument types.

Parameters

name

The name (optionally schema-qualified) of the procedure to create.

argmode

The mode of an argument: IN, INOUT, or VARIADIC. If omitted, the default is IN. (OUT arguments are currently not supported for procedures. Use INOUT instead.)

argname

The name of an argument.

argtype

The data type(s) of the procedure's arguments (optionally schema-qualified), if any. The argument types can be base, composite, or domain types, or can reference the type of a table column.

Depending on the implementation language it might also be allowed to specify “pseudo-types” such as `cstring`. Pseudo-types indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a procedure independent of changes to the definition of a table.

default_expr

An expression to be used as default value if the parameter is not specified. The expression has to be coercible to the argument type of the parameter. All input parameters following a parameter with a default value must have default values as well.

lang_name

The name of the language that the procedure is implemented in. It can be `sql`, `c`, `internal`, or the name of a user-defined procedural language, e.g. `plpgsql`. Enclosing the name in single quotes is deprecated and requires matching case.

TRANSFORM { FOR TYPE *type_name* } [, ...] }

Lists which transforms a call to the procedure should apply. Transforms convert between SQL types and language-specific data types; see CREATE TRANSFORM. Procedural language implementations usually have hardcoded knowledge of the built-in types, so those don't need to be listed here. If a procedural language implementation does not know how to handle a type and no transform is supplied, it will fall back to a default behavior for converting data types, but this depends on the implementation.

[EXTERNAL] SECURITY INVOKER

[EXTERNAL] SECURITY DEFINER

SECURITY INVOKER indicates that the procedure is to be executed with the privileges of the user that calls it. That is the default. SECURITY DEFINER specifies that the procedure is to be executed with the privileges of the user that owns it.

The key word EXTERNAL is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all procedures not only external ones.

A SECURITY DEFINER procedure cannot execute transaction control statements (for example, COMMIT and ROLLBACK, depending on the language).

*configuration_parameter
value*

The SET clause causes the specified configuration parameter to be set to the specified value when the procedure is entered, and then restored to its prior value when the procedure exits. SET FROM CURRENT saves the value of the parameter that is current when CREATE PROCEDURE is executed as the value to be applied when the procedure is entered.

If a SET clause is attached to a procedure, then the effects of a SET LOCAL command executed inside the procedure for the same variable are restricted to the procedure: the configuration parameter's prior value is still restored at procedure exit. However, an ordinary SET command (without LOCAL) overrides the SET clause, much as it would do for a previous SET LOCAL command: the effects of such a command will persist after procedure exit, unless the current transaction is rolled back.

If a SET clause is attached to a procedure, then that procedure cannot execute transaction control statements (for example, COMMIT and ROLLBACK, depending on the language).

See SET and Chapter 19 for more information about allowed parameter names and values.

definition

A string constant defining the procedure; the meaning depends on the language. It can be an internal procedure name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the procedure definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the procedure definition must be escaped by doubling them.

obj_file, link_symbol

This form of the AS clause is used for dynamically loadable C language procedures when the procedure name in the C language source code is not the same as the name of the SQL procedure. The string *obj_file* is the name of the shared library file containing the compiled C procedure, and is interpreted as for the LOAD command. The string *link_symbol* is the procedure's link symbol, that is, the name of the procedure in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL procedure being defined.

When repeated CREATE PROCEDURE calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session.

Notes

See CREATE FUNCTION for more details on function creation that also apply to procedures.

Use CALL to execute a procedure.

Examples

```
CREATE PROCEDURE insert_data(a integer, b integer)
LANGUAGE SQL
AS $$
INSERT INTO tbl VALUES (a);
INSERT INTO tbl VALUES (b);
$$;
```

```
CALL insert_data(1, 2);
```

Compatibility

A CREATE PROCEDURE command is defined in the SQL standard. The PostgreSQL version is similar but not fully compatible. For details see also CREATE FUNCTION.

See Also

ALTER PROCEDURE, DROP PROCEDURE, CALL, CREATE FUNCTION

CREATE PUBLICATION

CREATE PUBLICATION — define a new publication

Synopsis

```
CREATE PUBLICATION name
  [ FOR TABLE [ ONLY ] table_name [ * ] [, ...]
    | FOR ALL TABLES ]
  [ WITH ( publication_parameter [= value] [, ... ] ) ]
```

Description

CREATE PUBLICATION adds a new publication into the current database. The publication name must be distinct from the name of any existing publication in the current database.

A publication is essentially a group of tables whose data changes are intended to be replicated through logical replication. See Section 30.1 for details about how publications fit into the logical replication setup.

Parameters

name

The name of the new publication.

FOR TABLE

Specifies a list of tables to add to the publication. If ONLY is specified before the table name, only that table is added to the publication. If ONLY is not specified, the table and all its descendant tables (if any) are added. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

Only persistent base tables can be part of a publication. Temporary tables, unlogged tables, foreign tables, materialized views, regular views, and partitioned tables cannot be part of a publication. To replicate a partitioned table, add the individual partitions to the publication.

FOR ALL TABLES

Marks the publication as one that replicates changes for all tables in the database, including tables created in the future.

WITH (*publication_parameter* [= *value*] [, ...])

This clause specifies optional parameters for a publication. The following parameters are supported:

publish(*string*)

This parameter determines which DML operations will be published by the new publication to the subscribers. The value is comma-separated list of operations. The allowed operations are insert, update, delete, and truncate. The default is to publish all actions, and so the default value for this option is 'insert, update, delete, truncate'.

Notes

If neither `FOR TABLE` nor `FOR ALL TABLES` is specified, then the publication starts out with an empty set of tables. That is useful if tables are to be added later.

The creation of a publication does not start replication. It only defines a grouping and filtering logic for future subscribers.

To create a publication, the invoking user must have the `CREATE` privilege for the current database. (Of course, superusers bypass this check.)

To add a table to a publication, the invoking user must have ownership rights on the table. The `FOR ALL TABLES` clause requires the invoking user to be a superuser.

The tables added to a publication that publishes `UPDATE` and/or `DELETE` operations must have `REPLICA IDENTITY` defined. Otherwise those operations will be disallowed on those tables.

For an `INSERT . . . ON CONFLICT` command, the publication will publish the operation that actually results from the command. So depending of the outcome, it may be published as either `INSERT` or `UPDATE`, or it may not be published at all.

`COPY . . . FROM` commands are published as `INSERT` operations.

DDL operations are not published.

Examples

Create a publication that publishes all changes in two tables:

```
CREATE PUBLICATION mypublication FOR TABLE users, departments;
```

Create a publication that publishes all changes in all tables:

```
CREATE PUBLICATION alltables FOR ALL TABLES;
```

Create a publication that only publishes `INSERT` operations in one table:

```
CREATE PUBLICATION insert_only FOR TABLE mydata
WITH (publish = 'insert');
```

Compatibility

`CREATE PUBLICATION` is a PostgreSQL extension.

See Also

`ALTER PUBLICATION`, `DROP PUBLICATION`

CREATE ROLE

CREATE ROLE — define a new database role

Synopsis

```
CREATE ROLE name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
    SUPERUSER | NOSUPERUSER  
    |  
    CREATEDB | NOCREATEDB  
    |  
    CREATEROLE | NOCREATEROLE  
    |  
    INHERIT | NOINHERIT  
    |  
    LOGIN | NOLOGIN  
    |  
    REPLICATION | NOREPLICATION  
    |  
    BYPASSRLS | NOBYPASSRLS  
    |  
    CONNECTION LIMIT conlimit  
    |  
    [ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL  
    |  
    VALID UNTIL 'timestamp'  
    |  
    IN ROLE role_name [ , ... ]  
    |  
    IN GROUP role_name [ , ... ]  
    |  
    ROLE role_name [ , ... ]  
    |  
    ADMIN role_name [ , ... ]  
    |  
    USER role_name [ , ... ]  
    |  
    SYSID uid
```

Description

CREATE ROLE adds a new role to a PostgreSQL database cluster. A role is an entity that can own database objects and have database privileges; a role can be considered a “user”, a “group”, or both depending on how it is used. Refer to Chapter 21 and Chapter 20 for information about managing users and authentication. You must have CREATEROLE privilege or be a database superuser to use this command.

Note that roles are defined at the database cluster level, and so are valid in all databases in the cluster.

Parameters

name

The name of the new role.

SUPERUSER
NOSUPERUSER

These clauses determine whether the new role is a “superuser”, who can override all access restrictions within the database. Superuser status is dangerous and should be used only when really needed. You must yourself be a superuser to create a new superuser. If not specified, NOSUPERUSER is the default.

CREATEDB
NOCREATEDB

These clauses define a role's ability to create databases. If `CREATEDB` is specified, the role being defined will be allowed to create new databases. Specifying `NOCREATEDB` will deny a role the ability to create databases. If not specified, `NOCREATEDB` is the default.

CREATEROLE
NOCREATEROLE

These clauses determine whether a role will be permitted to create new roles (that is, execute `CREATE ROLE`). A role with `CREATEROLE` privilege can also alter and drop other roles. If not specified, `NOCREATEROLE` is the default.

INHERIT
NOINHERIT

These clauses determine whether a role “inherits” the privileges of roles it is a member of. A role with the `INHERIT` attribute can automatically use whatever database privileges have been granted to all roles it is directly or indirectly a member of. Without `INHERIT`, membership in another role only grants the ability to `SET ROLE` to that other role; the privileges of the other role are only available after having done so. If not specified, `INHERIT` is the default.

LOGIN
NOLOGIN

These clauses determine whether a role is allowed to log in; that is, whether the role can be given as the initial session authorization name during client connection. A role having the `LOGIN` attribute can be thought of as a user. Roles without this attribute are useful for managing database privileges, but are not users in the usual sense of the word. If not specified, `NOLOGIN` is the default, except when `CREATE ROLE` is invoked through its alternative spelling `CREATE USER`.

REPLICATION
NOREPLICATION

These clauses determine whether a role is a replication role. A role must have this attribute (or be a superuser) in order to be able to connect to the server in replication mode (physical or logical replication) and in order to be able to create or drop replication slots. A role having the `REPLICATION` attribute is a very highly privileged role, and should only be used on roles actually used for replication. If not specified, `NOREPLICATION` is the default.

BYPASSRLS
NOBYPASSRLS

These clauses determine whether a role bypasses every row-level security (RLS) policy. `NOBYPASSRLS` is the default. Note that `pg_dump` will set `row_security` to `OFF` by default, to ensure all contents of a table are dumped out. If the user running `pg_dump` does not have appropriate permissions, an error will be returned. The superuser and owner of the table being dumped always bypass RLS.

CONNECTION LIMIT *conlimit*

If role can log in, this specifies how many concurrent connections the role can make. -1 (the default) means no limit. Note that only normal connections are counted towards this limit. Neither prepared transactions nor background worker connections are counted towards this limit.

[ENCRYPTED] PASSWORD '*password*'
PASSWORD NULL

Sets the role's password. (A password is only of use for roles having the `LOGIN` attribute, but you can nonetheless define one for roles without it.) If you do not plan to use password authentication

you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as `PASSWORD NULL`.

Note

Specifying an empty string will also set the password to null, but that was not the case before PostgreSQL version 10. In earlier versions, an empty string could be used, or not, depending on the authentication method and the exact version, and libpq would refuse to use it in any case. To avoid the ambiguity, specifying an empty string should be avoided.

The password is always stored encrypted in the system catalogs. The `ENCRYPTED` keyword has no effect, but is accepted for backwards compatibility. The method of encryption is determined by the configuration parameter `password_encryption`. If the presented password string is already in MD5-encrypted or SCRAM-encrypted format, then it is stored as-is regardless of `password_encryption` (since the system cannot decrypt the specified encrypted password string, to encrypt it in a different format). This allows reloading of encrypted passwords during dump/restore.

`VALID UNTIL 'timestamp'`

The `VALID UNTIL` clause sets a date and time after which the role's password is no longer valid. If this clause is omitted the password will be valid for all time.

`IN ROLE role_name`

The `IN ROLE` clause lists one or more existing roles to which the new role will be immediately added as a new member. (Note that there is no option to add the new role as an administrator; use a separate `GRANT` command to do that.)

`IN GROUP role_name`

`IN GROUP` is an obsolete spelling of `IN ROLE`.

`ROLE role_name`

The `ROLE` clause lists one or more existing roles which are automatically added as members of the new role. (This in effect makes the new role a “group”.)

`ADMIN role_name`

The `ADMIN` clause is like `ROLE`, but the named roles are added to the new role `WITH ADMIN OPTION`, giving them the right to grant membership in this role to others.

`USER role_name`

The `USER` clause is an obsolete spelling of the `ROLE` clause.

`SYSID uid`

The `SYSID` clause is ignored, but is accepted for backwards compatibility.

Notes

Use `ALTER ROLE` to change the attributes of a role, and `DROP ROLE` to remove a role. All the attributes specified by `CREATE ROLE` can be modified by later `ALTER ROLE` commands.

The preferred way to add and remove members of roles that are being used as groups is to use `GRANT` and `REVOKE`.

The `VALID UNTIL` clause defines an expiration time for a password only, not for the role *per se*. In particular, the expiration time is not enforced when logging in using a non-password-based authentication method.

The `INHERIT` attribute governs inheritance of grantable privileges (that is, access privileges for database objects and role memberships). It does not apply to the special role attributes set by `CREATE ROLE` and `ALTER ROLE`. For example, being a member of a role with `CREATEDB` privilege does not immediately grant the ability to create databases, even if `INHERIT` is set; it would be necessary to become that role via `SET ROLE` before creating a database.

The `INHERIT` attribute is the default for reasons of backwards compatibility: in prior releases of PostgreSQL, users always had access to all privileges of groups they were members of. However, `NOINHERIT` provides a closer match to the semantics specified in the SQL standard.

Be careful with the `CREATEROLE` privilege. There is no concept of inheritance for the privileges of a `CREATEROLE`-role. That means that even if a role does not have a certain privilege but is allowed to create other roles, it can easily create another role with different privileges than its own (except for creating roles with superuser privileges). For example, if the role “user” has the `CREATEROLE` privilege but not the `CREATEDB` privilege, nonetheless it can create a new role with the `CREATEDB` privilege. Therefore, regard roles that have the `CREATEROLE` privilege as almost-superuser-roles.

PostgreSQL includes a program `createuser` that has the same functionality as `CREATE ROLE` (in fact, it calls this command) but can be run from the command shell.

The `CONNECTION LIMIT` option is only enforced approximately; if two new sessions start at about the same time when just one connection “slot” remains for the role, it is possible that both will fail. Also, the limit is never enforced for superusers.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in cleartext, and it might also be logged in the client's command history or the server log. The command `createuser`, however, transmits the password encrypted. Also, `psql` contains a command `\password` that can be used to safely change the password later.

Examples

Create a role that can log in, but don't give it a password:

```
CREATE ROLE jonathan LOGIN;
```

Create a role with a password:

```
CREATE USER davide WITH PASSWORD 'jw8s0F4';
```

(`CREATE USER` is the same as `CREATE ROLE` except that it implies `LOGIN`.)

Create a role with a password that is valid until the end of 2004. After one second has ticked in 2005, the password is no longer valid.

```
CREATE ROLE miriam WITH LOGIN PASSWORD 'jw8s0F4' VALID UNTIL
'2005-01-01';
```

Create a role that can create databases and manage roles:

```
CREATE ROLE admin WITH CREATEDB CREATEROLE;
```

Compatibility

The `CREATE ROLE` statement is in the SQL standard, but the standard only requires the syntax

```
CREATE ROLE name [ WITH ADMIN role_name ]
```

Multiple initial administrators, and all the other options of `CREATE ROLE`, are PostgreSQL extensions.

The SQL standard defines the concepts of users and roles, but it regards them as distinct concepts and leaves all commands defining users to be specified by each database implementation. In PostgreSQL we have chosen to unify users and roles into a single kind of entity. Roles therefore have many more optional attributes than they do in the standard.

The behavior specified by the SQL standard is most closely approximated by giving users the `NOINHERIT` attribute, while roles are given the `INHERIT` attribute.

See Also

`SET ROLE`, `ALTER ROLE`, `DROP ROLE`, `GRANT`, `REVOKE`, `createuser`

CREATE RULE

CREATE RULE — define a new rewrite rule

Synopsis

```
CREATE [ OR REPLACE ] RULE name AS ON event
    TO table_name [ WHERE condition ]
    DO [ ALSO | INSTEAD ] { NOTHING | command | ( command ; command
... ) }
```

where *event* can be one of:

```
SELECT | INSERT | UPDATE | DELETE
```

Description

CREATE RULE defines a new rule applying to a specified table or view. CREATE OR REPLACE RULE will either create a new rule, or replace an existing rule of the same name for the same table.

The PostgreSQL rule system allows one to define an alternative action to be performed on insertions, updates, or deletions in database tables. Roughly speaking, a rule causes additional commands to be executed when a given command on a given table is executed. Alternatively, an INSTEAD rule can replace a given command by another, or cause a command not to be executed at all. Rules are used to implement SQL views as well. It is important to realize that a rule is really a command transformation mechanism, or command macro. The transformation happens before the execution of the command starts. If you actually want an operation that fires independently for each physical row, you probably want to use a trigger, not a rule. More information about the rules system is in Chapter 40.

Presently, ON SELECT rules must be unconditional INSTEAD rules and must have actions that consist of a single SELECT command. Thus, an ON SELECT rule effectively turns the table into a view, whose visible contents are the rows returned by the rule's SELECT command rather than whatever had been stored in the table (if anything). It is considered better style to write a CREATE VIEW command than to create a real table and define an ON SELECT rule for it.

You can create the illusion of an updatable view by defining ON INSERT, ON UPDATE, and ON DELETE rules (or any subset of those that's sufficient for your purposes) to replace update actions on the view with appropriate updates on other tables. If you want to support INSERT RETURNING and so on, then be sure to put a suitable RETURNING clause into each of these rules.

There is a catch if you try to use conditional rules for complex view updates: there *must* be an unconditional INSTEAD rule for each action you wish to allow on the view. If the rule is conditional, or is not INSTEAD, then the system will still reject attempts to perform the update action, because it thinks it might end up trying to perform the action on the dummy table of the view in some cases. If you want to handle all the useful cases in conditional rules, add an unconditional DO INSTEAD NOTHING rule to ensure that the system understands it will never be called on to update the dummy table. Then make the conditional rules non-INSTEAD; in the cases where they are applied, they add to the default INSTEAD NOTHING action. (This method does not currently work to support RETURNING queries, however.)

Note

A view that is simple enough to be automatically updatable (see CREATE VIEW) does not require a user-created rule in order to be updatable. While you can create an

explicit rule anyway, the automatic update transformation will generally outperform an explicit rule.

Another alternative worth considering is to use `INSTEAD OF` triggers (see `CREATE TRIGGER`) in place of rules.

Parameters

name

The name of a rule to create. This must be distinct from the name of any other rule for the same table. Multiple rules on the same table and same event type are applied in alphabetical name order.

event

The event is one of `SELECT`, `INSERT`, `UPDATE`, or `DELETE`. Note that an `INSERT` containing an `ON CONFLICT` clause cannot be used on tables that have either `INSERT` or `UPDATE` rules. Consider using an updatable view instead.

table_name

The name (optionally schema-qualified) of the table or view the rule applies to.

condition

Any SQL conditional expression (returning `boolean`). The condition expression cannot refer to any tables except `NEW` and `OLD`, and cannot contain aggregate functions.

`INSTEAD`

`INSTEAD` indicates that the commands should be executed *instead of* the original command.

`ALSO`

`ALSO` indicates that the commands should be executed *in addition to* the original command.

If neither `ALSO` nor `INSTEAD` is specified, `ALSO` is the default.

command

The command or commands that make up the rule action. Valid commands are `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `NOTIFY`.

Within *condition* and *command*, the special table names `NEW` and `OLD` can be used to refer to values in the referenced table. `NEW` is valid in `ON INSERT` and `ON UPDATE` rules to refer to the new row being inserted or updated. `OLD` is valid in `ON UPDATE` and `ON DELETE` rules to refer to the existing row being updated or deleted.

Notes

You must be the owner of a table to create or change rules for it.

In a rule for `INSERT`, `UPDATE`, or `DELETE` on a view, you can add a `RETURNING` clause that emits the view's columns. This clause will be used to compute the outputs if the rule is triggered by an `INSERT RETURNING`, `UPDATE RETURNING`, or `DELETE RETURNING` command respectively. When the rule is triggered by a command without `RETURNING`, the rule's `RETURNING` clause will be ignored. The current implementation allows only unconditional `INSTEAD` rules to contain `RETURNING`; furthermore there can be at most one `RETURNING` clause among all the rules for the same event. (This ensures that there is only one candidate `RETURNING` clause to be used to compute

the results.) RETURNING queries on the view will be rejected if there is no RETURNING clause in any available rule.

It is very important to take care to avoid circular rules. For example, though each of the following two rule definitions are accepted by PostgreSQL, the SELECT command would cause PostgreSQL to report an error because of recursive expansion of a rule:

```
CREATE RULE "_RETURN" AS
  ON SELECT TO t1
  DO INSTEAD
    SELECT * FROM t2;
```

```
CREATE RULE "_RETURN" AS
  ON SELECT TO t2
  DO INSTEAD
    SELECT * FROM t1;
```

```
SELECT * FROM t1;
```

Presently, if a rule action contains a NOTIFY command, the NOTIFY command will be executed unconditionally, that is, the NOTIFY will be issued even if there are not any rows that the rule should apply to. For example, in:

```
CREATE RULE notify_me AS ON UPDATE TO mytable DO ALSO NOTIFY
  mytable;
```

```
UPDATE mytable SET name = 'foo' WHERE id = 42;
```

one NOTIFY event will be sent during the UPDATE, whether or not there are any rows that match the condition `id = 42`. This is an implementation restriction that might be fixed in future releases.

Compatibility

CREATE RULE is a PostgreSQL language extension, as is the entire query rewrite system.

See Also

ALTER RULE, DROP RULE

CREATE SCHEMA

CREATE SCHEMA — define a new schema

Synopsis

```
CREATE SCHEMA schema_name [ AUTHORIZATION role_specification ]
  [ schema_element [ ... ] ]
CREATE SCHEMA AUTHORIZATION role_specification [ schema_element
  [ ... ] ]
CREATE SCHEMA IF NOT EXISTS schema_name
  [ AUTHORIZATION role_specification ]
CREATE SCHEMA IF NOT EXISTS AUTHORIZATION role_specification
```

where *role_specification* can be:

```
    user_name
  | CURRENT_USER
  | SESSION_USER
```

Description

CREATE SCHEMA enters a new schema into the current database. The schema name must be distinct from the name of any existing schema in the current database.

A schema is essentially a namespace: it contains named objects (tables, data types, functions, and operators) whose names can duplicate those of other objects existing in other schemas. Named objects are accessed either by “qualifying” their names with the schema name as a prefix, or by setting a search path that includes the desired schema(s). A CREATE command specifying an unqualified object name creates the object in the current schema (the one at the front of the search path, which can be determined with the function `current_schema`).

Optionally, CREATE SCHEMA can include subcommands to create objects within the new schema. The subcommands are treated essentially the same as separate commands issued after creating the schema, except that if the AUTHORIZATION clause is used, all the created objects will be owned by that user.

Parameters

schema_name

The name of a schema to be created. If this is omitted, the *user_name* is used as the schema name. The name cannot begin with `pg_`, as such names are reserved for system schemas.

user_name

The role name of the user who will own the new schema. If omitted, defaults to the user executing the command. To create a schema owned by another role, you must be a direct or indirect member of that role, or be a superuser.

schema_element

An SQL statement defining an object to be created within the schema. Currently, only CREATE TABLE, CREATE VIEW, CREATE INDEX, CREATE SEQUENCE, CREATE TRIGGER and

GRANT are accepted as clauses within CREATE SCHEMA. Other kinds of objects may be created in separate commands after the schema is created.

IF NOT EXISTS

Do nothing (except issuing a notice) if a schema with the same name already exists. *schema_element* subcommands cannot be included when this option is used.

Notes

To create a schema, the invoking user must have the CREATE privilege for the current database. (Of course, superusers bypass this check.)

Examples

Create a schema:

```
CREATE SCHEMA myschema;
```

Create a schema for user joe; the schema will also be named joe:

```
CREATE SCHEMA AUTHORIZATION joe;
```

Create a schema named test that will be owned by user joe, unless there already is a schema named test. (It does not matter whether joe owns the pre-existing schema.)

```
CREATE SCHEMA IF NOT EXISTS test AUTHORIZATION joe;
```

Create a schema and create a table and view within it:

```
CREATE SCHEMA hollywood
  CREATE TABLE films (title text, release date, awards text[])
  CREATE VIEW winners AS
    SELECT title, release FROM films WHERE awards IS NOT NULL;
```

Notice that the individual subcommands do not end with semicolons.

The following is an equivalent way of accomplishing the same result:

```
CREATE SCHEMA hollywood;
CREATE TABLE hollywood.films (title text, release date, awards
  text[]);
CREATE VIEW hollywood.winners AS
  SELECT title, release FROM hollywood.films WHERE awards IS NOT
  NULL;
```

Compatibility

The SQL standard allows a DEFAULT CHARACTER SET clause in CREATE SCHEMA, as well as more subcommand types than are presently accepted by PostgreSQL.

The SQL standard specifies that the subcommands in CREATE SCHEMA can appear in any order. The present PostgreSQL implementation does not handle all cases of forward references in subcommands; it might sometimes be necessary to reorder the subcommands in order to avoid forward references.

According to the SQL standard, the owner of a schema always owns all objects within it. PostgreSQL allows schemas to contain objects owned by users other than the schema owner. This can happen only if the schema owner grants the `CREATE` privilege on their schema to someone else, or a superuser chooses to create objects in it.

The `IF NOT EXISTS` option is a PostgreSQL extension.

See Also

`ALTER SCHEMA`, `DROP SCHEMA`

CREATE SEQUENCE

CREATE SEQUENCE — define a new sequence generator

Synopsis

```
CREATE [ TEMPORARY | TEMP ] SEQUENCE [ IF NOT EXISTS ] name
  [ AS data_type ]
  [ INCREMENT [ BY ] increment ]
  [ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO
MAXVALUE ]
  [ START [ WITH ] start ] [ CACHE cache ] [ [ NO ] CYCLE ]
  [ OWNED BY { table_name.column_name | NONE } ]
```

Description

CREATE SEQUENCE creates a new sequence number generator. This involves creating and initializing a new special single-row table with the name *name*. The generator will be owned by the user issuing the command.

If a schema name is given then the sequence is created in the specified schema. Otherwise it is created in the current schema. Temporary sequences exist in a special schema, so a schema name cannot be given when creating a temporary sequence. The sequence name must be distinct from the name of any other sequence, table, index, view, or foreign table in the same schema.

After a sequence is created, you use the functions `nextval`, `currval`, and `setval` to operate on the sequence. These functions are documented in Section 9.16.

Although you cannot update a sequence directly, you can use a query like:

```
SELECT * FROM name;
```

to examine the parameters and current state of a sequence. In particular, the `last_value` field of the sequence shows the last value allocated by any session. (Of course, this value might be obsolete by the time it's printed, if other sessions are actively doing `nextval` calls.)

Parameters

TEMPORARY or TEMP

If specified, the sequence object is created only for this session, and is automatically dropped on session exit. Existing permanent sequences with the same name are not visible (in this session) while the temporary sequence exists, unless they are referenced with schema-qualified names.

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the sequence that would have been created - it might not even be a sequence.

name

The name (optionally schema-qualified) of the sequence to be created.

data_type

The optional clause `AS data_type` specifies the data type of the sequence. Valid types are `smallint`, `integer`, and `bigint`. `bigint` is the default. The data type determines the default minimum and maximum values of the sequence.

increment

The optional clause `INCREMENT BY increment` specifies which value is added to the current sequence value to create a new value. A positive value will make an ascending sequence, a negative one a descending sequence. The default value is 1.

minvalue

`NO MINVALUE`

The optional clause `MINVALUE minvalue` determines the minimum value a sequence can generate. If this clause is not supplied or `NO MINVALUE` is specified, then defaults will be used. The default for an ascending sequence is 1. The default for a descending sequence is the minimum value of the data type.

maxvalue

`NO MAXVALUE`

The optional clause `MAXVALUE maxvalue` determines the maximum value for the sequence. If this clause is not supplied or `NO MAXVALUE` is specified, then default values will be used. The default for an ascending sequence is the maximum value of the data type. The default for a descending sequence is -1.

start

The optional clause `START WITH start` allows the sequence to begin anywhere. The default starting value is *minvalue* for ascending sequences and *maxvalue* for descending ones.

cache

The optional clause `CACHE cache` specifies how many sequence numbers are to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache), and this is also the default.

`CYCLE`

`NO CYCLE`

The `CYCLE` option allows the sequence to wrap around when the *maxvalue* or *minvalue* has been reached by an ascending or descending sequence respectively. If the limit is reached, the next number generated will be the *minvalue* or *maxvalue*, respectively.

If `NO CYCLE` is specified, any calls to `nextval` after the sequence has reached its maximum value will return an error. If neither `CYCLE` or `NO CYCLE` are specified, `NO CYCLE` is the default.

`OWNED BY table_name.column_name`

`OWNED BY NONE`

The `OWNED BY` option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. The specified table must have the same owner and be in the same schema as the sequence. `OWNED BY NONE`, the default, specifies that there is no such association.

Notes

Use `DROP SEQUENCE` to remove a sequence.

Sequences are based on `bigint` arithmetic, so the range cannot exceed the range of an eight-byte integer (-9223372036854775808 to 9223372036854775807).

Because `nextval` and `setval` calls are never rolled back, sequence objects cannot be used if “gapless” assignment of sequence numbers is needed. It is possible to build gapless assignment by using exclusive locking of a table containing a counter; but this solution is much more expensive than sequence objects, especially if many transactions need sequence numbers concurrently.

Unexpected results might be obtained if a `cache` setting greater than one is used for a sequence object that will be used concurrently by multiple sessions. Each session will allocate and cache successive sequence values during one access to the sequence object and increase the sequence object's `last_value` accordingly. Then, the next `cache-1` uses of `nextval` within that session simply return the preallocated values without touching the sequence object. So, any numbers allocated but not used within a session will be lost when that session ends, resulting in “holes” in the sequence.

Furthermore, although multiple sessions are guaranteed to allocate distinct sequence values, the values might be generated out of sequence when all the sessions are considered. For example, with a `cache` setting of 10, session A might reserve values 1..10 and return `nextval=1`, then session B might reserve values 11..20 and return `nextval=11` before session A has generated `nextval=2`. Thus, with a `cache` setting of one it is safe to assume that `nextval` values are generated sequentially; with a `cache` setting greater than one you should only assume that the `nextval` values are all distinct, not that they are generated purely sequentially. Also, `last_value` will reflect the latest value reserved by any session, whether or not it has yet been returned by `nextval`.

Another consideration is that a `setval` executed on such a sequence will not be noticed by other sessions until they have used up any preallocated values they have cached.

Examples

Create an ascending sequence called `serial`, starting at 101:

```
CREATE SEQUENCE serial START 101;
```

Select the next number from this sequence:

```
SELECT nextval('serial');
```

```
nextval
-----
      101
```

Select the next number from this sequence:

```
SELECT nextval('serial');
```

```
nextval
-----
      102
```

Use this sequence in an `INSERT` command:

```
INSERT INTO distributors VALUES (nextval('serial'), 'nothing');
```

Update the sequence value after a `COPY FROM`:

```
BEGIN;  
COPY distributors FROM 'input_file';  
SELECT setval('serial', max(id)) FROM distributors;  
END;
```

Compatibility

CREATE SEQUENCE conforms to the SQL standard, with the following exceptions:

- Obtaining the next value is done using the `nextval()` function instead of the standard's `NEXT VALUE FOR` expression.
- The `OWNED BY` clause is a PostgreSQL extension.

See Also

ALTER SEQUENCE, DROP SEQUENCE

CREATE SERVER

CREATE SERVER — define a new foreign server

Synopsis

```
CREATE SERVER [ IF NOT EXISTS ] server_name [ TYPE 'server_type' ]  
  [ VERSION 'server_version' ]  
  FOREIGN DATA WRAPPER fdw_name  
  [ OPTIONS ( option 'value' [, ... ] ) ]
```

Description

CREATE SERVER defines a new foreign server. The user who defines the server becomes its owner.

A foreign server typically encapsulates connection information that a foreign-data wrapper uses to access an external data resource. Additional user-specific connection information may be specified by means of user mappings.

The server name must be unique within the database.

Creating a server requires USAGE privilege on the foreign-data wrapper being used.

Parameters

IF NOT EXISTS

Do not throw an error if a server with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing server is anything like the one that would have been created.

server_name

The name of the foreign server to be created.

server_type

Optional server type, potentially useful to foreign-data wrappers.

server_version

Optional server version, potentially useful to foreign-data wrappers.

fdw_name

The name of the foreign-data wrapper that manages the server.

OPTIONS (*option* '*value*' [, ...])

This clause specifies the options for the server. The options typically define the connection details of the server, but the actual names and values are dependent on the server's foreign-data wrapper.

Notes

When using the dblink module, a foreign server's name can be used as an argument of the dblink_connect function to indicate the connection parameters. It is necessary to have the USAGE privilege on the foreign server to be able to use it in this way.

Examples

Create a server `myserver` that uses the foreign-data wrapper `postgres_fdw`:

```
CREATE SERVER myservers FOREIGN DATA WRAPPER postgres_fdw OPTIONS
(host 'foo', dbname 'foodb', port '5432');
```

See `postgres_fdw` for more details.

Compatibility

`CREATE SERVER` conforms to ISO/IEC 9075-9 (SQL/MED).

See Also

`ALTER SERVER`, `DROP SERVER`, `CREATE FOREIGN DATA WRAPPER`, `CREATE FOREIGN TABLE`, `CREATE USER MAPPING`

CREATE STATISTICS

CREATE STATISTICS — define extended statistics

Synopsis

```
CREATE STATISTICS [ IF NOT EXISTS ] statistics_name
  [ ( statistics_kind [, ... ] ) ]
  ON column_name, column_name [, ...]
  FROM table_name
```

Description

CREATE STATISTICS will create a new extended statistics object tracking data about the specified table, foreign table or materialized view. The statistics object will be created in the current database and will be owned by the user issuing the command.

If a schema name is given (for example, CREATE STATISTICS myschema.mystat ...) then the statistics object is created in the specified schema. Otherwise it is created in the current schema. The name of the statistics object must be distinct from the name of any other statistics object in the same schema.

Parameters

IF NOT EXISTS

Do not throw an error if a statistics object with the same name already exists. A notice is issued in this case. Note that only the name of the statistics object is considered here, not the details of its definition.

statistics_name

The name (optionally schema-qualified) of the statistics object to be created.

statistics_kind

A statistics kind to be computed in this statistics object. Currently supported kinds are `ndistinct`, which enables n-distinct statistics, `dependencies`, which enables functional dependency statistics, and `mcv` which enables most-common values lists. If this clause is omitted, all supported statistics kinds are included in the statistics object. For more information, see Section 14.2.2 and Section 70.2.

column_name

The name of a table column to be covered by the computed statistics. At least two column names must be given; the order of the column names is insignificant.

table_name

The name (optionally schema-qualified) of the table containing the column(s) the statistics are computed on.

Notes

You must be the owner of a table to create a statistics object reading it. Once created, however, the ownership of the statistics object is independent of the underlying table(s).

Examples

Create table `t1` with two functionally dependent columns, i.e. knowledge of a value in the first column is sufficient for determining the value in the other column. Then functional dependency statistics are built on those columns:

```
CREATE TABLE t1 (  
    a    int,  
    b    int  
);  
  
INSERT INTO t1 SELECT i/100, i/500  
    FROM generate_series(1,1000000) s(i);  
  
ANALYZE t1;  
  
-- the number of matching rows will be drastically underestimated:  
EXPLAIN ANALYZE SELECT * FROM t1 WHERE (a = 1) AND (b = 0);  
  
CREATE STATISTICS s1 (dependencies) ON a, b FROM t1;  
  
ANALYZE t1;  
  
-- now the row count estimate is more accurate:  
EXPLAIN ANALYZE SELECT * FROM t1 WHERE (a = 1) AND (b = 0);
```

Without functional-dependency statistics, the planner would assume that the two `WHERE` conditions are independent, and would multiply their selectivities together to arrive at a much-too-small row count estimate. With such statistics, the planner recognizes that the `WHERE` conditions are redundant and does not underestimate the row count.

Create table `t2` with two perfectly correlated columns (containing identical data), and a MCV list on those columns:

```
CREATE TABLE t2 (  
    a    int,  
    b    int  
);  
  
INSERT INTO t2 SELECT mod(i,100), mod(i,100)  
    FROM generate_series(1,1000000) s(i);  
  
CREATE STATISTICS s2 (mcv) ON a, b FROM t2;  
  
ANALYZE t2;  
  
-- valid combination (found in MCV)  
EXPLAIN ANALYZE SELECT * FROM t2 WHERE (a = 1) AND (b = 1);  
  
-- invalid combination (not found in MCV)  
EXPLAIN ANALYZE SELECT * FROM t2 WHERE (a = 1) AND (b = 2);
```

The MCV list gives the planner more detailed information about the specific values that commonly appear in the table, as well as an upper bound on the selectivities of combinations of values that do not appear in the table, allowing it to generate better estimates in both cases.

Compatibility

There is no `CREATE STATISTICS` command in the SQL standard.

See Also

`ALTER STATISTICS`, `DROP STATISTICS`

CREATE SUBSCRIPTION

CREATE SUBSCRIPTION — define a new subscription

Synopsis

```
CREATE SUBSCRIPTION subscription_name
  CONNECTION 'conninfo'
  PUBLICATION publication_name [, ...]
  [ WITH ( subscription_parameter [= value] [, ... ] ) ]
```

Description

CREATE SUBSCRIPTION adds a new subscription for the current database. The subscription name must be distinct from the name of any existing subscription in the database.

The subscription represents a replication connection to the publisher. As such this command does not only add definitions in the local catalogs but also creates a replication slot on the publisher.

A logical replication worker will be started to replicate data for the new subscription at the commit of the transaction where this command is run.

Additional information about subscriptions and logical replication as a whole is available at Section 30.2 and Chapter 30.

Parameters

subscription_name

The name of the new subscription.

CONNECTION '*conninfo*'

The connection string to the publisher. For details see Section 33.1.1.

PUBLICATION *publication_name*

Names of the publications on the publisher to subscribe to.

WITH (*subscription_parameter* [= *value*] [, ...])

This clause specifies optional parameters for a subscription. The following parameters are supported:

copy_data (boolean)

Specifies whether the existing data in the publications that are being subscribed to should be copied once the replication starts. The default is `true`.

create_slot (boolean)

Specifies whether the command should create the replication slot on the publisher. The default is `true`.

enabled (boolean)

Specifies whether the subscription should be actively replicating, or whether it should be just setup but not started yet. The default is `true`.

`slot_name` (string)

Name of the replication slot to use. The default behavior is to use the name of the subscription for the slot name.

When `slot_name` is set to `NONE`, there will be no replication slot associated with the subscription. This can be used if the replication slot will be created later manually. Such subscriptions must also have both `enabled` and `create_slot` set to `false`.

`synchronous_commit` (enum)

The value of this parameter overrides the `synchronous_commit` setting. The default value is `off`.

It is safe to use `off` for logical replication: If the subscriber loses transactions because of missing synchronization, the data will be resent from the publisher.

A different setting might be appropriate when doing synchronous logical replication. The logical replication workers report the positions of writes and flushes to the publisher, and when using synchronous replication, the publisher will wait for the actual flush. This means that setting `synchronous_commit` for the subscriber to `off` when the subscription is used for synchronous replication might increase the latency for `COMMIT` on the publisher. In this scenario, it can be advantageous to set `synchronous_commit` to `local` or higher.

`connect` (boolean)

Specifies whether the `CREATE SUBSCRIPTION` should connect to the publisher at all. Setting this to `false` will change default values of `enabled`, `create_slot` and `copy_data` to `false`.

It is not allowed to combine `connect` set to `false` and `enabled`, `create_slot`, or `copy_data` set to `true`.

Since no connection is made when this option is set to `false`, the tables are not subscribed, and so after you enable the subscription nothing will be replicated. It is required to run `ALTER SUBSCRIPTION ... REFRESH PUBLICATION` in order for tables to be subscribed.

Notes

See Section 30.7 for details on how to configure access control between the subscription and the publication instance.

When creating a replication slot (the default behavior), `CREATE SUBSCRIPTION` cannot be executed inside a transaction block.

Creating a subscription that connects to the same database cluster (for example, to replicate between databases in the same cluster or to replicate within the same database) will only succeed if the replication slot is not created as part of the same command. Otherwise, the `CREATE SUBSCRIPTION` call will hang. To make this work, create the replication slot separately (using the function `pg_create_logical_replication_slot` with the plugin name `pgoutput`) and create the subscription using the parameter `create_slot = false`. This is an implementation restriction that might be lifted in a future release.

Examples

Create a subscription to a remote server that replicates tables in the publications `mypublication` and `insert_only` and starts replicating immediately on commit:

```
CREATE SUBSCRIPTION mysub
```

```
        CONNECTION 'host=192.168.1.50 port=5432 user=foo
dbname=foodb'
        PUBLICATION mypublication, insert_only;
```

Create a subscription to a remote server that replicates tables in the `insert_only` publication and does not start replicating until enabled at a later time.

```
CREATE SUBSCRIPTION mysub
        CONNECTION 'host=192.168.1.50 port=5432 user=foo
dbname=foodb'
        PUBLICATION insert_only
        WITH (enabled = false);
```

Compatibility

`CREATE SUBSCRIPTION` is a PostgreSQL extension.

See Also

`ALTER SUBSCRIPTION`, `DROP SUBSCRIPTION`, `CREATE PUBLICATION`, `ALTER PUBLICATION`

CREATE TABLE

CREATE TABLE — define a new table

Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE
[ IF NOT EXISTS ] table_name ( [
  { column_name data_type [ COLLATE collation ] [ column_constraint
  [ ... ] ]
  | table_constraint
  | LIKE source_table [ like_option ... ] }
  [, ... ]
] )
[ INHERITS ( parent_table [, ... ] ) ]
[ PARTITION BY { RANGE | LIST | HASH } ( { column_name |
( expression ) } [ COLLATE collation ] [ opclass ] [, ... ] ) ]
[ USING method ]
[ WITH ( storage_parameter [= value] [, ... ] ) | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]
```

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE
[ IF NOT EXISTS ] table_name
  OF type_name [ (
  { column_name [ WITH OPTIONS ] [ column_constraint [ ... ] ]
  | table_constraint }
  [, ... ]
) ]
[ PARTITION BY { RANGE | LIST | HASH } ( { column_name |
( expression ) } [ COLLATE collation ] [ opclass ] [, ... ] ) ]
[ USING method ]
[ WITH ( storage_parameter [= value] [, ... ] ) | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]
```

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE
[ IF NOT EXISTS ] table_name
  PARTITION OF parent_table [ (
  { column_name [ WITH OPTIONS ] [ column_constraint [ ... ] ]
  | table_constraint }
  [, ... ]
) ] { FOR VALUES partition_bound_spec | DEFAULT }
[ PARTITION BY { RANGE | LIST | HASH } ( { column_name |
( expression ) } [ COLLATE collation ] [ opclass ] [, ... ] ) ]
[ USING method ]
[ WITH ( storage_parameter [= value] [, ... ] ) | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]
```

where *column_constraint* is:

```
[ CONSTRAINT constraint_name ]
{ NOT NULL |
```

```

NULL |
CHECK ( expression ) [ NO INHERIT ] |
DEFAULT default_expr |
GENERATED ALWAYS AS ( generation_expr ) STORED |
GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY
[ ( sequence_options ) ] |
UNIQUE index_parameters |
PRIMARY KEY index_parameters |
REFERENCES reftable [ ( refcolumn ) ] [ MATCH FULL | MATCH
PARTIAL | MATCH SIMPLE ]
    [ ON DELETE referential_action ] [ ON UPDATE referential_action
] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]

```

and *table_constraint* is:

```

[ CONSTRAINT constraint_name ]
{ CHECK ( expression ) [ NO INHERIT ] |
  UNIQUE ( column_name [, ... ] ) index_parameters |
  PRIMARY KEY ( column_name [, ... ] ) index_parameters |
  EXCLUDE [ USING index_method ] ( exclude_element WITH operator
[, ... ] ) index_parameters [ WHERE ( predicate ) ] |
  FOREIGN KEY ( column_name [, ... ] ) REFERENCES reftable
[ ( refcolumn [, ... ] ) ]
    [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON
DELETE referential_action ] [ ON UPDATE referential_action ] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY
IMMEDIATE ]

```

and *like_option* is:

```

{ INCLUDING | EXCLUDING } { COMMENTS | CONSTRAINTS | DEFAULTS |
GENERATED | IDENTITY | INDEXES | STATISTICS | STORAGE | ALL }

```

and *partition_bound_spec* is:

```

IN ( partition_bound_expr [, ...] ) |
FROM ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] )
  TO ( { partition_bound_expr | MINVALUE | MAXVALUE } [, ...] ) |
WITH ( MODULUS numeric_literal, REMAINDER numeric_literal )

```

index_parameters in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

```

[ INCLUDE ( column_name [, ... ] ) ]
[ WITH ( storage_parameter [= value] [, ... ] ) ]
[ USING INDEX TABLESPACE tablespace_name ]

```

exclude_element in an EXCLUDE constraint is:

```

{ column_name | ( expression ) } [ opclass ] [ ASC | DESC ] [ NULLS
{ FIRST | LAST } ]

```

Description

CREATE TABLE will create a new, initially empty table in the current database. The table will be owned by the user issuing the command.

If a schema name is given (for example, `CREATE TABLE myschema.mytable . . .`) then the table is created in the specified schema. Otherwise it is created in the current schema. Temporary tables exist in a special schema, so a schema name cannot be given when creating a temporary table. The name of the table must be distinct from the name of any other table, sequence, index, view, or foreign table in the same schema.

`CREATE TABLE` also automatically creates a data type that represents the composite type corresponding to one row of the table. Therefore, tables cannot have the same name as any existing data type in the same schema.

The optional constraint clauses specify constraints (tests) that new or updated rows must satisfy for an insert or update operation to succeed. A constraint is an SQL object that helps define the set of valid values in the table in various ways.

There are two ways to define constraints: table constraints and column constraints. A column constraint is defined as part of a column definition. A table constraint definition is not tied to a particular column, and it can encompass more than one column. Every column constraint can also be written as a table constraint; a column constraint is only a notational convenience for use when the constraint only affects one column.

To be able to create a table, you must have `USAGE` privilege on all column types or the type in the `OF` clause, respectively.

Parameters

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Temporary tables are automatically dropped at the end of a session, or optionally at the end of the current transaction (see `ON COMMIT` below). Existing permanent tables with the same name are not visible to the current session while the temporary table exists, unless they are referenced with schema-qualified names. Any indexes created on a temporary table are automatically temporary as well.

The autovacuum daemon cannot access and therefore cannot vacuum or analyze temporary tables. For this reason, appropriate vacuum and analyze operations should be performed via session SQL commands. For example, if a temporary table is going to be used in complex queries, it is wise to run `ANALYZE` on the temporary table after it is populated.

Optionally, `GLOBAL` or `LOCAL` can be written before `TEMPORARY` or `TEMP`. This presently makes no difference in PostgreSQL and is deprecated; see [Compatibility](#).

UNLOGGED

If specified, the table is created as an unlogged table. Data written to unlogged tables is not written to the write-ahead log (see [Chapter 29](#)), which makes them considerably faster than ordinary tables. However, they are not crash-safe: an unlogged table is automatically truncated after a crash or unclean shutdown. The contents of an unlogged table are also not replicated to standby servers. Any indexes created on an unlogged table are automatically unlogged as well.

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

table_name

The name (optionally schema-qualified) of the table to be created.

OF *type_name*

Creates a *typed table*, which takes its structure from the specified composite type (name optionally schema-qualified). A typed table is tied to its type; for example the table will be dropped if the type is dropped (with `DROP TYPE . . . CASCADE`).

When a typed table is created, then the data types of the columns are determined by the underlying composite type and are not specified by the `CREATE TABLE` command. But the `CREATE TABLE` command can add defaults and constraints to the table and can specify storage parameters.

column_name

The name of a column to be created in the new table.

data_type

The data type of the column. This can include array specifiers. For more information on the data types supported by PostgreSQL, refer to Chapter 8.

COLLATE *collation*

The `COLLATE` clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

INHERITS (*parent_table* [, ...])

The optional `INHERITS` clause specifies a list of tables from which the new table automatically inherits all columns. Parent tables can be plain tables or foreign tables.

Use of `INHERITS` creates a persistent relationship between the new child table and its parent table(s). Schema modifications to the parent(s) normally propagate to children as well, and by default the data of the child table is included in scans of the parent(s).

If the same column name exists in more than one parent table, an error is reported unless the data types of the columns match in each of the parent tables. If there is no conflict, then the duplicate columns are merged to form a single column in the new table. If the column name list of the new table contains a column name that is also inherited, the data type must likewise match the inherited column(s), and the column definitions are merged into one. If the new table explicitly specifies a default value for the column, this default overrides any defaults from inherited declarations of the column. Otherwise, any parents that specify default values for the column must all specify the same default, or an error will be reported.

`CHECK` constraints are merged in essentially the same way as columns: if multiple parent tables and/or the new table definition contain identically-named `CHECK` constraints, these constraints must all have the same check expression, or an error will be reported. Constraints having the same name and expression will be merged into one copy. A constraint marked `NO INHERIT` in a parent will not be considered. Notice that an unnamed `CHECK` constraint in the new table will never be merged, since a unique name will always be chosen for it.

Column `STORAGE` settings are also copied from parent tables.

If a column in the parent table is an identity column, that property is not inherited. A column in the child table can be declared identity column if desired.

PARTITION BY { RANGE | LIST | HASH } ({ *column_name* | (*expression*) } [*opclass*] [, ...])

The optional `PARTITION BY` clause specifies a strategy of partitioning the table. The table thus created is called a *partitioned* table. The parenthesized list of columns or expressions forms

the *partition key* for the table. When using range or hash partitioning, the partition key can include multiple columns or expressions (up to 32, but this limit can be altered when building PostgreSQL), but for list partitioning, the partition key must consist of a single column or expression.

Range and list partitioning require a btree operator class, while hash partitioning requires a hash operator class. If no operator class is specified explicitly, the default operator class of the appropriate type will be used; if no default operator class exists, an error will be raised. When hash partitioning is used, the operator class used must implement support function 2 (see Section 37.16.3 for details).

A partitioned table is divided into sub-tables (called partitions), which are created using separate CREATE TABLE commands. The partitioned table is itself empty. A data row inserted into the table is routed to a partition based on the value of columns or expressions in the partition key. If no existing partition matches the values in the new row, an error will be reported.

Partitioned tables do not support EXCLUDE constraints; however, you can define these constraints on individual partitions.

See Section 5.11 for more discussion on table partitioning.

```
PARTITION OF parent_table { FOR VALUES partition_bound_spec | DE-
FAULT }
```

Creates the table as a *partition* of the specified parent table. The table can be created either as a partition for specific values using FOR VALUES or as a default partition using DEFAULT.

The *partition_bound_spec* must correspond to the partitioning method and partition key of the parent table, and must not overlap with any existing partition of that parent. The form with IN is used for list partitioning, the form with FROM and TO is used for range partitioning, and the form with WITH is used for hash partitioning.

partition_bound_expr is any variable-free expression (subqueries, window functions, aggregate functions, and set-returning functions are not allowed). Its data type must match the data type of the corresponding partition key column. The expression is evaluated once at table creation time, so it can even contain volatile expressions such as CURRENT_TIMESTAMP.

When creating a list partition, NULL can be specified to signify that the partition allows the partition key column to be null. However, there cannot be more than one such list partition for a given parent table. NULL cannot be specified for range partitions.

When creating a range partition, the lower bound specified with FROM is an inclusive bound, whereas the upper bound specified with TO is an exclusive bound. That is, the values specified in the FROM list are valid values of the corresponding partition key columns for this partition, whereas those in the TO list are not. Note that this statement must be understood according to the rules of row-wise comparison (Section 9.23.5). For example, given PARTITION BY RANGE (*x*, *y*), a partition bound FROM (1, 2) TO (3, 4) allows *x*=1 with any *y*>=2, *x*=2 with any non-null *y*, and *x*=3 with any *y*<4.

The special values MINVALUE and MAXVALUE may be used when creating a range partition to indicate that there is no lower or upper bound on the column's value. For example, a partition defined using FROM (MINVALUE) TO (10) allows any values less than 10, and a partition defined using FROM (10) TO (MAXVALUE) allows any values greater than or equal to 10.

When creating a range partition involving more than one column, it can also make sense to use MAXVALUE as part of the lower bound, and MINVALUE as part of the upper bound. For example, a partition defined using FROM (0, MAXVALUE) TO (10, MAXVALUE) allows any rows where the first partition key column is greater than 0 and less than or equal to 10. Similarly, a partition defined using FROM ('a', MINVALUE) TO ('b', MINVALUE) allows any rows where the first partition key column starts with "a".

Note that if `MINVALUE` or `MAXVALUE` is used for one column of a partitioning bound, the same value must be used for all subsequent columns. For example, `(10, MINVALUE, 0)` is not a valid bound; you should write `(10, MINVALUE, MINVALUE)`.

Also note that some element types, such as `timestamp`, have a notion of "infinity", which is just another value that can be stored. This is different from `MINVALUE` and `MAXVALUE`, which are not real values that can be stored, but rather they are ways of saying that the value is unbounded. `MAXVALUE` can be thought of as being greater than any other value, including "infinity" and `MINVALUE` as being less than any other value, including "minus infinity". Thus the range `FROM ('infinity') TO (MAXVALUE)` is not an empty range; it allows precisely one value to be stored — "infinity".

If `DEFAULT` is specified, the table will be created as the default partition of the parent table. This option is not available for hash-partitioned tables. A partition key value not fitting into any other partition of the given parent will be routed to the default partition.

When a table has an existing `DEFAULT` partition and a new partition is added to it, the default partition must be scanned to verify that it does not contain any rows which properly belong in the new partition. If the default partition contains a large number of rows, this may be slow. The scan will be skipped if the default partition is a foreign table or if it has a constraint which proves that it cannot contain rows which should be placed in the new partition.

When creating a hash partition, a modulus and remainder must be specified. The modulus must be a positive integer, and the remainder must be a non-negative integer less than the modulus. Typically, when initially setting up a hash-partitioned table, you should choose a modulus equal to the number of partitions and assign every table the same modulus and a different remainder (see examples, below). However, it is not required that every partition have the same modulus, only that every modulus which occurs among the partitions of a hash-partitioned table is a factor of the next larger modulus. This allows the number of partitions to be increased incrementally without needing to move all the data at once. For example, suppose you have a hash-partitioned table with 8 partitions, each of which has modulus 8, but find it necessary to increase the number of partitions to 16. You can detach one of the modulus-8 partitions, create two new modulus-16 partitions covering the same portion of the key space (one with a remainder equal to the remainder of the detached partition, and the other with a remainder equal to that value plus 8), and repopulate them with data. You can then repeat this -- perhaps at a later time -- for each modulus-8 partition until none remain. While this may still involve a large amount of data movement at each step, it is still better than having to create a whole new table and move all the data at once.

A partition must have the same column names and types as the partitioned table to which it belongs. Modifications to the column names or types of a partitioned table will automatically propagate to all partitions. `CHECK` constraints will be inherited automatically by every partition, but an individual partition may specify additional `CHECK` constraints; additional constraints with the same name and condition as in the parent will be merged with the parent constraint. Defaults may be specified separately for each partition.

Rows inserted into a partitioned table will be automatically routed to the correct partition. If no suitable partition exists, an error will occur.

Operations such as `TRUNCATE` which normally affect a table and all of its inheritance children will cascade to all partitions, but may also be performed on an individual partition. Note that dropping a partition with `DROP TABLE` requires taking an `ACCESS EXCLUSIVE` lock on the parent table.

```
LIKE source_table [ like_option ... ]
```

The `LIKE` clause specifies a table from which the new table automatically copies all column names, their data types, and their not-null constraints.

Unlike `INHERITS`, the new table and original table are completely decoupled after creation is complete. Changes to the original table will not be applied to the new table, and it is not possible to include data of the new table in scans of the original table.

Also unlike `INHERITS`, columns and constraints copied by `LIKE` are not merged with similarly named columns and constraints. If the same name is specified explicitly or in another `LIKE` clause, an error is signaled.

The optional *like_option* clauses specify which additional properties of the original table to copy. Specifying `INCLUDING` copies the property, specifying `EXCLUDING` omits the property. `EXCLUDING` is the default. If multiple specifications are made for the same kind of object, the last one is used. The available options are:

`INCLUDING COMMENTS`

Comments for the copied columns, constraints, and indexes will be copied. The default behavior is to exclude comments, resulting in the copied columns and constraints in the new table having no comments.

`INCLUDING CONSTRAINTS`

`CHECK` constraints will be copied. No distinction is made between column constraints and table constraints. Not-null constraints are always copied to the new table.

`INCLUDING DEFAULTS`

Default expressions for the copied column definitions will be copied. Otherwise, default expressions are not copied, resulting in the copied columns in the new table having null defaults. Note that copying defaults that call database-modification functions, such as `nextval`, may create a functional linkage between the original and new tables.

`INCLUDING GENERATED`

Any generation expressions of copied column definitions will be copied. By default, new columns will be regular base columns.

`INCLUDING IDENTITY`

Any identity specifications of copied column definitions will be copied. A new sequence is created for each identity column of the new table, separate from the sequences associated with the old table.

`INCLUDING INDEXES`

Indexes, `PRIMARY KEY`, `UNIQUE`, and `EXCLUDE` constraints on the original table will be created on the new table. Names for the new indexes and constraints are chosen according to the default rules, regardless of how the originals were named. (This behavior avoids possible duplicate-name failures for the new indexes.)

`INCLUDING STATISTICS`

Extended statistics are copied to the new table.

`INCLUDING STORAGE`

`STORAGE` settings for the copied column definitions will be copied. The default behavior is to exclude `STORAGE` settings, resulting in the copied columns in the new table having type-specific default settings. For more on `STORAGE` settings, see Section 68.2.

`INCLUDING ALL`

`INCLUDING ALL` is an abbreviated form selecting all the available individual options. (It could be useful to write individual `EXCLUDING` clauses after `INCLUDING ALL` to select all but some specific options.)

The `LIKE` clause can also be used to copy column definitions from views, foreign tables, or composite types. Inapplicable options (e.g., `INCLUDING INDEXES` from a view) are ignored.

`CONSTRAINT constraint_name`

An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `col must be positive` can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

`NOT NULL`

The column is not allowed to contain null values.

`NULL`

The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

`CHECK (expression) [NO INHERIT]`

The `CHECK` clause specifies an expression producing a Boolean result which new or updated rows must satisfy for an insert or update operation to succeed. Expressions evaluating to `TRUE` or `UNKNOWN` succeed. Should any row of an insert or update operation produce a `FALSE` result, an error exception is raised and the insert or update does not alter the database. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns.

Currently, `CHECK` expressions cannot contain subqueries nor refer to variables other than columns of the current row (see Section 5.4.1). The system column `tableoid` may be referenced, but not any other system column.

A constraint marked with `NO INHERIT` will not propagate to child tables.

When a table has multiple `CHECK` constraints, they will be tested for each row in alphabetical order by name, after checking `NOT NULL` constraints. (PostgreSQL versions before 9.5 did not honor any particular firing order for `CHECK` constraints.)

`DEFAULT default_expr`

The `DEFAULT` clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (in particular, cross-references to other columns in the current table are not allowed). Subqueries are not allowed either. The data type of the default expression must match the data type of the column.

The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

`GENERATED ALWAYS AS (generation_expr) STORED`

This clause creates the column as a *generated column*. The column cannot be written to, and when read the result of the specified expression will be returned.

The keyword `STORED` is required to signify that the column will be computed on write and will be stored on disk.

The generation expression can refer to other columns in the table, but not other generated columns. Any functions and operators used must be immutable. References to other tables are not allowed.

GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [(*sequence_options*)]

This clause creates the column as an *identity column*. It will have an implicit sequence attached to it and the column in new rows will automatically have values from the sequence assigned to it.

The clauses ALWAYS and BY DEFAULT determine how the sequence value is given precedence over a user-specified value in an INSERT statement. If ALWAYS is specified, a user-specified value is only accepted if the INSERT statement specifies OVERRIDING SYSTEM VALUE. If BY DEFAULT is specified, then the user-specified value takes precedence. See INSERT for details. (In the COPY command, user-specified values are always used regardless of this setting.)

The optional *sequence_options* clause can be used to override the options of the sequence. See CREATE SEQUENCE for details.

UNIQUE (column constraint)

UNIQUE (*column_name* [, ...]) [INCLUDE (*column_name* [, ...])] (table constraint)

The UNIQUE constraint specifies that a group of one or more columns of a table can contain only unique values. The behavior of the unique table constraint is the same as that for column constraints, with the additional capability to span multiple columns.

For the purpose of a unique constraint, null values are not considered equal.

Each unique table constraint must name a set of columns that is different from the set of columns named by any other unique or primary key constraint defined for the table. (Otherwise it would just be the same constraint listed twice.)

When establishing a unique constraint for a multi-level partition hierarchy, all the columns in the partition key of the target partitioned table, as well as those of all its descendant partitioned tables, must be included in the constraint definition.

Adding a unique constraint will automatically create a unique btree index on the column or group of columns used in the constraint. The optional clause INCLUDE adds to that index one or more columns on which the uniqueness is not enforced. Note that although the constraint is not enforced on the included columns, it still depends on them. Consequently, some operations on these columns (e.g. DROP COLUMN) can cause cascaded constraint and index deletion.

PRIMARY KEY (column constraint)

PRIMARY KEY (*column_name* [, ...]) [INCLUDE (*column_name* [, ...])] (table constraint)

The PRIMARY KEY constraint specifies that a column or columns of a table can contain only unique (non-duplicate), nonnull values. Only one primary key can be specified for a table, whether as a column constraint or a table constraint.

The primary key constraint should name a set of columns that is different from the set of columns named by any unique constraint defined for the same table. (Otherwise, the unique constraint is redundant and will be discarded.)

PRIMARY KEY enforces the same data constraints as a combination of UNIQUE and NOT NULL, but identifying a set of columns as the primary key also provides metadata about the design of the schema, since a primary key implies that other tables can rely on this set of columns as a unique identifier for rows.

PRIMARY KEY constraints share the restrictions that UNIQUE constraints have when placed on partitioned tables.

Adding a PRIMARY KEY constraint will automatically create a unique btree index on the column or group of columns used in the constraint. The optional INCLUDE clause allows a list of columns to be specified which will be included in the non-key portion of the index. Although uniqueness is not enforced on the included columns, the constraint still depends on them. Consequently, some

operations on the included columns (e.g. `DROP COLUMN`) can cause cascaded constraint and index deletion.

```
EXCLUDE [ USING index_method ] ( exclude_element WITH operator
[ , ... ] ) index_parameters [ WHERE ( predicate ) ]
```

The `EXCLUDE` clause defines an exclusion constraint, which guarantees that if any two rows are compared on the specified column(s) or expression(s) using the specified operator(s), not all of these comparisons will return `TRUE`. If all of the specified operators test for equality, this is equivalent to a `UNIQUE` constraint, although an ordinary unique constraint will be faster. However, exclusion constraints can specify constraints that are more general than simple equality. For example, you can specify a constraint that no two rows in the table contain overlapping circles (see Section 8.8) by using the `&&` operator.

Exclusion constraints are implemented using an index, so each specified operator must be associated with an appropriate operator class (see Section 11.10) for the index access method *index_method*. The operators are required to be commutative. Each *exclude_element* can optionally specify an operator class and/or ordering options; these are described fully under `CREATE INDEX`.

The access method must support `amgettuple` (see Chapter 61); at present this means `GIN` cannot be used. Although it's allowed, there is little point in using `B-tree` or `hash` indexes with an exclusion constraint, because this does nothing that an ordinary unique constraint doesn't do better. So in practice the access method will always be `GiST` or `SP-GiST`.

The *predicate* allows you to specify an exclusion constraint on a subset of the table; internally this creates a partial index. Note that parentheses are required around the predicate.

```
REFERENCES reftable [ ( refcolumn ) ] [ MATCH matchtype ] [ ON DELETE
referential_action ] [ ON UPDATE referential_action ] (column constraint)
FOREIGN KEY ( column_name [ , ... ] ) REFERENCES reftable [ ( refcolumn
[ , ... ] ) ] [ MATCH matchtype ] [ ON DELETE referential_action ]
[ ON UPDATE referential_action ] (table constraint)
```

These clauses specify a foreign key constraint, which requires that a group of one or more columns of the new table must only contain values that match values in the referenced column(s) of some row of the referenced table. If the *refcolumn* list is omitted, the primary key of the *reftable* is used. The referenced columns must be the columns of a non-deferrable unique or primary key constraint in the referenced table. The user must have `REFERENCES` permission on the referenced table (either the whole table, or the specific referenced columns). The addition of a foreign key constraint requires a `SHARE ROW EXCLUSIVE` lock on the referenced table. Note that foreign key constraints cannot be defined between temporary tables and permanent tables.

A value inserted into the referencing column(s) is matched against the values of the referenced table and referenced columns using the given match type. There are three match types: `MATCH FULL`, `MATCH PARTIAL`, and `MATCH SIMPLE` (which is the default). `MATCH FULL` will not allow one column of a multicolumn foreign key to be null unless all foreign key columns are null; if they are all null, the row is not required to have a match in the referenced table. `MATCH SIMPLE` allows any of the foreign key columns to be null; if any of them are null, the row is not required to have a match in the referenced table. `MATCH PARTIAL` is not yet implemented. (Of course, `NOT NULL` constraints can be applied to the referencing column(s) to prevent these cases from arising.)

In addition, when the data in the referenced columns is changed, certain actions are performed on the data in this table's columns. The `ON DELETE` clause specifies the action to perform when a referenced row in the referenced table is being deleted. Likewise, the `ON UPDATE` clause specifies the action to perform when a referenced column in the referenced table is being updated to a new value. If the row is updated, but the referenced column is not actually changed, no action is done. Referential actions other than the `NO ACTION` check cannot be deferred, even if the constraint is declared deferrable. There are the following possible actions for each clause:

NO ACTION

Produce an error indicating that the deletion or update would create a foreign key constraint violation. If the constraint is deferred, this error will be produced at constraint check time if there still exist any referencing rows. This is the default action.

RESTRICT

Produce an error indicating that the deletion or update would create a foreign key constraint violation. This is the same as NO ACTION except that the check is not deferrable.

CASCADE

Delete any rows referencing the deleted row, or update the values of the referencing column(s) to the new values of the referenced columns, respectively.

SET NULL

Set the referencing column(s) to null.

SET DEFAULT

Set the referencing column(s) to their default values. (There must be a row in the referenced table matching the default values, if they are not null, or the operation will fail.)

If the referenced column(s) are changed frequently, it might be wise to add an index to the referencing column(s) so that referential actions associated with the foreign key constraint can be performed more efficiently.

DEFERRABLE

NOT DEFERRABLE

This controls whether the constraint can be deferred. A constraint that is not deferrable will be checked immediately after every command. Checking of constraints that are deferrable can be postponed until the end of the transaction (using the SET CONSTRAINTS command). NOT DEFERRABLE is the default. Currently, only UNIQUE, PRIMARY KEY, EXCLUDE, and REFERENCES (foreign key) constraints accept this clause. NOT NULL and CHECK constraints are not deferrable. Note that deferrable constraints cannot be used as conflict arbitrators in an INSERT statement that includes an ON CONFLICT DO UPDATE clause.

INITIALLY IMMEDIATE

INITIALLY DEFERRED

If a constraint is deferrable, this clause specifies the default time to check the constraint. If the constraint is INITIALLY IMMEDIATE, it is checked after each statement. This is the default. If the constraint is INITIALLY DEFERRED, it is checked only at the end of the transaction. The constraint check time can be altered with the SET CONSTRAINTS command.

USING *method*

This optional clause specifies the table access method to use to store the contents for the new table; the method needs be an access method of type TABLE. See Chapter 60 for more information. If this option is not specified, the default table access method is chosen for the new table. See `default_table_access_method` for more information.

WITH (*storage_parameter* [= *value*] [, ...])

This clause specifies optional storage parameters for a table or index; see Storage Parameters for more information. For backward-compatibility the WITH clause for a table can also include OIDS=FALSE to specify that rows of the new table should not contain OIDs (object identifiers), OIDS=TRUE is not supported anymore.

WITHOUT OIDS

This is backward-compatible syntax for declaring a table **WITHOUT OIDS**, creating a table **WITH OIDS** is not supported anymore.

ON COMMIT

The behavior of temporary tables at the end of a transaction block can be controlled using **ON COMMIT**. The three options are:

PRESERVE ROWS

No special action is taken at the ends of transactions. This is the default behavior.

DELETE ROWS

All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic **TRUNCATE** is done at each commit. When used on a partitioned table, this is not cascaded to its partitions.

DROP

The temporary table will be dropped at the end of the current transaction block. When used on a partitioned table, this action drops its partitions and when used on tables with inheritance children, it drops the dependent children.

TABLESPACE *tablespace_name*

The *tablespace_name* is the name of the tablespace in which the new table is to be created. If not specified, *default_tablespace* is consulted, or *temp_tablespaces* if the table is temporary. For partitioned tables, since no storage is required for the table itself, the tablespace specified overrides *default_tablespace* as the default tablespace to use for any newly created partitions when no other tablespace is explicitly specified.

USING INDEX TABLESPACE *tablespace_name*

This clause allows selection of the tablespace in which the index associated with a **UNIQUE**, **PRIMARY KEY**, or **EXCLUDE** constraint will be created. If not specified, *default_tablespace* is consulted, or *temp_tablespaces* if the table is temporary.

Storage Parameters

The **WITH** clause can specify *storage parameters* for tables, and for indexes associated with a **UNIQUE**, **PRIMARY KEY**, or **EXCLUDE** constraint. Storage parameters for indexes are documented in **CREATE INDEX**. The storage parameters currently available for tables are listed below. For many of these parameters, as shown, there is an additional parameter with the same name prefixed with *toast .*, which controls the behavior of the table's secondary **TOAST** table, if any (see Section 68.2 for more information about **TOAST**). If a table parameter value is set and the equivalent *toast .* parameter is not, the **TOAST** table will use the table's parameter value. Specifying these parameters for partitioned tables is not supported, but you may specify them for individual leaf partitions.

fillfactor (integer)

The fillfactor for a table is a percentage between 10 and 100. 100 (complete packing) is the default. When a smaller fillfactor is specified, **INSERT** operations pack table pages only to the indicated percentage; the remaining space on each page is reserved for updating rows on that page. This gives **UPDATE** a chance to place the updated copy of a row on the same page as the original, which is more efficient than placing it on a different page. For a table whose entries are never updated, complete packing is the best choice, but in heavily updated tables smaller fillfactors are appropriate. This parameter cannot be set for **TOAST** tables.

`toast_tuple_target` (integer)

The `toast_tuple_target` specifies the minimum tuple length required before we try to move long column values into TOAST tables, and is also the target length we try to reduce the length below once toasting begins. This only affects columns marked as either External or Extended and applies only to new tuples - there is no effect on existing rows. By default this parameter is set to allow at least 4 tuples per block, which with the default blocksize will be 2040 bytes. Valid values are between 128 bytes and the (blocksize - header), by default 8160 bytes. Changing this value may not be useful for very short or very long rows. Note that the default setting is often close to optimal, and it is possible that setting this parameter could have negative effects in some cases. This parameter cannot be set for TOAST tables.

`parallel_workers` (integer)

This sets the number of workers that should be used to assist a parallel scan of this table. If not set, the system will determine a value based on the relation size. The actual number of workers chosen by the planner or by utility statements that use parallel scans may be less, for example due to the setting of `max_worker_processes`.

`autovacuum_enabled`, `toast.autovacuum_enabled` (boolean)

Enables or disables the autovacuum daemon for a particular table. If true, the autovacuum daemon will perform automatic VACUUM and/or ANALYZE operations on this table following the rules discussed in Section 24.1.6. If false, this table will not be autovacuumed, except to prevent transaction ID wraparound. See Section 24.1.5 for more about wraparound prevention. Note that the autovacuum daemon does not run at all (except to prevent transaction ID wraparound) if the autovacuum parameter is false; setting individual tables' storage parameters does not override that. Therefore there is seldom much point in explicitly setting this storage parameter to true, only to false.

`vacuum_index_cleanup`, `toast.vacuum_index_cleanup` (boolean)

Enables or disables index cleanup when VACUUM is run on this table. The default value is true. Disabling index cleanup can speed up VACUUM very significantly, but may also lead to severely bloated indexes if table modifications are frequent. The INDEX_CLEANUP parameter of VACUUM, if specified, overrides the value of this option.

`vacuum_truncate`, `toast.vacuum_truncate` (boolean)

Enables or disables vacuum to try to truncate off any empty pages at the end of this table. The default value is true. If true, VACUUM and autovacuum do the truncation and the disk space for the truncated pages is returned to the operating system. Note that the truncation requires ACCESS EXCLUSIVE lock on the table. The TRUNCATE parameter of VACUUM, if specified, overrides the value of this option.

`autovacuum_vacuum_threshold`, `toast.autovacuum_vacuum_threshold` (integer)

Per-table value for `autovacuum_vacuum_threshold` parameter.

`autovacuum_vacuum_scale_factor`, `toast.autovacuum_vacuum_scale_factor` (float4)

Per-table value for `autovacuum_vacuum_scale_factor` parameter.

`autovacuum_analyze_threshold` (integer)

Per-table value for `autovacuum_analyze_threshold` parameter.

`autovacuum_analyze_scale_factor` (float4)

Per-table value for `autovacuum_analyze_scale_factor` parameter.

`autovacuum_vacuum_cost_delay, toast.autovacuum_vacuum_cost_delay`
(floating point)

Per-table value for `autovacuum_vacuum_cost_delay` parameter.

`autovacuum_vacuum_cost_limit, toast.autovacuum_vacuum_cost_limit` (integer)

Per-table value for `autovacuum_vacuum_cost_limit` parameter.

`autovacuum_freeze_min_age, toast.autovacuum_freeze_min_age` (integer)

Per-table value for `vacuum_freeze_min_age` parameter. Note that autovacuum will ignore per-table `autovacuum_freeze_min_age` parameters that are larger than half the system-wide `autovacuum_freeze_max_age` setting.

`autovacuum_freeze_max_age, toast.autovacuum_freeze_max_age` (integer)

Per-table value for `autovacuum_freeze_max_age` parameter. Note that autovacuum will ignore per-table `autovacuum_freeze_max_age` parameters that are larger than the system-wide setting (it can only be set smaller).

`autovacuum_freeze_table_age, toast.autovacuum_freeze_table_age` (integer)

Per-table value for `vacuum_freeze_table_age` parameter.

`autovacuum_multixact_freeze_min_age, toast.autovacuum_multixact_freeze_min_age` (integer)

Per-table value for `vacuum_multixact_freeze_min_age` parameter. Note that autovacuum will ignore per-table `autovacuum_multixact_freeze_min_age` parameters that are larger than half the system-wide `autovacuum_multixact_freeze_max_age` setting.

`autovacuum_multixact_freeze_max_age, toast.autovacuum_multixact_freeze_max_age` (integer)

Per-table value for `autovacuum_multixact_freeze_max_age` parameter. Note that autovacuum will ignore per-table `autovacuum_multixact_freeze_max_age` parameters that are larger than the system-wide setting (it can only be set smaller).

`autovacuum_multixact_freeze_table_age, toast.autovacuum_multixact_freeze_table_age` (integer)

Per-table value for `vacuum_multixact_freeze_table_age` parameter.

`log_autovacuum_min_duration, toast.log_autovacuum_min_duration` (integer)

Per-table value for `log_autovacuum_min_duration` parameter.

`user_catalog_table` (boolean)

Declare the table as an additional catalog table for purposes of logical replication. See Section 48.6.2 for details. This parameter cannot be set for TOAST tables.

Notes

PostgreSQL automatically creates an index for each unique constraint and primary key constraint to enforce uniqueness. Thus, it is not necessary to create an index explicitly for primary key columns. (See CREATE INDEX for more information.)

Unique constraints and primary keys are not inherited in the current implementation. This makes the combination of inheritance and unique constraints rather dysfunctional.

A table cannot have more than 1600 columns. (In practice, the effective limit is usually lower because of tuple-length constraints.)

Examples

Create table `films` and table `distributors`:

```
CREATE TABLE films (  
    code      char(5) CONSTRAINT firstkey PRIMARY KEY,  
    title     varchar(40) NOT NULL,  
    did       integer NOT NULL,  
    date_prod date,  
    kind      varchar(10),  
    len       interval hour to minute  
);
```

```
CREATE TABLE distributors (  
    did       integer PRIMARY KEY GENERATED BY DEFAULT AS IDENTITY,  
    name      varchar(40) NOT NULL CHECK (name <> '')  
);
```

Create a table with a 2-dimensional array:

```
CREATE TABLE array_int (  
    vector    int[][]  
);
```

Define a unique table constraint for the table `films`. Unique table constraints can be defined on one or more columns of the table:

```
CREATE TABLE films (  
    code      char(5),  
    title     varchar(40),  
    did       integer,  
    date_prod date,  
    kind      varchar(10),  
    len       interval hour to minute,  
    CONSTRAINT production UNIQUE(date_prod)  
);
```

Define a check column constraint:

```
CREATE TABLE distributors (  
    did       integer CHECK (did > 100),  
    name      varchar(40)  
);
```

Define a check table constraint:

```
CREATE TABLE distributors (  
    did       integer,  
    name      varchar(40),
```

```
        CONSTRAINT con1 CHECK (did > 100 AND name <> '')
    );
```

Define a primary key table constraint for the table films:

```
CREATE TABLE films (
    code          char(5),
    title         varchar(40),
    did           integer,
    date_prod    date,
    kind          varchar(10),
    len           interval hour to minute,
    CONSTRAINT code_title PRIMARY KEY(code,title)
);
```

Define a primary key constraint for table distributors. The following two examples are equivalent, the first using the table constraint syntax, the second the column constraint syntax:

```
CREATE TABLE distributors (
    did          integer,
    name         varchar(40),
    PRIMARY KEY(did)
);
```

```
CREATE TABLE distributors (
    did          integer PRIMARY KEY,
    name         varchar(40)
);
```

Assign a literal constant default value for the column name, arrange for the default value of column did to be generated by selecting the next value of a sequence object, and make the default value of modtime be the time at which the row is inserted:

```
CREATE TABLE distributors (
    name         varchar(40) DEFAULT 'Luso Films',
    did          integer DEFAULT nextval('distributors_serial'),
    modtime      timestamp DEFAULT current_timestamp
);
```

Define two NOT NULL column constraints on the table distributors, one of which is explicitly given a name:

```
CREATE TABLE distributors (
    did          integer CONSTRAINT no_null NOT NULL,
    name         varchar(40) NOT NULL
);
```

Define a unique constraint for the name column:

```
CREATE TABLE distributors (
    did          integer,
    name         varchar(40) UNIQUE
);
```

The same, specified as a table constraint:

```
CREATE TABLE distributors (  
    did      integer,  
    name     varchar(40),  
    UNIQUE(name)  
);
```

Create the same table, specifying 70% fill factor for both the table and its unique index:

```
CREATE TABLE distributors (  
    did      integer,  
    name     varchar(40),  
    UNIQUE(name) WITH (fillfactor=70)  
)  
WITH (fillfactor=70);
```

Create table circles with an exclusion constraint that prevents any two circles from overlapping:

```
CREATE TABLE circles (  
    c circle,  
    EXCLUDE USING gist (c WITH &&)  
);
```

Create table cinemas in tablespace diskv011:

```
CREATE TABLE cinemas (  
    id serial,  
    name text,  
    location text  
)  
TABLESPACE diskv011;
```

Create a composite type and a typed table:

```
CREATE TYPE employee_type AS (name text, salary numeric);  
  
CREATE TABLE employees OF employee_type (  
    PRIMARY KEY (name),  
    salary WITH OPTIONS DEFAULT 1000  
);
```

Create a range partitioned table:

```
CREATE TABLE measurement (  
    logdate      date not null,  
    peaktemp     int,  
    unitsales    int  
)  
PARTITION BY RANGE (logdate);
```

Create a range partitioned table with multiple columns in the partition key:

```
CREATE TABLE measurement_year_month (  
    logdate      date not null,  
    peaktemp     int,  
    unitsales    int
```

CREATE TABLE

```
) PARTITION BY RANGE (EXTRACT(YEAR FROM logdate), EXTRACT(MONTH
FROM logdate));
```

Create a list partitioned table:

```
CREATE TABLE cities (
    city_id      bigserial not null,
    name         text not null,
    population   bigint
) PARTITION BY LIST (left(lower(name), 1));
```

Create a hash partitioned table:

```
CREATE TABLE orders (
    order_id     bigint not null,
    cust_id      bigint not null,
    status       text
) PARTITION BY HASH (order_id);
```

Create partition of a range partitioned table:

```
CREATE TABLE measurement_y2016m07
    PARTITION OF measurement (
        unitsales DEFAULT 0
) FOR VALUES FROM ('2016-07-01') TO ('2016-08-01');
```

Create a few partitions of a range partitioned table with multiple columns in the partition key:

```
CREATE TABLE measurement_ym_older
    PARTITION OF measurement_year_month
    FOR VALUES FROM (MINVALUE, MINVALUE) TO (2016, 11);
```

```
CREATE TABLE measurement_ym_y2016m11
    PARTITION OF measurement_year_month
    FOR VALUES FROM (2016, 11) TO (2016, 12);
```

```
CREATE TABLE measurement_ym_y2016m12
    PARTITION OF measurement_year_month
    FOR VALUES FROM (2016, 12) TO (2017, 01);
```

```
CREATE TABLE measurement_ym_y2017m01
    PARTITION OF measurement_year_month
    FOR VALUES FROM (2017, 01) TO (2017, 02);
```

Create partition of a list partitioned table:

```
CREATE TABLE cities_ab
    PARTITION OF cities (
        CONSTRAINT city_id_nonzero CHECK (city_id != 0)
) FOR VALUES IN ('a', 'b');
```

Create partition of a list partitioned table that is itself further partitioned and then add a partition to it:

```
CREATE TABLE cities_ab
    PARTITION OF cities (
```

```
CONSTRAINT city_id_nonzero CHECK (city_id != 0)
) FOR VALUES IN ('a', 'b') PARTITION BY RANGE (population);

CREATE TABLE cities_ab_10000_to_100000
PARTITION OF cities_ab FOR VALUES FROM (10000) TO (100000);
```

Create partitions of a hash partitioned table:

```
CREATE TABLE orders_p1 PARTITION OF orders
FOR VALUES WITH (MODULUS 4, REMAINDER 0);
CREATE TABLE orders_p2 PARTITION OF orders
FOR VALUES WITH (MODULUS 4, REMAINDER 1);
CREATE TABLE orders_p3 PARTITION OF orders
FOR VALUES WITH (MODULUS 4, REMAINDER 2);
CREATE TABLE orders_p4 PARTITION OF orders
FOR VALUES WITH (MODULUS 4, REMAINDER 3);
```

Create a default partition:

```
CREATE TABLE cities_partdef
PARTITION OF cities DEFAULT;
```

Compatibility

The `CREATE TABLE` command conforms to the SQL standard, with exceptions listed below.

Temporary Tables

Although the syntax of `CREATE TEMPORARY TABLE` resembles that of the SQL standard, the effect is not the same. In the standard, temporary tables are defined just once and automatically exist (starting with empty contents) in every session that needs them. PostgreSQL instead requires each session to issue its own `CREATE TEMPORARY TABLE` command for each temporary table to be used. This allows different sessions to use the same temporary table name for different purposes, whereas the standard's approach constrains all instances of a given temporary table name to have the same table structure.

The standard's definition of the behavior of temporary tables is widely ignored. PostgreSQL's behavior on this point is similar to that of several other SQL databases.

The SQL standard also distinguishes between global and local temporary tables, where a local temporary table has a separate set of contents for each SQL module within each session, though its definition is still shared across sessions. Since PostgreSQL does not support SQL modules, this distinction is not relevant in PostgreSQL.

For compatibility's sake, PostgreSQL will accept the `GLOBAL` and `LOCAL` keywords in a temporary table declaration, but they currently have no effect. Use of these keywords is discouraged, since future versions of PostgreSQL might adopt a more standard-compliant interpretation of their meaning.

The `ON COMMIT` clause for temporary tables also resembles the SQL standard, but has some differences. If the `ON COMMIT` clause is omitted, SQL specifies that the default behavior is `ON COMMIT DELETE ROWS`. However, the default behavior in PostgreSQL is `ON COMMIT PRESERVE ROWS`. The `ON COMMIT DROP` option does not exist in SQL.

Non-Deferred Uniqueness Constraints

When a `UNIQUE` or `PRIMARY KEY` constraint is not deferrable, PostgreSQL checks for uniqueness immediately whenever a row is inserted or modified. The SQL standard says that uniqueness should

be enforced only at the end of the statement; this makes a difference when, for example, a single command updates multiple key values. To obtain standard-compliant behavior, declare the constraint as `DEFERRABLE` but not deferred (i.e., `INITIALLY IMMEDIATE`). Be aware that this can be significantly slower than immediate uniqueness checking.

Column Check Constraints

The SQL standard says that `CHECK` column constraints can only refer to the column they apply to; only `CHECK` table constraints can refer to multiple columns. PostgreSQL does not enforce this restriction; it treats column and table check constraints alike.

EXCLUDE Constraint

The `EXCLUDE` constraint type is a PostgreSQL extension.

NULL “Constraint”

The NULL “constraint” (actually a non-constraint) is a PostgreSQL extension to the SQL standard that is included for compatibility with some other database systems (and for symmetry with the `NOT NULL` constraint). Since it is the default for any column, its presence is simply noise.

Constraint Naming

The SQL standard says that table and domain constraints must have names that are unique across the schema containing the table or domain. PostgreSQL is laxer: it only requires constraint names to be unique across the constraints attached to a particular table or domain. However, this extra freedom does not exist for index-based constraints (`UNIQUE`, `PRIMARY KEY`, and `EXCLUDE` constraints), because the associated index is named the same as the constraint, and index names must be unique across all relations within the same schema.

Currently, PostgreSQL does not record names for `NOT NULL` constraints at all, so they are not subject to the uniqueness restriction. This might change in a future release.

Inheritance

Multiple inheritance via the `INHERITS` clause is a PostgreSQL language extension. SQL:1999 and later define single inheritance using a different syntax and different semantics. SQL:1999-style inheritance is not yet supported by PostgreSQL.

Zero-Column Tables

PostgreSQL allows a table of no columns to be created (for example, `CREATE TABLE foo() ;`). This is an extension from the SQL standard, which does not allow zero-column tables. Zero-column tables are not in themselves very useful, but disallowing them creates odd special cases for `ALTER TABLE DROP COLUMN`, so it seems cleaner to ignore this spec restriction.

Multiple Identity Columns

PostgreSQL allows a table to have more than one identity column. The standard specifies that a table can have at most one identity column. This is relaxed mainly to give more flexibility for doing schema changes or migrations. Note that the `INSERT` command supports only one override clause that applies to the entire statement, so having multiple identity columns with different behaviors is not well supported.

Generated Columns

The option `STORED` is not standard but is also used by other SQL implementations. The SQL standard does not specify the storage of generated columns.

LIKE Clause

While a `LIKE` clause exists in the SQL standard, many of the options that PostgreSQL accepts for it are not in the standard, and some of the standard's options are not implemented by PostgreSQL.

WITH Clause

The `WITH` clause is a PostgreSQL extension; storage parameters are not in the standard.

Tablespaces

The PostgreSQL concept of tablespaces is not part of the standard. Hence, the clauses `TABLESPACE` and `USING INDEX TABLESPACE` are extensions.

Typed Tables

Typed tables implement a subset of the SQL standard. According to the standard, a typed table has columns corresponding to the underlying composite type as well as one other column that is the “self-referencing column”. PostgreSQL does not support self-referencing columns explicitly.

PARTITION BY Clause

The `PARTITION BY` clause is a PostgreSQL extension.

PARTITION OF Clause

The `PARTITION OF` clause is a PostgreSQL extension.

See Also

`ALTER TABLE`, `DROP TABLE`, `CREATE TABLE AS`, `CREATE TABLESPACE`, `CREATE TYPE`

CREATE TABLE AS

CREATE TABLE AS — define a new table from the results of a query

Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE
 [ IF NOT EXISTS ] table_name
   [ ( column_name [, ...] ) ]
   [ USING method ]
   [ WITH ( storage_parameter [= value] [, ...] ) | WITHOUT
 OIDS ]
   [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
   [ TABLESPACE tablespace_name ]
 AS query
 [ WITH [ NO ] DATA ]
```

Description

CREATE TABLE AS creates a table and fills it with data computed by a SELECT command. The table columns have the names and data types associated with the output columns of the SELECT (except that you can override the column names by giving an explicit list of new column names).

CREATE TABLE AS bears some resemblance to creating a view, but it is really quite different: it creates a new table and evaluates the query just once to fill the new table initially. The new table will not track subsequent changes to the source tables of the query. In contrast, a view re-evaluates its defining SELECT statement whenever it is queried.

Parameters

GLOBAL or LOCAL

Ignored for compatibility. Use of these keywords is deprecated; refer to CREATE TABLE for details.

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED

If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Refer to CREATE TABLE for details.

table_name

The name (optionally schema-qualified) of the table to be created.

column_name

The name of a column in the new table. If column names are not provided, they are taken from the output column names of the query.

USING *method*

This optional clause specifies the table access method to use to store the contents for the new table; the method needs be an access method of type TABLE. See Chapter 60 for more information. If this option is not specified, the default table access method is chosen for the new table. See `default_table_access_method` for more information.

WITH (*storage_parameter* [= *value*] [, ...])

This clause specifies optional storage parameters for the new table; see Storage Parameters for more information. For backward-compatibility the WITH clause for a table can also include `OIDS=FALSE` to specify that rows of the new table should contain no OIDs (object identifiers), `OIDS=TRUE` is not supported anymore.

WITHOUT OIDS

This is backward-compatible syntax for declaring a table WITHOUT OIDS, creating a table WITH OIDS is not supported anymore.

ON COMMIT

The behavior of temporary tables at the end of a transaction block can be controlled using ON COMMIT. The three options are:

PRESERVE ROWS

No special action is taken at the ends of transactions. This is the default behavior.

DELETE ROWS

All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic TRUNCATE is done at each commit.

DROP

The temporary table will be dropped at the end of the current transaction block.

TABLESPACE *tablespace_name*

The *tablespace_name* is the name of the tablespace in which the new table is to be created. If not specified, `default_tablespace` is consulted, or `temp_tablespaces` if the table is temporary.

query

A SELECT, TABLE, or VALUES command, or an EXECUTE command that runs a prepared SELECT, TABLE, or VALUES query.

WITH [NO] DATA

This clause specifies whether or not the data produced by the query should be copied into the new table. If not, only the table structure is copied. The default is to copy the data.

Notes

This command is functionally similar to SELECT INTO, but it is preferred since it is less likely to be confused with other uses of the SELECT INTO syntax. Furthermore, CREATE TABLE AS offers a superset of the functionality offered by SELECT INTO.

Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
CREATE TABLE films_recent AS
  SELECT * FROM films WHERE date_prod >= '2002-01-01';
```

To copy a table completely, the short form using the TABLE command can also be used:

```
CREATE TABLE films2 AS
  TABLE films;
```

Create a new temporary table `films_recent`, consisting of only recent entries from the table `films`, using a prepared statement. The new table will be dropped at commit:

```
PREPARE recentfilms(date) AS
  SELECT * FROM films WHERE date_prod > $1;
CREATE TEMP TABLE films_recent ON COMMIT DROP AS
  EXECUTE recentfilms('2002-01-01');
```

Compatibility

CREATE TABLE AS conforms to the SQL standard. The following are nonstandard extensions:

- The standard requires parentheses around the subquery clause; in PostgreSQL, these parentheses are optional.
- In the standard, the WITH [NO] DATA clause is required; in PostgreSQL it is optional.
- PostgreSQL handles temporary tables in a way rather different from the standard; see CREATE TABLE for details.
- The WITH clause is a PostgreSQL extension; storage parameters are not in the standard.
- The PostgreSQL concept of tablespaces is not part of the standard. Hence, the clause TABLESPACE is an extension.

See Also

CREATE MATERIALIZED VIEW, CREATE TABLE, EXECUTE, SELECT, SELECT INTO, VALUES

CREATE TABLESPACE

CREATE TABLESPACE — define a new tablespace

Synopsis

```
CREATE TABLESPACE tablespace_name
  [ OWNER { new_owner | CURRENT_USER | SESSION_USER } ]
  LOCATION 'directory'
  [ WITH ( tablespace_option = value [, ... ] ) ]
```

Description

CREATE TABLESPACE registers a new cluster-wide tablespace. The tablespace name must be distinct from the name of any existing tablespace in the database cluster.

A tablespace allows superusers to define an alternative location on the file system where the data files containing database objects (such as tables and indexes) can reside.

A user with appropriate privileges can pass *tablespace_name* to CREATE DATABASE, CREATE TABLE, CREATE INDEX or ADD CONSTRAINT to have the data files for these objects stored within the specified tablespace.

Warning

A tablespace cannot be used independently of the cluster in which it is defined; see Section 22.6.

Parameters

tablespace_name

The name of a tablespace to be created. The name cannot begin with `pg_`, as such names are reserved for system tablespaces.

user_name

The name of the user who will own the tablespace. If omitted, defaults to the user executing the command. Only superusers can create tablespaces, but they can assign ownership of tablespaces to non-superusers.

directory

The directory that will be used for the tablespace. The directory must exist (CREATE TABLESPACE will not create it), should be empty, and must be owned by the PostgreSQL system user. The directory must be specified by an absolute path name.

tablespace_option

A tablespace parameter to be set or reset. Currently, the only available parameters are `seq_page_cost`, `random_page_cost` and `effective_io_concurrency`. Setting either value for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, as established by the configuration parameters of the same

name (see `seq_page_cost`, `random_page_cost`, `effective_io_concurrency`). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

Notes

Tablespaces are only supported on systems that support symbolic links.

`CREATE TABLESPACE` cannot be executed inside a transaction block.

Examples

To create a tablespace `dbspace` at file system location `/data/dbs`, first create the directory using operating system facilities and set the correct ownership:

```
mkdir /data/dbs
chown postgres:postgres /data/dbs
```

Then issue the tablespace creation command inside PostgreSQL:

```
CREATE TABLESPACE dbspace LOCATION '/data/dbs';
```

To create a tablespace owned by a different database user, use a command like this:

```
CREATE TABLESPACE indexspace OWNER genevieve LOCATION '/data/
indexes';
```

Compatibility

`CREATE TABLESPACE` is a PostgreSQL extension.

See Also

`CREATE DATABASE`, `CREATE TABLE`, `CREATE INDEX`, `DROP TABLESPACE`, `ALTER TABLESPACE`

CREATE TEXT SEARCH CONFIGURATION

CREATE TEXT SEARCH CONFIGURATION — define a new text search configuration

Synopsis

```
CREATE TEXT SEARCH CONFIGURATION name (  
    PARSER = parser_name |  
    COPY = source_config  
)
```

Description

CREATE TEXT SEARCH CONFIGURATION creates a new text search configuration. A text search configuration specifies a text search parser that can divide a string into tokens, plus dictionaries that can be used to determine which tokens are of interest for searching.

If only the parser is specified, then the new text search configuration initially has no mappings from token types to dictionaries, and therefore will ignore all words. Subsequent ALTER TEXT SEARCH CONFIGURATION commands must be used to create mappings to make the configuration useful. Alternatively, an existing text search configuration can be copied.

If a schema name is given then the text search configuration is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search configuration becomes its owner.

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search configuration to be created. The name can be schema-qualified.

parser_name

The name of the text search parser to use for this configuration.

source_config

The name of an existing text search configuration to copy.

Notes

The PARSER and COPY options are mutually exclusive, because when an existing configuration is copied, its parser selection is copied too.

Compatibility

There is no CREATE TEXT SEARCH CONFIGURATION statement in the SQL standard.

See Also

ALTER TEXT SEARCH CONFIGURATION, DROP TEXT SEARCH CONFIGURATION

CREATE TEXT SEARCH DICTIONARY

CREATE TEXT SEARCH DICTIONARY — define a new text search dictionary

Synopsis

```
CREATE TEXT SEARCH DICTIONARY name (  
    TEMPLATE = template  
    [, option = value [, ... ]]  
)
```

Description

CREATE TEXT SEARCH DICTIONARY creates a new text search dictionary. A text search dictionary specifies a way of recognizing interesting or uninteresting words for searching. A dictionary depends on a text search template, which specifies the functions that actually perform the work. Typically the dictionary provides some options that control the detailed behavior of the template's functions.

If a schema name is given then the text search dictionary is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search dictionary becomes its owner.

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search dictionary to be created. The name can be schema-qualified.

template

The name of the text search template that will define the basic behavior of this dictionary.

option

The name of a template-specific option to be set for this dictionary.

value

The value to use for a template-specific option. If the value is not a simple identifier or number, it must be quoted (but you can always quote it, if you wish).

The options can appear in any order.

Examples

The following example command creates a Snowball-based dictionary with a nonstandard list of stop words.

```
CREATE TEXT SEARCH DICTIONARY my_russian (  
    template = snowball,  
    language = russian,
```

```
    stopwords = myrussian  
);
```

Compatibility

There is no `CREATE TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

`ALTER TEXT SEARCH DICTIONARY`, `DROP TEXT SEARCH DICTIONARY`

CREATE TEXT SEARCH PARSER

CREATE TEXT SEARCH PARSER — define a new text search parser

Synopsis

```
CREATE TEXT SEARCH PARSER name (  
    START = start_function ,  
    GETTOKEN = gettoken_function ,  
    END = end_function ,  
    LEXTYPES = lextypes_function  
    [, HEADLINE = headline_function ]  
)
```

Description

CREATE TEXT SEARCH PARSER creates a new text search parser. A text search parser defines a method for splitting a text string into tokens and assigning types (categories) to the tokens. A parser is not particularly useful by itself, but must be bound into a text search configuration along with some text search dictionaries to be used for searching.

If a schema name is given then the text search parser is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use CREATE TEXT SEARCH PARSER. (This restriction is made because an erroneous text search parser definition could confuse or even crash the server.)

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search parser to be created. The name can be schema-qualified.

start_function

The name of the start function for the parser.

gettoken_function

The name of the get-next-token function for the parser.

end_function

The name of the end function for the parser.

lextypes_function

The name of the lextypes function for the parser (a function that returns information about the set of token types it produces).

headline_function

The name of the headline function for the parser (a function that summarizes a set of tokens).

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. All except the headline function are required.

The arguments can appear in any order, not only the one shown above.

Compatibility

There is no `CREATE TEXT SEARCH PARSER` statement in the SQL standard.

See Also

`ALTER TEXT SEARCH PARSER`, `DROP TEXT SEARCH PARSER`

CREATE TEXT SEARCH TEMPLATE

CREATE TEXT SEARCH TEMPLATE — define a new text search template

Synopsis

```
CREATE TEXT SEARCH TEMPLATE name (  
    [ INIT = init_function , ]  
    LEXIZE = lexize_function  
)
```

Description

CREATE TEXT SEARCH TEMPLATE creates a new text search template. Text search templates define the functions that implement text search dictionaries. A template is not useful by itself, but must be instantiated as a dictionary to be used. The dictionary typically specifies parameters to be given to the template functions.

If a schema name is given then the text search template is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use CREATE TEXT SEARCH TEMPLATE. This restriction is made because an erroneous text search template definition could confuse or even crash the server. The reason for separating templates from dictionaries is that a template encapsulates the “unsafe” aspects of defining a dictionary. The parameters that can be set when defining a dictionary are safe for unprivileged users to set, and so creating a dictionary need not be a privileged operation.

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search template to be created. The name can be schema-qualified.

init_function

The name of the init function for the template.

lexize_function

The name of the lexize function for the template.

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. The lexize function is required, but the init function is optional.

The arguments can appear in any order, not only the one shown above.

Compatibility

There is no CREATE TEXT SEARCH TEMPLATE statement in the SQL standard.

See Also

ALTER TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

CREATE TRANSFORM

CREATE TRANSFORM — define a new transform

Synopsis

```
CREATE [ OR REPLACE ] TRANSFORM FOR type_name LANGUAGE lang_name (  
    FROM SQL WITH FUNCTION from_sql_function_name [ (argument_type  
    [, ...]) ],  
    TO SQL WITH FUNCTION to_sql_function_name [ (argument_type  
    [, ...]) ]  
);
```

Description

CREATE TRANSFORM defines a new transform. CREATE OR REPLACE TRANSFORM will either create a new transform, or replace an existing definition.

A transform specifies how to adapt a data type to a procedural language. For example, when writing a function in PL/Python using the `hstore` type, PL/Python has no prior knowledge how to present `hstore` values in the Python environment. Language implementations usually default to using the text representation, but that is inconvenient when, for example, an associative array or a list would be more appropriate.

A transform specifies two functions:

- A “from SQL” function that converts the type from the SQL environment to the language. This function will be invoked on the arguments of a function written in the language.
- A “to SQL” function that converts the type from the language to the SQL environment. This function will be invoked on the return value of a function written in the language.

It is not necessary to provide both of these functions. If one is not specified, the language-specific default behavior will be used if necessary. (To prevent a transformation in a certain direction from happening at all, you could also write a transform function that always errors out.)

To be able to create a transform, you must own and have USAGE privilege on the type, have USAGE privilege on the language, and own and have EXECUTE privilege on the from-SQL and to-SQL functions, if specified.

Parameters

type_name

The name of the data type of the transform.

lang_name

The name of the language of the transform.

from_sql_function_name[(*argument_type* [, ...])]

The name of the function for converting the type from the SQL environment to the language. It must take one argument of type `internal` and return type `internal`. The actual argument will be of the type for the transform, and the function should be coded as if it were. (But it is not allowed

to declare an SQL-level function returning `internal` without at least one argument of type `internal`.) The actual return value will be something specific to the language implementation. If no argument list is specified, the function name must be unique in its schema.

```
to_sql_function_name[(argument_type [, ...])]
```

The name of the function for converting the type from the language to the SQL environment. It must take one argument of type `internal` and return the type that is the type for the transform. The actual argument value will be something specific to the language implementation. If no argument list is specified, the function name must be unique in its schema.

Notes

Use `DROP TRANSFORM` to remove transforms.

Examples

To create a transform for type `hstore` and language `plpythonu`, first set up the type and the language:

```
CREATE TYPE hstore ...;

CREATE EXTENSION plpythonu;
```

Then create the necessary functions:

```
CREATE FUNCTION hstore_to_plpython(val internal) RETURNS internal
LANGUAGE C STRICT IMMUTABLE
AS ...;

CREATE FUNCTION plpython_to_hstore(val internal) RETURNS hstore
LANGUAGE C STRICT IMMUTABLE
AS ...;
```

And finally create the transform to connect them all together:

```
CREATE TRANSFORM FOR hstore LANGUAGE plpythonu (
    FROM SQL WITH FUNCTION hstore_to_plpython(internal),
    TO SQL WITH FUNCTION plpython_to_hstore(internal)
);
```

In practice, these commands would be wrapped up in an extension.

The `contrib` section contains a number of extensions that provide transforms, which can serve as real-world examples.

Compatibility

This form of `CREATE TRANSFORM` is a PostgreSQL extension. There is a `CREATE TRANSFORM` command in the SQL standard, but it is for adapting data types to client languages. That usage is not supported by PostgreSQL.

See Also

`CREATE FUNCTION`, `CREATE LANGUAGE`, `CREATE TYPE`, `DROP TRANSFORM`

CREATE TRIGGER

CREATE TRIGGER — define a new trigger

Synopsis

```
CREATE [ CONSTRAINT ] TRIGGER name { BEFORE | AFTER | INSTEAD OF }
  { event [ OR ... ] }
  ON table_name
  [ FROM referenced_table_name ]
  [ NOT DEFERRABLE | [ DEFERRABLE ] [ INITIALLY IMMEDIATE |
INITIALLY DEFERRED ] ]
  [ REFERENCING { { OLD | NEW } TABLE
[ AS ] transition_relation_name } [ ... ] ]
  [ FOR [ EACH ] { ROW | STATEMENT } ]
  [ WHEN ( condition ) ]
  EXECUTE { FUNCTION | PROCEDURE } function_name ( arguments )
```

where *event* can be one of:

```
INSERT
UPDATE [ OF column_name [, ... ] ]
DELETE
TRUNCATE
```

Description

CREATE TRIGGER creates a new trigger. The trigger will be associated with the specified table, view, or foreign table and will execute the specified function *function_name* when certain operations are performed on that table.

The trigger can be specified to fire before the operation is attempted on a row (before constraints are checked and the INSERT, UPDATE, or DELETE is attempted); or after the operation has completed (after constraints are checked and the INSERT, UPDATE, or DELETE has completed); or instead of the operation (in the case of inserts, updates or deletes on a view). If the trigger fires before or instead of the event, the trigger can skip the operation for the current row, or change the row being inserted (for INSERT and UPDATE operations only). If the trigger fires after the event, all changes, including the effects of other triggers, are “visible” to the trigger.

A trigger that is marked FOR EACH ROW is called once for every row that the operation modifies. For example, a DELETE that affects 10 rows will cause any ON DELETE triggers on the target relation to be called 10 separate times, once for each deleted row. In contrast, a trigger that is marked FOR EACH STATEMENT only executes once for any given operation, regardless of how many rows it modifies (in particular, an operation that modifies zero rows will still result in the execution of any applicable FOR EACH STATEMENT triggers).

Triggers that are specified to fire INSTEAD OF the trigger event must be marked FOR EACH ROW, and can only be defined on views. BEFORE and AFTER triggers on a view must be marked as FOR EACH STATEMENT.

In addition, triggers may be defined to fire for TRUNCATE, though only FOR EACH STATEMENT.

The following table summarizes which types of triggers may be used on tables, views, and foreign tables:

When	Event	Row-level	Statement-level
BEFORE	INSERT/UP- DATE/DELETE	Tables and for- eign tables	Tables, views, and foreign tables
	TRUNCATE	—	Tables
AFTER	INSERT/UP- DATE/DELETE	Tables and for- eign tables	Tables, views, and foreign tables
	TRUNCATE	—	Tables
INSTEAD OF	INSERT/UP- DATE/DELETE	Views	—
	TRUNCATE	—	—

Also, a trigger definition can specify a Boolean `WHEN` condition, which will be tested to see whether the trigger should be fired. In row-level triggers the `WHEN` condition can examine the old and/or new values of columns of the row. Statement-level triggers can also have `WHEN` conditions, although the feature is not so useful for them since the condition cannot refer to any values in the table.

If multiple triggers of the same kind are defined for the same event, they will be fired in alphabetical order by name.

When the `CONSTRAINT` option is specified, this command creates a *constraint trigger*. This is the same as a regular trigger except that the timing of the trigger firing can be adjusted using `SET CONSTRAINTS`. Constraint triggers must be `AFTER ROW` triggers on plain tables (not foreign tables). They can be fired either at the end of the statement causing the triggering event, or at the end of the containing transaction; in the latter case they are said to be *deferred*. A pending deferred-trigger firing can also be forced to happen immediately by using `SET CONSTRAINTS`. Constraint triggers are expected to raise an exception when the constraints they implement are violated.

The `REFERENCING` option enables collection of *transition relations*, which are row sets that include all of the rows inserted, deleted, or modified by the current SQL statement. This feature lets the trigger see a global view of what the statement did, not just one row at a time. This option is only allowed for an `AFTER` trigger that is not a constraint trigger; also, if the trigger is an `UPDATE` trigger, it must not specify a `column_name` list. `OLD TABLE` may only be specified once, and only for a trigger that can fire on `UPDATE` or `DELETE`; it creates a transition relation containing the *before-images* of all rows updated or deleted by the statement. Similarly, `NEW TABLE` may only be specified once, and only for a trigger that can fire on `UPDATE` or `INSERT`; it creates a transition relation containing the *after-images* of all rows updated or inserted by the statement.

`SELECT` does not modify any rows so you cannot create `SELECT` triggers. Rules and views may provide workable solutions to problems that seem to need `SELECT` triggers.

Refer to Chapter 38 for more information about triggers.

Parameters

name

The name to give the new trigger. This must be distinct from the name of any other trigger for the same table. The name cannot be schema-qualified — the trigger inherits the schema of its table. For a constraint trigger, this is also the name to use when modifying the trigger's behavior using `SET CONSTRAINTS`.

`BEFORE`

`AFTER`

`INSTEAD OF`

Determines whether the function is called before, after, or instead of the event. A constraint trigger can only be specified as `AFTER`.

event

One of INSERT, UPDATE, DELETE, or TRUNCATE; this specifies the event that will fire the trigger. Multiple events can be specified using OR, except when transition relations are requested.

For UPDATE events, it is possible to specify a list of columns using this syntax:

```
UPDATE OF column_name1 [ , column_name2 ... ]
```

The trigger will only fire if at least one of the listed columns is mentioned as a target of the UPDATE command or if one of the listed columns is a generated column that depends on a column that is the target of the UPDATE.

INSTEAD OF UPDATE events do not allow a list of columns. A column list cannot be specified when requesting transition relations, either.

table_name

The name (optionally schema-qualified) of the table, view, or foreign table the trigger is for.

referenced_table_name

The (possibly schema-qualified) name of another table referenced by the constraint. This option is used for foreign-key constraints and is not recommended for general use. This can only be specified for constraint triggers.

```
DEFERRABLE  
NOT DEFERRABLE  
INITIALLY IMMEDIATE  
INITIALLY DEFERRED
```

The default timing of the trigger. See the CREATE TABLE documentation for details of these constraint options. This can only be specified for constraint triggers.

REFERENCING

This keyword immediately precedes the declaration of one or two relation names that provide access to the transition relations of the triggering statement.

```
OLD TABLE  
NEW TABLE
```

This clause indicates whether the following relation name is for the before-image transition relation or the after-image transition relation.

transition_relation_name

The (unqualified) name to be used within the trigger for this transition relation.

```
FOR EACH ROW  
FOR EACH STATEMENT
```

This specifies whether the trigger function should be fired once for every row affected by the trigger event, or just once per SQL statement. If neither is specified, FOR EACH STATEMENT is the default. Constraint triggers can only be specified FOR EACH ROW.

condition

A Boolean expression that determines whether the trigger function will actually be executed. If WHEN is specified, the function will only be called if the *condition* returns true. In FOR EACH ROW triggers, the WHEN condition can refer to columns of the old and/or new row val-

ues by writing `OLD.column_name` or `NEW.column_name` respectively. Of course, `INSERT` triggers cannot refer to `OLD` and `DELETE` triggers cannot refer to `NEW`.

`INSTEAD OF` triggers do not support `WHEN` conditions.

Currently, `WHEN` expressions cannot contain subqueries.

Note that for constraint triggers, evaluation of the `WHEN` condition is not deferred, but occurs immediately after the row update operation is performed. If the condition does not evaluate to true then the trigger is not queued for deferred execution.

function_name

A user-supplied function that is declared as taking no arguments and returning type `trigger`, which is executed when the trigger fires.

In the syntax of `CREATE TRIGGER`, the keywords `FUNCTION` and `PROCEDURE` are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword `PROCEDURE` here is historical and deprecated.

arguments

An optional comma-separated list of arguments to be provided to the function when the trigger is executed. The arguments are literal string constants. Simple names and numeric constants can be written here, too, but they will all be converted to strings. Please check the description of the implementation language of the trigger function to find out how these arguments can be accessed within the function; it might be different from normal function arguments.

Notes

To create a trigger on a table, the user must have the `TRIGGER` privilege on the table. The user must also have `EXECUTE` privilege on the trigger function.

Use `DROP TRIGGER` to remove a trigger.

A column-specific trigger (one defined using the `UPDATE OF column_name` syntax) will fire when any of its columns are listed as targets in the `UPDATE` command's `SET` list. It is possible for a column's value to change even when the trigger is not fired, because changes made to the row's contents by `BEFORE UPDATE` triggers are not considered. Conversely, a command such as `UPDATE . . . SET x = x . . .` will fire a trigger on column `x`, even though the column's value did not change.

In a `BEFORE` trigger, the `WHEN` condition is evaluated just before the function is or would be executed, so using `WHEN` is not materially different from testing the same condition at the beginning of the trigger function. Note in particular that the `NEW` row seen by the condition is the current value, as possibly modified by earlier triggers. Also, a `BEFORE` trigger's `WHEN` condition is not allowed to examine the system columns of the `NEW` row (such as `ctid`), because those won't have been set yet.

In an `AFTER` trigger, the `WHEN` condition is evaluated just after the row update occurs, and it determines whether an event is queued to fire the trigger at the end of statement. So when an `AFTER` trigger's `WHEN` condition does not return true, it is not necessary to queue an event nor to re-fetch the row at end of statement. This can result in significant speedups in statements that modify many rows, if the trigger only needs to be fired for a few of the rows.

In some cases it is possible for a single `SQL` command to fire more than one kind of trigger. For instance an `INSERT` with an `ON CONFLICT DO UPDATE` clause may cause both insert and update operations, so it will fire both kinds of triggers as needed. The transition relations supplied to triggers are specific to their event type; thus an `INSERT` trigger will see only the inserted rows, while an `UPDATE` trigger will see only the updated rows.

Row updates or deletions caused by foreign-key enforcement actions, such as `ON UPDATE CASCADE` or `ON DELETE SET NULL`, are treated as part of the `SQL` command that caused them (note that such

actions are never deferred). Relevant triggers on the affected table will be fired, so that this provides another way in which a SQL command might fire triggers not directly matching its type. In simple cases, triggers that request transition relations will see all changes caused in their table by a single original SQL command as a single transition relation. However, there are cases in which the presence of an `AFTER ROW` trigger that requests transition relations will cause the foreign-key enforcement actions triggered by a single SQL command to be split into multiple steps, each with its own transition relation(s). In such cases, any statement-level triggers that are present will be fired once per creation of a transition relation set, ensuring that the triggers see each affected row in a transition relation once and only once.

Statement-level triggers on a view are fired only if the action on the view is handled by a row-level `INSTEAD OF` trigger. If the action is handled by an `INSTEAD` rule, then whatever statements are emitted by the rule are executed in place of the original statement naming the view, so that the triggers that will be fired are those on tables named in the replacement statements. Similarly, if the view is automatically updatable, then the action is handled by automatically rewriting the statement into an action on the view's base table, so that the base table's statement-level triggers are the ones that are fired.

Creating a row-level trigger on a partitioned table will cause identical triggers to be created in all its existing partitions; and any partitions created or attached later will contain an identical trigger, too. Triggers on partitioned tables may only be `AFTER`.

Modifying a partitioned table or a table with inheritance children fires statement-level triggers attached to the explicitly named table, but not statement-level triggers for its partitions or child tables. In contrast, row-level triggers are fired on the rows in affected partitions or child tables, even if they are not explicitly named in the query. If a statement-level trigger has been defined with transition relations named by a `REFERENCING` clause, then before and after images of rows are visible from all affected partitions or child tables. In the case of inheritance children, the row images include only columns that are present in the table that the trigger is attached to. Currently, row-level triggers with transition relations cannot be defined on partitions or inheritance child tables.

In PostgreSQL versions before 7.3, it was necessary to declare trigger functions as returning the placeholder type `opaque`, rather than `trigger`. To support loading of old dump files, `CREATE TRIGGER` will accept a function declared as returning `opaque`, but it will issue a notice and change the function's declared return type to `trigger`.

Examples

Execute the function `check_account_update` whenever a row of the table `accounts` is about to be updated:

```
CREATE TRIGGER check_update
    BEFORE UPDATE ON accounts
    FOR EACH ROW
    EXECUTE FUNCTION check_account_update();
```

The same, but only execute the function if column `balance` is specified as a target in the `UPDATE` command:

```
CREATE TRIGGER check_update
    BEFORE UPDATE OF balance ON accounts
    FOR EACH ROW
    EXECUTE FUNCTION check_account_update();
```

This form only executes the function if column `balance` has in fact changed value:

```
CREATE TRIGGER check_update
  BEFORE UPDATE ON accounts
  FOR EACH ROW
  WHEN (OLD.balance IS DISTINCT FROM NEW.balance)
  EXECUTE FUNCTION check_account_update();
```

Call a function to log updates of `accounts`, but only if something changed:

```
CREATE TRIGGER log_update
  AFTER UPDATE ON accounts
  FOR EACH ROW
  WHEN (OLD.* IS DISTINCT FROM NEW.*)
  EXECUTE FUNCTION log_account_update();
```

Execute the function `view_insert_row` for each row to insert rows into the tables underlying a view:

```
CREATE TRIGGER view_insert
  INSTEAD OF INSERT ON my_view
  FOR EACH ROW
  EXECUTE FUNCTION view_insert_row();
```

Execute the function `check_transfer_balances_to_zero` for each statement to confirm that the transfer rows offset to a net of zero:

```
CREATE TRIGGER transfer_insert
  AFTER INSERT ON transfer
  REFERENCING NEW TABLE AS inserted
  FOR EACH STATEMENT
  EXECUTE FUNCTION check_transfer_balances_to_zero();
```

Execute the function `check_matching_pairs` for each row to confirm that changes are made to matching pairs at the same time (by the same statement):

```
CREATE TRIGGER paired_items_update
  AFTER UPDATE ON paired_items
  REFERENCING NEW TABLE AS newtab OLD TABLE AS oldtab
  FOR EACH ROW
  EXECUTE FUNCTION check_matching_pairs();
```

Section 38.4 contains a complete example of a trigger function written in C.

Compatibility

The `CREATE TRIGGER` statement in PostgreSQL implements a subset of the SQL standard. The following functionalities are currently missing:

- While transition table names for `AFTER` triggers are specified using the `REFERENCING` clause in the standard way, the row variables used in `FOR EACH ROW` triggers may not be specified in a `REFERENCING` clause. They are available in a manner that is dependent on the language in which the trigger function is written, but is fixed for any one language. Some languages effectively behave as though there is a `REFERENCING` clause containing `OLD ROW AS OLD NEW ROW AS NEW`.
- The standard allows transition tables to be used with column-specific `UPDATE` triggers, but then the set of rows that should be visible in the transition tables depends on the trigger's column list. This is not currently implemented by PostgreSQL.

- PostgreSQL only allows the execution of a user-defined function for the triggered action. The standard allows the execution of a number of other SQL commands, such as `CREATE TABLE`, as the triggered action. This limitation is not hard to work around by creating a user-defined function that executes the desired commands.

SQL specifies that multiple triggers should be fired in time-of-creation order. PostgreSQL uses name order, which was judged to be more convenient.

SQL specifies that `BEFORE DELETE` triggers on cascaded deletes fire *after* the cascaded `DELETE` completes. The PostgreSQL behavior is for `BEFORE DELETE` to always fire before the delete action, even a cascading one. This is considered more consistent. There is also nonstandard behavior if `BEFORE` triggers modify rows or prevent updates during an update that is caused by a referential action. This can lead to constraint violations or stored data that does not honor the referential constraint.

The ability to specify multiple actions for a single trigger using `OR` is a PostgreSQL extension of the SQL standard.

The ability to fire triggers for `TRUNCATE` is a PostgreSQL extension of the SQL standard, as is the ability to define statement-level triggers on views.

`CREATE CONSTRAINT TRIGGER` is a PostgreSQL extension of the SQL standard.

See Also

`ALTER TRIGGER`, `DROP TRIGGER`, `CREATE FUNCTION`, `SET CONSTRAINTS`

CREATE TYPE

CREATE TYPE — define a new data type

Synopsis

```
CREATE TYPE name AS  
    ( [ attribute_name data_type [ COLLATE collation ] [, ... ] ] )
```

```
CREATE TYPE name AS ENUM  
    ( [ 'label' [, ... ] ] )
```

```
CREATE TYPE name AS RANGE (  
    SUBTYPE = subtype  
    [ , SUBTYPE_OPCLASS = subtype_operator_class ]  
    [ , COLLATION = collation ]  
    [ , CANONICAL = canonical_function ]  
    [ , SUBTYPE_DIFF = subtype_diff_function ]  
)
```

```
CREATE TYPE name (  
    INPUT = input_function,  
    OUTPUT = output_function  
    [ , RECEIVE = receive_function ]  
    [ , SEND = send_function ]  
    [ , TYPMOD_IN = type_modifier_input_function ]  
    [ , TYPMOD_OUT = type_modifier_output_function ]  
    [ , ANALYZE = analyze_function ]  
    [ , INTERNALLENGTH = { internallength | VARIABLE } ]  
    [ , PASSEDBYVALUE ]  
    [ , ALIGNMENT = alignment ]  
    [ , STORAGE = storage ]  
    [ , LIKE = like_type ]  
    [ , CATEGORY = category ]  
    [ , PREFERRED = preferred ]  
    [ , DEFAULT = default ]  
    [ , ELEMENT = element ]  
    [ , DELIMITER = delimiter ]  
    [ , COLLATABLE = collatable ]  
)
```

```
CREATE TYPE name
```

Description

CREATE TYPE registers a new data type for use in the current database. The user who defines a type becomes its owner.

If a schema name is given then the type is created in the specified schema. Otherwise it is created in the current schema. The type name must be distinct from the name of any existing type or domain in the same schema. (Because tables have associated data types, the type name must also be distinct from the name of any existing table in the same schema.)

There are five forms of CREATE TYPE, as shown in the syntax synopsis above. They respectively create a *composite type*, an *enum type*, a *range type*, a *base type*, or a *shell type*. The first four of

these are discussed in turn below. A shell type is simply a placeholder for a type to be defined later; it is created by issuing `CREATE TYPE` with no parameters except for the type name. Shell types are needed as forward references when creating range types and base types, as discussed in those sections.

Composite Types

The first form of `CREATE TYPE` creates a composite type. The composite type is specified by a list of attribute names and data types. An attribute's collation can be specified too, if its data type is collatable. A composite type is essentially the same as the row type of a table, but using `CREATE TYPE` avoids the need to create an actual table when all that is wanted is to define a type. A stand-alone composite type is useful, for example, as the argument or return type of a function.

To be able to create a composite type, you must have `USAGE` privilege on all attribute types.

Enumerated Types

The second form of `CREATE TYPE` creates an enumerated (enum) type, as described in Section 8.7. Enum types take a list of quoted labels, each of which must be less than `NAMEDATALEN` bytes long (64 bytes in a standard PostgreSQL build). (It is possible to create an enumerated type with zero labels, but such a type cannot be used to hold values before at least one label is added using `ALTER TYPE`.)

Range Types

The third form of `CREATE TYPE` creates a new range type, as described in Section 8.17.

The range type's *subtype* can be any type with an associated b-tree operator class (to determine the ordering of values for the range type). Normally the subtype's default b-tree operator class is used to determine ordering; to use a non-default operator class, specify its name with *subtype_opclass*. If the subtype is collatable, and you want to use a non-default collation in the range's ordering, specify the desired collation with the *collation* option.

The optional *canonical* function must take one argument of the range type being defined, and return a value of the same type. This is used to convert range values to a canonical form, when applicable. See Section 8.17.8 for more information. Creating a *canonical* function is a bit tricky, since it must be defined before the range type can be declared. To do this, you must first create a shell type, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the function can be declared using the shell type as argument and result, and finally the range type can be declared using the same name. This automatically replaces the shell type entry with a valid range type.

The optional *subtype_diff* function must take two values of the *subtype* type as argument, and return a `double precision` value representing the difference between the two given values. While this is optional, providing it allows much greater efficiency of GiST indexes on columns of the range type. See Section 8.17.8 for more information.

Base Types

The fourth form of `CREATE TYPE` creates a new base type (scalar type). To create a new base type, you must be a superuser. (This restriction is made because an erroneous type definition could confuse or even crash the server.)

The parameters can appear in any order, not only that illustrated above, and most are optional. You must register two or more functions (using `CREATE FUNCTION`) before defining the type. The support functions *input_function* and *output_function* are required, while the functions *receive_function*, *send_function*, *type_modifier_input_function*, *type_modifier_output_function* and *analyze_function* are optional. Generally these functions have to be coded in C or another low-level language.

The *input_function* converts the type's external textual representation to the internal representation used by the operators and functions defined for the type. *output_function* performs the

reverse transformation. The input function can be declared as taking one argument of type `cstring`, or as taking three arguments of types `cstring`, `oid`, `integer`. The first argument is the input text as a C string, the second argument is the type's own OID (except for array types, which instead receive their element type's OID), and the third is the `typmod` of the destination column, if known (-1 will be passed if not). The input function must return a value of the data type itself. Usually, an input function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain input functions, which might need to reject `NULL` inputs.) The output function must be declared as taking one argument of the new data type. The output function must return type `cstring`. Output functions are not invoked for `NULL` values.

The optional *receive_function* converts the type's external binary representation to the internal representation. If this function is not supplied, the type cannot participate in binary input. The binary representation should be chosen to be cheap to convert to internal form, while being reasonably portable. (For example, the standard integer data types use network byte order as the external binary representation, while the internal representation is in the machine's native byte order.) The receive function should perform adequate checking to ensure that the value is valid. The receive function can be declared as taking one argument of type `internal`, or as taking three arguments of types `internal`, `oid`, `integer`. The first argument is a pointer to a `StringInfo` buffer holding the received byte string; the optional arguments are the same as for the text input function. The receive function must return a value of the data type itself. Usually, a receive function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain receive functions, which might need to reject `NULL` inputs.) Similarly, the optional *send_function* converts from the internal representation to the external binary representation. If this function is not supplied, the type cannot participate in binary output. The send function must be declared as taking one argument of the new data type. The send function must return type `bytea`. Send functions are not invoked for `NULL` values.

You should at this point be wondering how the input and output functions can be declared to have results or arguments of the new type, when they have to be created before the new type can be created. The answer is that the type should first be defined as a *shell type*, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the C I/O functions can be defined referencing the shell type. Finally, `CREATE TYPE` with a full definition replaces the shell entry with a complete, valid type definition, after which the new type can be used normally.

The optional *type_modifier_input_function* and *type_modifier_output_function* are needed if the type supports modifiers, that is optional constraints attached to a type declaration, such as `char(5)` or `numeric(30,2)`. PostgreSQL allows user-defined types to take one or more simple constants or identifiers as modifiers. However, this information must be capable of being packed into a single non-negative integer value for storage in the system catalogs. The *type_modifier_input_function* is passed the declared modifier(s) in the form of a `cstring` array. It must check the values for validity (throwing an error if they are wrong), and if they are correct, return a single non-negative integer value that will be stored as the column "typmod". Type modifiers will be rejected if the type does not have a *type_modifier_input_function*. The *type_modifier_output_function* converts the internal integer typmod value back to the correct form for user display. It must return a `cstring` value that is the exact string to append to the type name; for example `numeric`'s function might return `(30,2)`. It is allowed to omit the *type_modifier_output_function*, in which case the default display format is just the stored typmod integer value enclosed in parentheses.

The optional *analyze_function* performs type-specific statistics collection for columns of the data type. By default, `ANALYZE` will attempt to gather statistics using the type's "equals" and "less-than" operators, if there is a default b-tree operator class for the type. For non-scalar types this behavior is likely to be unsuitable, so it can be overridden by specifying a custom analysis function. The analysis function must be declared to take a single argument of type `internal`, and return a `boolean` result. The detailed API for analysis functions appears in `src/include/commands/vacuum.h`.

While the details of the new type's internal representation are only known to the I/O functions and other functions you create to work with the type, there are several properties of the internal representation that must be declared to PostgreSQL. Foremost of these is *internallength*. Base data types can be fixed-length, in which case *internallength* is a positive integer, or variable-length, indicated by setting *internallength* to `VARIABLE`. (Internally, this is represented by setting `typplen` to -1.) The internal representation of all variable-length types must start with a 4-byte integer giving the total length of this value of the type. (Note that the length field is often encoded, as described in Section 68.2; it's unwise to access it directly.)

The optional flag `PASSEDBYVALUE` indicates that values of this data type are passed by value, rather than by reference. Types passed by value must be fixed-length, and their internal representation cannot be larger than the size of the `Datum` type (4 bytes on some machines, 8 bytes on others).

The *alignment* parameter specifies the storage alignment required for the data type. The allowed values equate to alignment on 1, 2, 4, or 8 byte boundaries. Note that variable-length types must have an alignment of at least 4, since they necessarily contain an `int4` as their first component.

The *storage* parameter allows selection of storage strategies for variable-length data types. (Only `plain` is allowed for fixed-length types.) `plain` specifies that data of the type will always be stored in-line and not compressed. `extended` specifies that the system will first try to compress a long data value, and will move the value out of the main table row if it's still too long. `external` allows the value to be moved out of the main table, but the system will not try to compress it. `main` allows compression, but discourages moving the value out of the main table. (Data items with this storage strategy might still be moved out of the main table if there is no other way to make a row fit, but they will be kept in the main table preferentially over `extended` and `external` items.)

All *storage* values other than `plain` imply that the functions of the data type can handle values that have been *toasted*, as described in Section 68.2 and Section 37.13.1. The specific other value given merely determines the default TOAST storage strategy for columns of a toastable data type; users can pick other strategies for individual columns using `ALTER TABLE SET STORAGE`.

The *like_type* parameter provides an alternative method for specifying the basic representation properties of a data type: copy them from some existing type. The values of *internallength*, *passedbyvalue*, *alignment*, and *storage* are copied from the named type. (It is possible, though usually undesirable, to override some of these values by specifying them along with the `LIKE` clause.) Specifying representation this way is especially useful when the low-level implementation of the new type “piggybacks” on an existing type in some fashion.

The *category* and *preferred* parameters can be used to help control which implicit cast will be applied in ambiguous situations. Each data type belongs to a category named by a single ASCII character, and each type is either “preferred” or not within its category. The parser will prefer casting to preferred types (but only from other types within the same category) when this rule is helpful in resolving overloaded functions or operators. For more details see Chapter 10. For types that have no implicit casts to or from any other types, it is sufficient to leave these settings at the defaults. However, for a group of related types that have implicit casts, it is often helpful to mark them all as belonging to a category and select one or two of the “most general” types as being preferred within the category. The *category* parameter is especially useful when adding a user-defined type to an existing built-in category, such as the numeric or string types. However, it is also possible to create new entirely-user-defined type categories. Select any ASCII character other than an upper-case letter to name such a category.

A default value can be specified, in case a user wants columns of the data type to default to something other than the null value. Specify the default with the `DEFAULT` key word. (Such a default can be overridden by an explicit `DEFAULT` clause attached to a particular column.)

To indicate that a type is an array, specify the type of the array elements using the `ELEMENT` key word. For example, to define an array of 4-byte integers (`int4`), specify `ELEMENT = int4`. More details about array types appear below.

To indicate the delimiter to be used between values in the external representation of arrays of this type, *delimiter* can be set to a specific character. The default delimiter is the comma (,). Note that the delimiter is associated with the array element type, not the array type itself.

If the optional Boolean parameter *collatable* is true, column definitions and expressions of the type may carry collation information through use of the COLLATE clause. It is up to the implementations of the functions operating on the type to actually make use of the collation information; this does not happen automatically merely by marking the type collatable.

Array Types

Whenever a user-defined type is created, PostgreSQL automatically creates an associated array type, whose name consists of the element type's name prepended with an underscore, and truncated if necessary to keep it less than NAMEDATALEN bytes long. (If the name so generated collides with an existing type name, the process is repeated until a non-colliding name is found.) This implicitly-created array type is variable length and uses the built-in input and output functions `array_in` and `array_out`. The array type tracks any changes in its element type's owner or schema, and is dropped if the element type is.

You might reasonably ask why there is an ELEMENT option, if the system makes the correct array type automatically. The only case where it's useful to use ELEMENT is when you are making a fixed-length type that happens to be internally an array of a number of identical things, and you want to allow these things to be accessed directly by subscripting, in addition to whatever operations you plan to provide for the type as a whole. For example, type `point` is represented as just two floating-point numbers, which can be accessed using `point[0]` and `point[1]`. Note that this facility only works for fixed-length types whose internal form is exactly a sequence of identical fixed-length fields. A subscriptable variable-length type must have the generalized internal representation used by `array_in` and `array_out`. For historical reasons (i.e., this is clearly wrong but it's far too late to change it), subscripting of fixed-length array types starts from zero, rather than from one as for variable-length arrays.

Parameters

name

The name (optionally schema-qualified) of a type to be created.

attribute_name

The name of an attribute (column) for the composite type.

data_type

The name of an existing data type to become a column of the composite type.

collation

The name of an existing collation to be associated with a column of a composite type, or with a range type.

label

A string literal representing the textual label associated with one value of an enum type.

subtype

The name of the element type that the range type will represent ranges of.

subtype_operator_class

The name of a b-tree operator class for the subtype.

canonical_function

The name of the canonicalization function for the range type.

subtype_diff_function

The name of a difference function for the subtype.

input_function

The name of a function that converts data from the type's external textual form to its internal form.

output_function

The name of a function that converts data from the type's internal form to its external textual form.

receive_function

The name of a function that converts data from the type's external binary form to its internal form.

send_function

The name of a function that converts data from the type's internal form to its external binary form.

type_modifier_input_function

The name of a function that converts an array of modifier(s) for the type into internal form.

type_modifier_output_function

The name of a function that converts the internal form of the type's modifier(s) to external textual form.

analyze_function

The name of a function that performs statistical analysis for the data type.

internallength

A numeric constant that specifies the length in bytes of the new type's internal representation. The default assumption is that it is variable-length.

alignment

The storage alignment requirement of the data type. If specified, it must be `char`, `int2`, `int4`, or `double`; the default is `int4`.

storage

The storage strategy for the data type. If specified, must be `plain`, `external`, `extended`, or `main`; the default is `plain`.

like_type

The name of an existing data type that the new type will have the same representation as. The values of *internallength*, *passedbyvalue*, *alignment*, and *storage* are copied from that type, unless overridden by explicit specification elsewhere in this `CREATE TYPE` command.

category

The category code (a single ASCII character) for this type. The default is 'U' for "user-defined type". Other standard category codes can be found in Table 51.64. You may also choose other ASCII characters in order to create custom categories.

preferred

True if this type is a preferred type within its type category, else false. The default is false. Be very careful about creating a new preferred type within an existing type category, as this could cause surprising changes in behavior.

default

The default value for the data type. If this is omitted, the default is null.

element

The type being created is an array; this specifies the type of the array elements.

delimiter

The delimiter character to be used between values in arrays made of this type.

collatable

True if this type's operations can use collation information. The default is false.

Notes

Because there are no restrictions on use of a data type once it's been created, creating a base type or range type is tantamount to granting public execute permission on the functions mentioned in the type definition. This is usually not an issue for the sorts of functions that are useful in a type definition. But you might want to think twice before designing a type in a way that would require “secret” information to be used while converting it to or from external form.

Before PostgreSQL version 8.3, the name of a generated array type was always exactly the element type's name with one underscore character (`_`) prepended. (Type names were therefore restricted in length to one less character than other names.) While this is still usually the case, the array type name may vary from this in case of maximum-length names or collisions with user type names that begin with underscore. Writing code that depends on this convention is therefore deprecated. Instead, use `pg_type.typarray` to locate the array type associated with a given type.

It may be advisable to avoid using type and table names that begin with underscore. While the server will change generated array type names to avoid collisions with user-given names, there is still risk of confusion, particularly with old client software that may assume that type names beginning with underscores always represent arrays.

Before PostgreSQL version 8.2, the shell-type creation syntax `CREATE TYPE name` did not exist. The way to create a new base type was to create its input function first. In this approach, PostgreSQL will first see the name of the new data type as the return type of the input function. The shell type is implicitly created in this situation, and then it can be referenced in the definitions of the remaining I/O functions. This approach still works, but is deprecated and might be disallowed in some future release. Also, to avoid accidentally cluttering the catalogs with shell types as a result of simple typos in function definitions, a shell type will only be made this way when the input function is written in C.

In PostgreSQL versions before 7.3, it was customary to avoid creating a shell type at all, by replacing the functions' forward references to the type name with the placeholder pseudo-type `opaque`. The `cstring` arguments and results also had to be declared as `opaque` before 7.3. To support loading of old dump files, `CREATE TYPE` will accept I/O functions declared using `opaque`, but it will issue a notice and change the function declarations to use the correct types.

Examples

This example creates a composite type and uses it in a function definition:

```
CREATE TYPE compfoo AS (f1 int, f2 text);

CREATE FUNCTION getfoo() RETURNS SETOF compfoo AS $$
    SELECT fooid, fooname FROM foo
$$ LANGUAGE SQL;
```

This example creates an enumerated type and uses it in a table definition:

```
CREATE TYPE bug_status AS ENUM ('new', 'open', 'closed');

CREATE TABLE bug (
    id serial,
    description text,
    status bug_status
);
```

This example creates a range type:

```
CREATE TYPE float8_range AS RANGE (subtype = float8, subtype_diff =
    float8mi);
```

This example creates the base data type box and then uses the type in a table definition:

```
CREATE TYPE box;

CREATE FUNCTION my_box_in_function(cstring) RETURNS box AS ... ;
CREATE FUNCTION my_box_out_function(box) RETURNS cstring AS ... ;

CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function
);

CREATE TABLE myboxes (
    id integer,
    description box
);
```

If the internal structure of box were an array of four float4 elements, we might instead use:

```
CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function,
    ELEMENT = float4
);
```

which would allow a box value's component numbers to be accessed by subscripting. Otherwise the type behaves the same as before.

This example creates a large object type and uses it in a table definition:

```
CREATE TYPE bigobj (
```

```
        INPUT = lo_filein, OUTPUT = lo_fileout,  
        INTERNALLENGTH = VARIABLE  
    );  
CREATE TABLE big_objs (  
    id integer,  
    obj bigobj  
);
```

More examples, including suitable input and output functions, are in Section 37.13.

Compatibility

The first form of the `CREATE TYPE` command, which creates a composite type, conforms to the SQL standard. The other forms are PostgreSQL extensions. The `CREATE TYPE` statement in the SQL standard also defines other forms that are not implemented in PostgreSQL.

The ability to create a composite type with zero attributes is a PostgreSQL-specific deviation from the standard (analogous to the same case in `CREATE TABLE`).

See Also

`ALTER TYPE`, `CREATE DOMAIN`, `CREATE FUNCTION`, `DROP TYPE`

CREATE USER

CREATE USER — define a new database role

Synopsis

```
CREATE USER name [ [ WITH ] option [ ... ] ]
```

where *option* can be:

```
SUPERUSER | NOSUPERUSER  
|  
CREATEDB | NOCREATEDB  
|  
CREATEROLE | NOCREATEROLE  
|  
INHERIT | NOINHERIT  
|  
LOGIN | NOLOGIN  
|  
REPLICATION | NOREPLICATION  
|  
BYPASSRLS | NOBYPASSRLS  
|  
CONNECTION LIMIT connlimit  
|  
[ ENCRYPTED ] PASSWORD 'password' | PASSWORD NULL  
|  
VALID UNTIL 'timestamp'  
|  
IN ROLE role_name [ , ... ]  
|  
IN GROUP role_name [ , ... ]  
|  
ROLE role_name [ , ... ]  
|  
ADMIN role_name [ , ... ]  
|  
USER role_name [ , ... ]  
|  
SYSID uid
```

Description

CREATE USER is now an alias for CREATE ROLE. The only difference is that when the command is spelled CREATE USER, LOGIN is assumed by default, whereas NOLOGIN is assumed when the command is spelled CREATE ROLE.

Compatibility

The CREATE USER statement is a PostgreSQL extension. The SQL standard leaves the definition of users to the implementation.

See Also

CREATE ROLE

CREATE USER MAPPING

CREATE USER MAPPING — define a new mapping of a user to a foreign server

Synopsis

```
CREATE USER MAPPING [ IF NOT EXISTS ] FOR { user_name | USER |  
CURRENT_USER | PUBLIC }  
    SERVER server_name  
    [ OPTIONS ( option 'value' [ , ... ] ) ]
```

Description

CREATE USER MAPPING defines a mapping of a user to a foreign server. A user mapping typically encapsulates connection information that a foreign-data wrapper uses together with the information encapsulated by a foreign server to access an external data resource.

The owner of a foreign server can create user mappings for that server for any user. Also, a user can create a user mapping for their own user name if USAGE privilege on the server has been granted to the user.

Parameters

IF NOT EXISTS

Do not throw an error if a mapping of the given user to the given foreign server already exists. A notice is issued in this case. Note that there is no guarantee that the existing user mapping is anything like the one that would have been created.

user_name

The name of an existing user that is mapped to foreign server. CURRENT_USER and USER match the name of the current user. When PUBLIC is specified, a so-called public mapping is created that is used when no user-specific mapping is applicable.

server_name

The name of an existing server for which the user mapping is to be created.

OPTIONS (*option* '*value*' [, ...])

This clause specifies the options of the user mapping. The options typically define the actual user name and password of the mapping. Option names must be unique. The allowed option names and values are specific to the server's foreign-data wrapper.

Examples

Create a user mapping for user bob, server foo:

```
CREATE USER MAPPING FOR bob SERVER foo OPTIONS (user 'bob',  
password 'secret');
```

Compatibility

CREATE USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED).

See Also

ALTER USER MAPPING, DROP USER MAPPING, CREATE FOREIGN DATA WRAPPER, CREATE SERVER

CREATE VIEW

CREATE VIEW — define a new view

Synopsis

```
CREATE [ OR REPLACE ] [ TEMP | TEMPORARY ] [ RECURSIVE ] VIEW name
  [ ( column_name [, ...] ) ]
  [ WITH ( view_option_name [= view_option_value] [, ... ] ) ]
  AS query
  [ WITH [ CASCADED | LOCAL ] CHECK OPTION ]
```

Description

CREATE VIEW defines a view of a query. The view is not physically materialized. Instead, the query is run every time the view is referenced in a query.

CREATE OR REPLACE VIEW is similar, but if a view of the same name already exists, it is replaced. The new query must generate the same columns that were generated by the existing view query (that is, the same column names in the same order and with the same data types), but it may add additional columns to the end of the list. The calculations giving rise to the output columns may be completely different.

If a schema name is given (for example, CREATE VIEW myschema.myview ...) then the view is created in the specified schema. Otherwise it is created in the current schema. Temporary views exist in a special schema, so a schema name cannot be given when creating a temporary view. The name of the view must be distinct from the name of any other view, table, sequence, index or foreign table in the same schema.

Parameters

TEMPORARY or TEMP

If specified, the view is created as a temporary view. Temporary views are automatically dropped at the end of the current session. Existing permanent relations with the same name are not visible to the current session while the temporary view exists, unless they are referenced with schema-qualified names.

If any of the tables referenced by the view are temporary, the view is created as a temporary view (whether TEMPORARY is specified or not).

RECURSIVE

Creates a recursive view. The syntax

```
CREATE RECURSIVE VIEW [ schema . ] view_name (column_names) AS
  SELECT ...;
```

is equivalent to

```
CREATE VIEW [ schema . ] view_name AS WITH RECURSIVE view_name
  (column_names) AS (SELECT ...) SELECT column_names
  FROM view_name;
```

A view column name list must be specified for a recursive view.

name

The name (optionally schema-qualified) of a view to be created.

column_name

An optional list of names to be used for columns of the view. If not given, the column names are deduced from the query.

WITH (*view_option_name* [= *view_option_value*] [, ...])

This clause specifies optional parameters for a view; the following parameters are supported:

check_option (string)

This parameter may be either `local` or `cascaded`, and is equivalent to specifying WITH [`CASCADED` | `LOCAL`] `CHECK OPTION` (see below). This option can be changed on existing views using `ALTER VIEW`.

security_barrier (boolean)

This should be used if the view is intended to provide row-level security. See Section 40.5 for full details.

query

A `SELECT` or `VALUES` command which will provide the columns and rows of the view.

WITH [`CASCADED` | `LOCAL`] `CHECK OPTION`

This option controls the behavior of automatically updatable views. When this option is specified, `INSERT` and `UPDATE` commands on the view will be checked to ensure that new rows satisfy the view-defining condition (that is, the new rows are checked to ensure that they are visible through the view). If they are not, the update will be rejected. If the `CHECK OPTION` is not specified, `INSERT` and `UPDATE` commands on the view are allowed to create rows that are not visible through the view. The following check options are supported:

`LOCAL`

New rows are only checked against the conditions defined directly in the view itself. Any conditions defined on underlying base views are not checked (unless they also specify the `CHECK OPTION`).

`CASCADED`

New rows are checked against the conditions of the view and all underlying base views. If the `CHECK OPTION` is specified, and neither `LOCAL` nor `CASCADED` is specified, then `CASCADED` is assumed.

The `CHECK OPTION` may not be used with `RECURSIVE` views.

Note that the `CHECK OPTION` is only supported on views that are automatically updatable, and do not have `INSTEAD OF` triggers or `INSTEAD` rules. If an automatically updatable view is defined on top of a base view that has `INSTEAD OF` triggers, then the `LOCAL CHECK OPTION` may be used to check the conditions on the automatically updatable view, but the conditions on the base view with `INSTEAD OF` triggers will not be checked (a cascaded check option will not cascade down to a trigger-updatable view, and any check options defined directly on a trigger-updatable view will be ignored). If the view or any of its base relations has an `INSTEAD` rule that causes the `INSERT` or `UPDATE` command to be rewritten, then all check options will be ignored in the

rewritten query, including any checks from automatically updatable views defined on top of the relation with the `INSTEAD` rule.

Notes

Use the `DROP VIEW` statement to drop views.

Be careful that the names and types of the view's columns will be assigned the way you want. For example:

```
CREATE VIEW vista AS SELECT 'Hello World';
```

is bad form because the column name defaults to `?column?`; also, the column data type defaults to `text`, which might not be what you wanted. Better style for a string literal in a view's result is something like:

```
CREATE VIEW vista AS SELECT text 'Hello World' AS hello;
```

Access to tables referenced in the view is determined by permissions of the view owner. In some cases, this can be used to provide secure but restricted access to the underlying tables. However, not all views are secure against tampering; see Section 40.5 for details. Functions called in the view are treated the same as if they had been called directly from the query using the view. Therefore the user of a view must have permissions to call all functions used by the view.

When `CREATE OR REPLACE VIEW` is used on an existing view, only the view's defining `SELECT` rule is changed. Other view properties, including ownership, permissions, and non-`SELECT` rules, remain unchanged. You must own the view to replace it (this includes being a member of the owning role).

Updatable Views

Simple views are automatically updatable: the system will allow `INSERT`, `UPDATE` and `DELETE` statements to be used on the view in the same way as on a regular table. A view is automatically updatable if it satisfies all of the following conditions:

- The view must have exactly one entry in its `FROM` list, which must be a table or another updatable view.
- The view definition must not contain `WITH`, `DISTINCT`, `GROUP BY`, `HAVING`, `LIMIT`, or `OFFSET` clauses at the top level.
- The view definition must not contain set operations (`UNION`, `INTERSECT` or `EXCEPT`) at the top level.
- The view's select list must not contain any aggregates, window functions or set-returning functions.

An automatically updatable view may contain a mix of updatable and non-updatable columns. A column is updatable if it is a simple reference to an updatable column of the underlying base relation; otherwise the column is read-only, and an error will be raised if an `INSERT` or `UPDATE` statement attempts to assign a value to it.

If the view is automatically updatable the system will convert any `INSERT`, `UPDATE` or `DELETE` statement on the view into the corresponding statement on the underlying base relation. `INSERT` statements that have an `ON CONFLICT UPDATE` clause are fully supported.

If an automatically updatable view contains a `WHERE` condition, the condition restricts which rows of the base relation are available to be modified by `UPDATE` and `DELETE` statements on the view. However, an `UPDATE` is allowed to change a row so that it no longer satisfies the `WHERE` condition,

and thus is no longer visible through the view. Similarly, an `INSERT` command can potentially insert base-relation rows that do not satisfy the `WHERE` condition and thus are not visible through the view (ON `CONFLICT UPDATE` may similarly affect an existing row not visible through the view). The `CHECK OPTION` may be used to prevent `INSERT` and `UPDATE` commands from creating such rows that are not visible through the view.

If an automatically updatable view is marked with the `security_barrier` property then all the view's `WHERE` conditions (and any conditions using operators which are marked as `LEAKPROOF`) will always be evaluated before any conditions that a user of the view has added. See Section 40.5 for full details. Note that, due to this, rows which are not ultimately returned (because they do not pass the user's `WHERE` conditions) may still end up being locked. `EXPLAIN` can be used to see which conditions are applied at the relation level (and therefore do not lock rows) and which are not.

A more complex view that does not satisfy all these conditions is read-only by default: the system will not allow an insert, update, or delete on the view. You can get the effect of an updatable view by creating `INSTEAD OF` triggers on the view, which must convert attempted inserts, etc. on the view into appropriate actions on other tables. For more information see `CREATE TRIGGER`. Another possibility is to create rules (see `CREATE RULE`), but in practice triggers are easier to understand and use correctly.

Note that the user performing the insert, update or delete on the view must have the corresponding insert, update or delete privilege on the view. In addition the view's owner must have the relevant privileges on the underlying base relations, but the user performing the update does not need any permissions on the underlying base relations (see Section 40.5).

Examples

Create a view consisting of all comedy films:

```
CREATE VIEW comedies AS
  SELECT *
  FROM films
  WHERE kind = 'Comedy';
```

This will create a view containing the columns that are in the `film` table at the time of view creation. Though `*` was used to create the view, columns added later to the table will not be part of the view.

Create a view with `LOCAL CHECK OPTION`:

```
CREATE VIEW universal_comedies AS
  SELECT *
  FROM comedies
  WHERE classification = 'U'
  WITH LOCAL CHECK OPTION;
```

This will create a view based on the `comedies` view, showing only films with `kind = 'Comedy'` and `classification = 'U'`. Any attempt to `INSERT` or `UPDATE` a row in the view will be rejected if the new row doesn't have `classification = 'U'`, but the film kind will not be checked.

Create a view with `CASCADED CHECK OPTION`:

```
CREATE VIEW pg_comedies AS
  SELECT *
  FROM comedies
  WHERE classification = 'PG'
```

```
WITH CASCADED CHECK OPTION;
```

This will create a view that checks both the kind and classification of new rows.

Create a view with a mix of updatable and non-updatable columns:

```
CREATE VIEW comedies AS
  SELECT f.*,
         country_code_to_name(f.country_code) AS country,
         (SELECT avg(r.rating)
          FROM user_ratings r
          WHERE r.film_id = f.id) AS avg_rating
  FROM films f
  WHERE f.kind = 'Comedy';
```

This view will support INSERT, UPDATE and DELETE. All the columns from the `films` table will be updatable, whereas the computed columns `country` and `avg_rating` will be read-only.

Create a recursive view consisting of the numbers from 1 to 100:

```
CREATE RECURSIVE VIEW public.nums_1_100 (n) AS
  VALUES (1)
 UNION ALL
  SELECT n+1 FROM nums_1_100 WHERE n < 100;
```

Notice that although the recursive view's name is schema-qualified in this CREATE, its internal self-reference is not schema-qualified. This is because the implicitly-created CTE's name cannot be schema-qualified.

Compatibility

CREATE OR REPLACE VIEW is a PostgreSQL language extension. So is the concept of a temporary view. The WITH (...) clause is an extension as well.

See Also

ALTER VIEW, DROP VIEW, CREATE MATERIALIZED VIEW

DEALLOCATE

DEALLOCATE — deallocate a prepared statement

Synopsis

```
DEALLOCATE [ PREPARE ] { name | ALL }
```

Description

DEALLOCATE is used to deallocate a previously prepared SQL statement. If you do not explicitly deallocate a prepared statement, it is deallocated when the session ends.

For more information on prepared statements, see PREPARE.

Parameters

PREPARE

This key word is ignored.

name

The name of the prepared statement to deallocate.

ALL

Deallocate all prepared statements.

Compatibility

The SQL standard includes a DEALLOCATE statement, but it is only for use in embedded SQL.

See Also

EXECUTE, PREPARE

DECLARE

DECLARE — define a cursor

Synopsis

```
DECLARE name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]  
        CURSOR [ { WITH | WITHOUT } HOLD ] FOR query
```

Description

DECLARE allows a user to create cursors, which can be used to retrieve a small number of rows at a time out of a larger query. After the cursor is created, rows are fetched from it using FETCH.

Note

This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different — see Section 42.7.

Parameters

name

The name of the cursor to be created.

BINARY

Causes the cursor to return data in binary rather than in text format.

INSENSITIVE

Indicates that data retrieved from the cursor should be unaffected by updates to the table(s) underlying the cursor that occur after the cursor is created. In PostgreSQL, this is the default behavior; so this key word has no effect and is only accepted for compatibility with the SQL standard.

SCROLL

NO SCROLL

SCROLL specifies that the cursor can be used to retrieve rows in a nonsequential fashion (e.g., backward). Depending upon the complexity of the query's execution plan, specifying SCROLL might impose a performance penalty on the query's execution time. NO SCROLL specifies that the cursor cannot be used to retrieve rows in a nonsequential fashion. The default is to allow scrolling in some cases; this is not the same as specifying SCROLL. See Notes for details.

WITH HOLD

WITHOUT HOLD

WITH HOLD specifies that the cursor can continue to be used after the transaction that created it successfully commits. WITHOUT HOLD specifies that the cursor cannot be used outside of the transaction that created it. If neither WITHOUT HOLD nor WITH HOLD is specified, WITHOUT HOLD is the default.

query

A SELECT or VALUES command which will provide the rows to be returned by the cursor.

The key words `BINARY`, `INSENSITIVE`, and `SCROLL` can appear in any order.

Notes

Normal cursors return data in text format, the same as a `SELECT` would produce. The `BINARY` option specifies that the cursor should return data in binary format. This reduces conversion effort for both the server and client, at the cost of more programmer effort to deal with platform-dependent binary data formats. As an example, if a query returns a value of one from an integer column, you would get a string of 1 with a default cursor, whereas with a binary cursor you would get a 4-byte field containing the internal representation of the value (in big-endian byte order).

Binary cursors should be used carefully. Many applications, including `psql`, are not prepared to handle binary cursors and expect data to come back in the text format.

Note

When the client application uses the “extended query” protocol to issue a `FETCH` command, the Bind protocol message specifies whether data is to be retrieved in text or binary format. This choice overrides the way that the cursor is defined. The concept of a binary cursor as such is thus obsolete when using extended query protocol — any cursor can be treated as either text or binary.

Unless `WITH HOLD` is specified, the cursor created by this command can only be used within the current transaction. Thus, `DECLARE` without `WITH HOLD` is useless outside a transaction block: the cursor would survive only to the completion of the statement. Therefore PostgreSQL reports an error if such a command is used outside a transaction block. Use `BEGIN` and `COMMIT` (or `ROLLBACK`) to define a transaction block.

If `WITH HOLD` is specified and the transaction that created the cursor successfully commits, the cursor can continue to be accessed by subsequent transactions in the same session. (But if the creating transaction is aborted, the cursor is removed.) A cursor created with `WITH HOLD` is closed when an explicit `CLOSE` command is issued on it, or the session ends. In the current implementation, the rows represented by a held cursor are copied into a temporary file or memory area so that they remain available for subsequent transactions.

`WITH HOLD` may not be specified when the query includes `FOR UPDATE` or `FOR SHARE`.

The `SCROLL` option should be specified when defining a cursor that will be used to fetch backwards. This is required by the SQL standard. However, for compatibility with earlier versions, PostgreSQL will allow backward fetches without `SCROLL`, if the cursor's query plan is simple enough that no extra overhead is needed to support it. However, application developers are advised not to rely on using backward fetches from a cursor that has not been created with `SCROLL`. If `NO SCROLL` is specified, then backward fetches are disallowed in any case.

Backward fetches are also disallowed when the query includes `FOR UPDATE` or `FOR SHARE`; therefore `SCROLL` may not be specified in this case.

Caution

Scrollable and `WITH HOLD` cursors may give unexpected results if they invoke any volatile functions (see Section 37.7). When a previously fetched row is re-fetched, the functions might be re-executed, perhaps leading to results different from the first time. One workaround for such cases is to declare the cursor `WITH HOLD` and commit the transaction before reading any rows from it. This will force the entire output of the cursor to be materialized in temporary storage, so that volatile functions are executed exactly once for each row.

If the cursor's query includes `FOR UPDATE` or `FOR SHARE`, then returned rows are locked at the time they are first fetched, in the same way as for a regular `SELECT` command with these options. In addition, the returned rows will be the most up-to-date versions; therefore these options provide the equivalent of what the SQL standard calls a “sensitive cursor”. (Specifying `INSENSITIVE` together with `FOR UPDATE` or `FOR SHARE` is an error.)

Caution

It is generally recommended to use `FOR UPDATE` if the cursor is intended to be used with `UPDATE ... WHERE CURRENT OF` or `DELETE ... WHERE CURRENT OF`. Using `FOR UPDATE` prevents other sessions from changing the rows between the time they are fetched and the time they are updated. Without `FOR UPDATE`, a subsequent `WHERE CURRENT OF` command will have no effect if the row was changed since the cursor was created.

Another reason to use `FOR UPDATE` is that without it, a subsequent `WHERE CURRENT OF` might fail if the cursor query does not meet the SQL standard's rules for being “simply updatable” (in particular, the cursor must reference just one table and not use grouping or `ORDER BY`). Cursors that are not simply updatable might work, or might not, depending on plan choice details; so in the worst case, an application might work in testing and then fail in production. If `FOR UPDATE` is specified, the cursor is guaranteed to be updatable.

The main reason not to use `FOR UPDATE` with `WHERE CURRENT OF` is if you need the cursor to be scrollable, or to be insensitive to the subsequent updates (that is, continue to show the old data). If this is a requirement, pay close heed to the caveats shown above.

The SQL standard only makes provisions for cursors in embedded SQL. The PostgreSQL server does not implement an `OPEN` statement for cursors; a cursor is considered to be open when it is declared. However, ECPG, the embedded SQL preprocessor for PostgreSQL, supports the standard SQL cursor conventions, including those involving `DECLARE` and `OPEN` statements.

You can see all available cursors by querying the `pg_cursors` system view.

Examples

To declare a cursor:

```
DECLARE liahona CURSOR FOR SELECT * FROM films;
```

See `FETCH` for more examples of cursor usage.

Compatibility

The SQL standard says that it is implementation-dependent whether cursors are sensitive to concurrent updates of the underlying data by default. In PostgreSQL, cursors are insensitive by default, and can be made sensitive by specifying `FOR UPDATE`. Other products may work differently.

The SQL standard allows cursors only in embedded SQL and in modules. PostgreSQL permits cursors to be used interactively.

Binary cursors are a PostgreSQL extension.

See Also

`CLOSE`, `FETCH`, `MOVE`

DELETE

DELETE — delete rows of a table

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
DELETE FROM [ ONLY ] table_name [ * ] [ [ AS ] alias ]
    [ USING using_list ]
    [ WHERE condition | WHERE CURRENT OF cursor_name ]
    [ RETURNING * | output_expression [ [ AS ] output_name ]
    [, ...] ]
```

Description

DELETE deletes rows that satisfy the WHERE clause from the specified table. If the WHERE clause is absent, the effect is to delete all rows in the table. The result is a valid, but empty table.

<p style="text-align: center;">Tip</p>

<p>TRUNCATE provides a faster mechanism to remove all rows from a table.</p>
--

There are two ways to delete rows in a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the USING clause. Which technique is more appropriate depends on the specific circumstances.

The optional RETURNING clause causes DELETE to compute and return value(s) based on each row actually deleted. Any expression using the table's columns, and/or columns of other tables mentioned in USING, can be computed. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have the DELETE privilege on the table to delete from it, as well as the SELECT privilege for any table in the USING clause or whose values are read in the *condition*.

Parameters

with_query

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the DELETE query. See Section 7.8 and SELECT for details.

table_name

The name (optionally schema-qualified) of the table to delete rows from. If ONLY is specified before the table name, matching rows are deleted from the named table only. If ONLY is not specified, matching rows are also deleted from any tables inheriting from the named table. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

alias

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given DELETE FROM foo AS f, the remainder of the DELETE statement must refer to this table as f not foo.

using_list

A list of table expressions, allowing columns from other tables to appear in the `WHERE` condition. This is similar to the list of tables that can be specified in the `FROM` Clause of a `SELECT` statement; for example, an alias for the table name can be specified. Do not repeat the target table in the *using_list*, unless you wish to set up a self-join.

condition

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be deleted.

cursor_name

The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be deleted is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the `DELETE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with a Boolean condition. See `DECLARE` for more information about using cursors with `WHERE CURRENT OF`.

output_expression

An expression to be computed and returned by the `DELETE` command after each row is deleted. The expression can use any column names of the table named by *table_name* or table(s) listed in `USING`. Write `*` to return all columns.

output_name

A name to use for a returned column.

Outputs

On successful completion, a `DELETE` command returns a command tag of the form

```
DELETE count
```

The *count* is the number of rows deleted. Note that the number may be less than the number of rows that matched the *condition* when deletes were suppressed by a `BEFORE DELETE` trigger. If *count* is 0, no rows were deleted by the query (this is not considered an error).

If the `DELETE` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) deleted by the command.

Notes

PostgreSQL lets you reference columns of other tables in the `WHERE` condition by specifying the other tables in the `USING` clause. For example, to delete all films produced by a given producer, one can do:

```
DELETE FROM films USING producers
  WHERE producer_id = producers.id AND producers.name = 'foo';
```

What is essentially happening here is a join between `films` and `producers`, with all successfully joined `films` rows being marked for deletion. This syntax is not standard. A more standard way to do it is:

```
DELETE FROM films
```

```
WHERE producer_id IN (SELECT id FROM producers WHERE name =  
'foo');
```

In some cases the join style is easier to write or faster to execute than the sub-select style.

Examples

Delete all films but musicals:

```
DELETE FROM films WHERE kind <> 'Musical';
```

Clear the table films:

```
DELETE FROM films;
```

Delete completed tasks, returning full details of the deleted rows:

```
DELETE FROM tasks WHERE status = 'DONE' RETURNING *;
```

Delete the row of tasks on which the cursor `c_tasks` is currently positioned:

```
DELETE FROM tasks WHERE CURRENT OF c_tasks;
```

Compatibility

This command conforms to the SQL standard, except that the `USING` and `RETURNING` clauses are PostgreSQL extensions, as is the ability to use `WITH` with `DELETE`.

See Also

`TRUNCATE`

DISCARD

DISCARD — discard session state

Synopsis

```
DISCARD { ALL | PLANS | SEQUENCES | TEMPORARY | TEMP }
```

Description

DISCARD releases internal resources associated with a database session. This command is useful for partially or fully resetting the session's state. There are several subcommands to release different types of resources; the DISCARD ALL variant subsumes all the others, and also resets additional state.

Parameters

PLANS

Releases all cached query plans, forcing re-planning to occur the next time the associated prepared statement is used.

SEQUENCES

Discards all cached sequence-related state, including `currval()`/`lastval()` information and any preallocated sequence values that have not yet been returned by `nextval()`. (See CREATE SEQUENCE for a description of preallocated sequence values.)

TEMPORARY or TEMP

Drops all temporary tables created in the current session.

ALL

Releases all temporary resources associated with the current session and resets the session to its initial state. Currently, this has the same effect as executing the following sequence of statements:

```
CLOSE ALL;  
SET SESSION AUTHORIZATION DEFAULT;  
RESET ALL;  
DEALLOCATE ALL;  
UNLISTEN *;  
SELECT pg_advisory_unlock_all();  
DISCARD PLANS;  
DISCARD TEMP;  
DISCARD SEQUENCES;
```

Notes

DISCARD ALL cannot be executed inside a transaction block.

Compatibility

DISCARD is a PostgreSQL extension.

DO

DO — execute an anonymous code block

Synopsis

```
DO [ LANGUAGE lang_name ] code
```

Description

DO executes an anonymous code block, or in other words a transient anonymous function in a procedural language.

The code block is treated as though it were the body of a function with no parameters, returning `void`. It is parsed and executed a single time.

The optional `LANGUAGE` clause can be written either before or after the code block.

Parameters

code

The procedural language code to be executed. This must be specified as a string literal, just as in `CREATE FUNCTION`. Use of a dollar-quoted literal is recommended.

lang_name

The name of the procedural language the code is written in. If omitted, the default is `plpgsql`.

Notes

The procedural language to be used must already have been installed into the current database by means of `CREATE EXTENSION`. `plpgsql` is installed by default, but other languages are not.

The user must have `USAGE` privilege for the procedural language, or must be a superuser if the language is untrusted. This is the same privilege requirement as for creating a function in the language.

If `DO` is executed in a transaction block, then the procedure code cannot execute transaction control statements. Transaction control statements are only allowed if `DO` is executed in its own transaction.

Examples

Grant all privileges on all views in schema `public` to role `webuser`:

```
DO $$DECLARE r record;
BEGIN
    FOR r IN SELECT table_schema, table_name FROM
information_schema.tables
            WHERE table_type = 'VIEW' AND table_schema = 'public'
    LOOP
        EXECUTE 'GRANT ALL ON ' || quote_ident(r.table_schema) ||
'.' || quote_ident(r.table_name) || ' TO webuser';
    END LOOP;
END $$;
```

END\$\$;

Compatibility

There is no DO statement in the SQL standard.

See Also

CREATE LANGUAGE

DROP ACCESS METHOD

DROP ACCESS METHOD — remove an access method

Synopsis

```
DROP ACCESS METHOD [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP ACCESS METHOD removes an existing access method. Only superusers can drop access methods.

Parameters

IF EXISTS

Do not throw an error if the access method does not exist. A notice is issued in this case.

name

The name of an existing access method.

CASCADE

Automatically drop objects that depend on the access method (such as operator classes, operator families, and indexes), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the access method if any objects depend on it. This is the default.

Examples

Drop the access method `heptree`:

```
DROP ACCESS METHOD heptree;
```

Compatibility

DROP ACCESS METHOD is a PostgreSQL extension.

See Also

CREATE ACCESS METHOD

DROP AGGREGATE

DROP AGGREGATE — remove an aggregate function

Synopsis

```
DROP AGGREGATE [ IF EXISTS ] name ( aggregate_signature ) [ , ... ]  
[ CASCADE | RESTRICT ]
```

where *aggregate_signature* is:

```
* |  
[ argmode ] [ argname ] argtype [ , ... ] |  
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]  
[ argname ] argtype [ , ... ]
```

Description

DROP AGGREGATE removes an existing aggregate function. To execute this command the current user must be the owner of the aggregate function.

Parameters

IF EXISTS

Do not throw an error if the aggregate does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing aggregate function.

argmode

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

argname

The name of an argument. Note that DROP AGGREGATE does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

argtype

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write * in place of the list of argument specifications. To reference an ordered-set aggregate function, write ORDER BY between the direct and aggregated argument specifications.

CASCADE

Automatically drop objects that depend on the aggregate function (such as views using it), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the aggregate function if any objects depend on it. This is the default.

Notes

Alternative syntaxes for referencing ordered-set aggregates are described under ALTER AGGREGATE.

Examples

To remove the aggregate function `myavg` for type `integer`:

```
DROP AGGREGATE myavg(integer);
```

To remove the hypothetical-set aggregate function `myrank`, which takes an arbitrary list of ordering columns and a matching list of direct arguments:

```
DROP AGGREGATE myrank(VARIADIC "any" ORDER BY VARIADIC "any");
```

To remove multiple aggregate functions in one command:

```
DROP AGGREGATE myavg(integer), myavg(bigint);
```

Compatibility

There is no `DROP AGGREGATE` statement in the SQL standard.

See Also

ALTER AGGREGATE, CREATE AGGREGATE

DROP CAST

DROP CAST — remove a cast

Synopsis

```
DROP CAST [ IF EXISTS ] (source_type AS target_type) [ CASCADE |  
RESTRICT ]
```

Description

DROP CAST removes a previously defined cast.

To be able to drop a cast, you must own the source or the target data type. These are the same privileges that are required to create a cast.

Parameters

IF EXISTS

Do not throw an error if the cast does not exist. A notice is issued in this case.

source_type

The name of the source data type of the cast.

target_type

The name of the target data type of the cast.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on casts.

Examples

To drop the cast from type text to type int:

```
DROP CAST (text AS int);
```

Compatibility

The DROP CAST command conforms to the SQL standard.

See Also

CREATE CAST

DROP COLLATION

DROP COLLATION — remove a collation

Synopsis

```
DROP COLLATION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP COLLATION removes a previously defined collation. To be able to drop a collation, you must own the collation.

Parameters

IF EXISTS

Do not throw an error if the collation does not exist. A notice is issued in this case.

name

The name of the collation. The collation name can be schema-qualified.

CASCADE

Automatically drop objects that depend on the collation, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the collation if any objects depend on it. This is the default.

Examples

To drop the collation named `german`:

```
DROP COLLATION german;
```

Compatibility

The DROP COLLATION command conforms to the SQL standard, apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER COLLATION, CREATE COLLATION

DROP CONVERSION

DROP CONVERSION — remove a conversion

Synopsis

```
DROP CONVERSION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP CONVERSION removes a previously defined conversion. To be able to drop a conversion, you must own the conversion.

Parameters

IF EXISTS

Do not throw an error if the conversion does not exist. A notice is issued in this case.

name

The name of the conversion. The conversion name can be schema-qualified.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on conversions.

Examples

To drop the conversion named myname:

```
DROP CONVERSION myname ;
```

Compatibility

There is no DROP CONVERSION statement in the SQL standard, but a DROP TRANSLATION statement that goes along with the CREATE TRANSLATION statement that is similar to the CREATE CONVERSION statement in PostgreSQL.

See Also

ALTER CONVERSION, CREATE CONVERSION

DROP DATABASE

DROP DATABASE — remove a database

Synopsis

```
DROP DATABASE [ IF EXISTS ] name
```

Description

DROP DATABASE drops a database. It removes the catalog entries for the database and deletes the directory containing the data. It can only be executed by the database owner. Also, it cannot be executed while you or anyone else are connected to the target database. (Connect to `postgres` or any other database to issue this command.)

DROP DATABASE cannot be undone. Use it with care!

Parameters

IF EXISTS

Do not throw an error if the database does not exist. A notice is issued in this case.

name

The name of the database to remove.

Notes

DROP DATABASE cannot be executed inside a transaction block.

This command cannot be executed while connected to the target database. Thus, it might be more convenient to use the program `dropdb` instead, which is a wrapper around this command.

Compatibility

There is no DROP DATABASE statement in the SQL standard.

See Also

CREATE DATABASE

DROP DOMAIN

DROP DOMAIN — remove a domain

Synopsis

```
DROP DOMAIN [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP DOMAIN removes a domain. Only the owner of a domain can remove it.

Parameters

IF EXISTS

Do not throw an error if the domain does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing domain.

CASCADE

Automatically drop objects that depend on the domain (such as table columns), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the domain if any objects depend on it. This is the default.

Examples

To remove the domain `box`:

```
DROP DOMAIN box;
```

Compatibility

This command conforms to the SQL standard, except for the IF EXISTS option, which is a PostgreSQL extension.

See Also

CREATE DOMAIN, ALTER DOMAIN

DROP EVENT TRIGGER

DROP EVENT TRIGGER — remove an event trigger

Synopsis

```
DROP EVENT TRIGGER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP EVENT TRIGGER removes an existing event trigger. To execute this command, the current user must be the owner of the event trigger.

Parameters

IF EXISTS

Do not throw an error if the event trigger does not exist. A notice is issued in this case.

name

The name of the event trigger to remove.

CASCADE

Automatically drop objects that depend on the trigger, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the trigger if any objects depend on it. This is the default.

Examples

Destroy the trigger `snitch`:

```
DROP EVENT TRIGGER snitch;
```

Compatibility

There is no DROP EVENT TRIGGER statement in the SQL standard.

See Also

CREATE EVENT TRIGGER, ALTER EVENT TRIGGER

DROP EXTENSION

DROP EXTENSION — remove an extension

Synopsis

```
DROP EXTENSION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP EXTENSION removes extensions from the database. Dropping an extension causes its component objects to be dropped as well.

You must own the extension to use DROP EXTENSION.

Parameters

IF EXISTS

Do not throw an error if the extension does not exist. A notice is issued in this case.

name

The name of an installed extension.

CASCADE

Automatically drop objects that depend on the extension, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the extension if any objects depend on it (other than its own member objects and other extensions listed in the same DROP command). This is the default.

Examples

To remove the extension `hstore` from the current database:

```
DROP EXTENSION hstore;
```

This command will fail if any of `hstore`'s objects are in use in the database, for example if any tables have columns of the `hstore` type. Add the `CASCADE` option to forcibly remove those dependent objects as well.

Compatibility

DROP EXTENSION is a PostgreSQL extension.

See Also

CREATE EXTENSION, ALTER EXTENSION

DROP FOREIGN DATA WRAPPER

DROP FOREIGN DATA WRAPPER — remove a foreign-data wrapper

Synopsis

```
DROP FOREIGN DATA WRAPPER [ IF EXISTS ] name [, ...] [ CASCADE |  
RESTRICT ]
```

Description

DROP FOREIGN DATA WRAPPER removes an existing foreign-data wrapper. To execute this command, the current user must be the owner of the foreign-data wrapper.

Parameters

IF EXISTS

Do not throw an error if the foreign-data wrapper does not exist. A notice is issued in this case.

name

The name of an existing foreign-data wrapper.

CASCADE

Automatically drop objects that depend on the foreign-data wrapper (such as foreign tables and servers), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the foreign-data wrapper if any objects depend on it. This is the default.

Examples

Drop the foreign-data wrapper `dbi`:

```
DROP FOREIGN DATA WRAPPER dbi;
```

Compatibility

DROP FOREIGN DATA WRAPPER conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a PostgreSQL extension.

See Also

CREATE FOREIGN DATA WRAPPER, ALTER FOREIGN DATA WRAPPER

DROP FOREIGN TABLE

DROP FOREIGN TABLE — remove a foreign table

Synopsis

```
DROP FOREIGN TABLE [ IF EXISTS ] name [, ...] [ CASCADE |  
RESTRICT ]
```

Description

DROP FOREIGN TABLE removes a foreign table. Only the owner of a foreign table can remove it.

Parameters

IF EXISTS

Do not throw an error if the foreign table does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the foreign table to drop.

CASCADE

Automatically drop objects that depend on the foreign table (such as views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the foreign table if any objects depend on it. This is the default.

Examples

To destroy two foreign tables, `films` and `distributors`:

```
DROP FOREIGN TABLE films, distributors;
```

Compatibility

This command conforms to the ISO/IEC 9075-9 (SQL/MED), except that the standard only allows one foreign table to be dropped per command, and apart from the `IF EXISTS` option, which is a PostgreSQL extension.

See Also

ALTER FOREIGN TABLE, CREATE FOREIGN TABLE

DROP FUNCTION

DROP FUNCTION — remove a function

Synopsis

```
DROP FUNCTION [ IF EXISTS ] name [ ( [ [ argmode ] [ argname ] ] argtype [ , ... ] ) ] [ , ... ]  
[ CASCADE | RESTRICT ]
```

Description

DROP FUNCTION removes the definition of an existing function. To execute this command the user must be the owner of the function. The argument types to the function must be specified, since several different functions can exist with the same name and different argument lists.

Parameters

IF EXISTS

Do not throw an error if the function does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing function. If no argument list is specified, the name must be unique in its schema.

argmode

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that DROP FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of an argument. Note that DROP FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type(s) of the function's arguments (optionally schema-qualified), if any.

CASCADE

Automatically drop objects that depend on the function (such as operators or triggers), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the function if any objects depend on it. This is the default.

Examples

This command removes the square root function:

```
DROP FUNCTION sqrt(integer);
```

Drop multiple functions in one command:

```
DROP FUNCTION sqrt(integer), sqrt(bigint);
```

If the function name is unique in its schema, it can be referred to without an argument list:

```
DROP FUNCTION update_employee_salaries;
```

Note that this is different from

```
DROP FUNCTION update_employee_salaries();
```

which refers to a function with zero arguments, whereas the first variant can refer to a function with any number of arguments, including zero, as long as the name is unique.

Compatibility

This command conforms to the SQL standard, with these PostgreSQL extensions:

- The standard only allows one function to be dropped per command.
- The `IF EXISTS` option
- The ability to specify argument modes and names

See Also

`CREATE FUNCTION`, `ALTER FUNCTION`, `DROP PROCEDURE`, `DROP ROUTINE`

DROP GROUP

DROP GROUP — remove a database role

Synopsis

```
DROP GROUP [ IF EXISTS ] name [, ...]
```

Description

DROP GROUP is now an alias for DROP ROLE.

Compatibility

There is no DROP GROUP statement in the SQL standard.

See Also

DROP ROLE

DROP INDEX

DROP INDEX — remove an index

Synopsis

```
DROP INDEX [ CONCURRENTLY ] [ IF EXISTS ] name [, ...] [ CASCADE |  
RESTRICT ]
```

Description

DROP INDEX drops an existing index from the database system. To execute this command you must be the owner of the index.

Parameters

CONCURRENTLY

Drop the index without locking out concurrent selects, inserts, updates, and deletes on the index's table. A normal DROP INDEX acquires exclusive lock on the table, blocking other accesses until the index drop can be completed. With this option, the command instead waits until conflicting transactions have completed.

There are several caveats to be aware of when using this option. Only one index name can be specified, and the CASCADE option is not supported. (Thus, an index that supports a UNIQUE or PRIMARY KEY constraint cannot be dropped this way.) Also, regular DROP INDEX commands can be performed within a transaction block, but DROP INDEX CONCURRENTLY cannot.

IF EXISTS

Do not throw an error if the index does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an index to remove.

CASCADE

Automatically drop objects that depend on the index, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the index if any objects depend on it. This is the default.

Examples

This command will remove the index `title_idx`:

```
DROP INDEX title_idx;
```

Compatibility

DROP INDEX is a PostgreSQL language extension. There are no provisions for indexes in the SQL standard.

See Also

CREATE INDEX

DROP LANGUAGE

DROP LANGUAGE — remove a procedural language

Synopsis

```
DROP [ PROCEDURAL ] LANGUAGE [ IF EXISTS ] name [ CASCADE |  
RESTRICT ]
```

Description

DROP LANGUAGE removes the definition of a previously registered procedural language. You must be a superuser or the owner of the language to use DROP LANGUAGE.

Note

As of PostgreSQL 9.1, most procedural languages have been made into “extensions”, and should therefore be removed with DROP EXTENSION not DROP LANGUAGE.

Parameters

IF EXISTS

Do not throw an error if the language does not exist. A notice is issued in this case.

name

The name of an existing procedural language. For backward compatibility, the name can be enclosed by single quotes.

CASCADE

Automatically drop objects that depend on the language (such as functions in the language), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the language if any objects depend on it. This is the default.

Examples

This command removes the procedural language `plsample`:

```
DROP LANGUAGE plsample;
```

Compatibility

There is no DROP LANGUAGE statement in the SQL standard.

See Also

ALTER LANGUAGE, CREATE LANGUAGE

DROP MATERIALIZED VIEW

DROP MATERIALIZED VIEW — remove a materialized view

Synopsis

```
DROP MATERIALIZED VIEW [ IF EXISTS ] name [, ...] [ CASCADE |  
RESTRICT ]
```

Description

DROP MATERIALIZED VIEW drops an existing materialized view. To execute this command you must be the owner of the materialized view.

Parameters

IF EXISTS

Do not throw an error if the materialized view does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the materialized view to remove.

CASCADE

Automatically drop objects that depend on the materialized view (such as other materialized views, or regular views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the materialized view if any objects depend on it. This is the default.

Examples

This command will remove the materialized view called `order_summary`:

```
DROP MATERIALIZED VIEW order_summary;
```

Compatibility

DROP MATERIALIZED VIEW is a PostgreSQL extension.

See Also

CREATE MATERIALIZED VIEW, ALTER MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

DROP OPERATOR

DROP OPERATOR — remove an operator

Synopsis

```
DROP OPERATOR [ IF EXISTS ] name ( { left_type | NONE } ,  
  { right_type | NONE } ) [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP OPERATOR drops an existing operator from the database system. To execute this command you must be the owner of the operator.

Parameters

IF EXISTS

Do not throw an error if the operator does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing operator.

left_type

The data type of the operator's left operand; write NONE if the operator has no left operand.

right_type

The data type of the operator's right operand; write NONE if the operator has no right operand.

CASCADE

Automatically drop objects that depend on the operator (such as views using it), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the operator if any objects depend on it. This is the default.

Examples

Remove the power operator a^b for type integer:

```
DROP OPERATOR ^ (integer, integer);
```

Remove the left unary bitwise complement operator $\sim b$ for type bit:

```
DROP OPERATOR ~ (none, bit);
```

Remove the right unary factorial operator $x!$ for type bigint:

```
DROP OPERATOR ! (bigint, none);
```

Remove multiple operators in one command:

```
DROP OPERATOR ~ (none, bit), ! (bigint, none);
```

Compatibility

There is no `DROP OPERATOR` statement in the SQL standard.

See Also

`CREATE OPERATOR`, `ALTER OPERATOR`

DROP OPERATOR CLASS

DROP OPERATOR CLASS — remove an operator class

Synopsis

```
DROP OPERATOR CLASS [ IF EXISTS ] name USING index_method [ CASCADE  
| RESTRICT ]
```

Description

DROP OPERATOR CLASS drops an existing operator class. To execute this command you must be the owner of the operator class.

DROP OPERATOR CLASS does not drop any of the operators or functions referenced by the class. If there are any indexes depending on the operator class, you will need to specify CASCADE for the drop to complete.

Parameters

IF EXISTS

Do not throw an error if the operator class does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing operator class.

index_method

The name of the index access method the operator class is for.

CASCADE

Automatically drop objects that depend on the operator class (such as indexes), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the operator class if any objects depend on it. This is the default.

Notes

DROP OPERATOR CLASS will not drop the operator family containing the class, even if there is nothing else left in the family (in particular, in the case where the family was implicitly created by CREATE OPERATOR CLASS). An empty operator family is harmless, but for the sake of tidiness you might wish to remove the family with DROP OPERATOR FAMILY; or perhaps better, use DROP OPERATOR FAMILY in the first place.

Examples

Remove the B-tree operator class `widget_ops`:

```
DROP OPERATOR CLASS widget_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator class. Add `CASCADE` to drop such indexes along with the operator class.

Compatibility

There is no `DROP OPERATOR CLASS` statement in the SQL standard.

See Also

`ALTER OPERATOR CLASS`, `CREATE OPERATOR CLASS`, `DROP OPERATOR FAMILY`

DROP OPERATOR FAMILY

DROP OPERATOR FAMILY — remove an operator family

Synopsis

```
DROP OPERATOR FAMILY [ IF EXISTS ] name USING index_method
[ CASCADE | RESTRICT ]
```

Description

DROP OPERATOR FAMILY drops an existing operator family. To execute this command you must be the owner of the operator family.

DROP OPERATOR FAMILY includes dropping any operator classes contained in the family, but it does not drop any of the operators or functions referenced by the family. If there are any indexes depending on operator classes within the family, you will need to specify CASCADE for the drop to complete.

Parameters

IF EXISTS

Do not throw an error if the operator family does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing operator family.

index_method

The name of the index access method the operator family is for.

CASCADE

Automatically drop objects that depend on the operator family, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the operator family if any objects depend on it. This is the default.

Examples

Remove the B-tree operator family `float_ops`:

```
DROP OPERATOR FAMILY float_ops USING btree;
```

This command will not succeed if there are any existing indexes that use operator classes within the family. Add CASCADE to drop such indexes along with the operator family.

Compatibility

There is no DROP OPERATOR FAMILY statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, CREATE OPERATOR FAMILY, ALTER OPERATOR CLASS,
CREATE OPERATOR CLASS, DROP OPERATOR CLASS

DROP OWNED

DROP OWNED — remove database objects owned by a database role

Synopsis

```
DROP OWNED BY { name | CURRENT_USER | SESSION_USER } [, ...]  
[ CASCADE | RESTRICT ]
```

Description

DROP OWNED drops all the objects within the current database that are owned by one of the specified roles. Any privileges granted to the given roles on objects in the current database or on shared objects (databases, tablespaces) will also be revoked.

Parameters

name

The name of a role whose objects will be dropped, and whose privileges will be revoked.

CASCADE

Automatically drop objects that depend on the affected objects, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the objects owned by a role if any other database objects depend on one of the affected objects. This is the default.

Notes

DROP OWNED is often used to prepare for the removal of one or more roles. Because DROP OWNED only affects the objects in the current database, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.

Using the CASCADE option might make the command recurse to objects owned by other users.

The REASSIGN OWNED command is an alternative that reassigns the ownership of all the database objects owned by one or more roles. However, REASSIGN OWNED does not deal with privileges for other objects.

Databases and tablespaces owned by the role(s) will not be removed.

See Section 21.4 for more discussion.

Compatibility

The DROP OWNED command is a PostgreSQL extension.

See Also

REASSIGN OWNED, DROP ROLE

DROP POLICY

DROP POLICY — remove a row level security policy from a table

Synopsis

```
DROP POLICY [ IF EXISTS ] name ON table_name [ CASCADE | RESTRICT ]
```

Description

DROP POLICY removes the specified policy from the table. Note that if the last policy is removed for a table and the table still has row level security enabled via ALTER TABLE, then the default-deny policy will be used. ALTER TABLE ... DISABLE ROW LEVEL SECURITY can be used to disable row level security for a table, whether policies for the table exist or not.

Parameters

IF EXISTS

Do not throw an error if the policy does not exist. A notice is issued in this case.

name

The name of the policy to drop.

table_name

The name (optionally schema-qualified) of the table that the policy is on.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on policies.

Examples

To drop the policy called p1 on the table named my_table:

```
DROP POLICY p1 ON my_table;
```

Compatibility

DROP POLICY is a PostgreSQL extension.

See Also

CREATE POLICY, ALTER POLICY

DROP PROCEDURE

DROP PROCEDURE — remove a procedure

Synopsis

```
DROP PROCEDURE [ IF EXISTS ] name [ ( [ [ argmode ] [ argname  
] argtype [ , ... ] ] ) ] [ , ... ]  
[ CASCADE | RESTRICT ]
```

Description

DROP PROCEDURE removes the definition of an existing procedure. To execute this command the user must be the owner of the procedure. The argument types to the procedure must be specified, since several different procedures can exist with the same name and different argument lists.

Parameters

IF EXISTS

Do not throw an error if the procedure does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing procedure. If no argument list is specified, the name must be unique in its schema.

argmode

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

argname

The name of an argument. Note that DROP PROCEDURE does not actually pay any attention to argument names, since only the argument data types are needed to determine the procedure's identity.

argtype

The data type(s) of the procedure's arguments (optionally schema-qualified), if any.

CASCADE

Automatically drop objects that depend on the procedure, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the procedure if any objects depend on it. This is the default.

Examples

```
DROP PROCEDURE do_db_maintenance();
```

Compatibility

This command conforms to the SQL standard, with these PostgreSQL extensions:

- The standard only allows one procedure to be dropped per command.
- The `IF EXISTS` option
- The ability to specify argument modes and names

See Also

`CREATE PROCEDURE`, `ALTER PROCEDURE`, `DROP FUNCTION`, `DROP ROUTINE`

DROP PUBLICATION

DROP PUBLICATION — remove a publication

Synopsis

```
DROP PUBLICATION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP PUBLICATION removes an existing publication from the database.

A publication can only be dropped by its owner or a superuser.

Parameters

IF EXISTS

Do not throw an error if the publication does not exist. A notice is issued in this case.

name

The name of an existing publication.

CASCADE

RESTRICT

These key words do not have any effect, since there are no dependencies on publications.

Examples

Drop a publication:

```
DROP PUBLICATION mypublication;
```

Compatibility

DROP PUBLICATION is a PostgreSQL extension.

See Also

CREATE PUBLICATION, ALTER PUBLICATION

DROP ROLE

DROP ROLE — remove a database role

Synopsis

```
DROP ROLE [ IF EXISTS ] name [, ...]
```

Description

DROP ROLE removes the specified role(s). To drop a superuser role, you must be a superuser yourself; to drop non-superuser roles, you must have CREATEROLE privilege.

A role cannot be removed if it is still referenced in any database of the cluster; an error will be raised if so. Before dropping the role, you must drop all the objects it owns (or reassign their ownership) and revoke any privileges the role has been granted on other objects. The REASSIGN OWNED and DROP OWNED commands can be useful for this purpose; see Section 21.4 for more discussion.

However, it is not necessary to remove role memberships involving the role; DROP ROLE automatically revokes any memberships of the target role in other roles, and of other roles in the target role. The other roles are not dropped nor otherwise affected.

Parameters

IF EXISTS

Do not throw an error if the role does not exist. A notice is issued in this case.

name

The name of the role to remove.

Notes

PostgreSQL includes a program dropuser that has the same functionality as this command (in fact, it calls this command) but can be run from the command shell.

Examples

To drop a role:

```
DROP ROLE jonathan;
```

Compatibility

The SQL standard defines DROP ROLE, but it allows only one role to be dropped at a time, and it specifies different privilege requirements than PostgreSQL uses.

See Also

CREATE ROLE, ALTER ROLE, SET ROLE

DROP ROUTINE

DROP ROUTINE — remove a routine

Synopsis

```
DROP ROUTINE [ IF EXISTS ] name [ ( [ [ argmode ] [ argname ]
] argtype [, ...] ) ] [, ...]
[ CASCADE | RESTRICT ]
```

Description

DROP ROUTINE removes the definition of an existing routine, which can be an aggregate function, a normal function, or a procedure. See under DROP AGGREGATE, DROP FUNCTION, and DROP PROCEDURE for the description of the parameters, more examples, and further details.

Examples

To drop the routine `foo` for type `integer`:

```
DROP ROUTINE foo(integer);
```

This command will work independent of whether `foo` is an aggregate, function, or procedure.

Compatibility

This command conforms to the SQL standard, with these PostgreSQL extensions:

- The standard only allows one routine to be dropped per command.
- The `IF EXISTS` option
- The ability to specify argument modes and names
- Aggregate functions are an extension.

See Also

DROP AGGREGATE, DROP FUNCTION, DROP PROCEDURE, ALTER ROUTINE

Note that there is no `CREATE ROUTINE` command.

DROP RULE

DROP RULE — remove a rewrite rule

Synopsis

```
DROP RULE [ IF EXISTS ] name ON table_name [ CASCADE | RESTRICT ]
```

Description

DROP RULE drops a rewrite rule.

Parameters

IF EXISTS

Do not throw an error if the rule does not exist. A notice is issued in this case.

name

The name of the rule to drop.

table_name

The name (optionally schema-qualified) of the table or view that the rule applies to.

CASCADE

Automatically drop objects that depend on the rule, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the rule if any objects depend on it. This is the default.

Examples

To drop the rewrite rule `newrule`:

```
DROP RULE newrule ON mytable;
```

Compatibility

DROP RULE is a PostgreSQL language extension, as is the entire query rewrite system.

See Also

CREATE RULE, ALTER RULE

DROP SCHEMA

DROP SCHEMA — remove a schema

Synopsis

```
DROP SCHEMA [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP SCHEMA removes schemas from the database.

A schema can only be dropped by its owner or a superuser. Note that the owner can drop the schema (and thereby all contained objects) even if they do not own some of the objects within the schema.

Parameters

IF EXISTS

Do not throw an error if the schema does not exist. A notice is issued in this case.

name

The name of a schema.

CASCADE

Automatically drop objects (tables, functions, etc.) that are contained in the schema, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the schema if it contains any objects. This is the default.

Notes

Using the CASCADE option might make the command remove objects in other schemas besides the one(s) named.

Examples

To remove schema `mystuff` from the database, along with everything it contains:

```
DROP SCHEMA mystuff CASCADE;
```

Compatibility

DROP SCHEMA is fully conforming with the SQL standard, except that the standard only allows one schema to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER SCHEMA, CREATE SCHEMA

DROP SEQUENCE

DROP SEQUENCE — remove a sequence

Synopsis

```
DROP SEQUENCE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP SEQUENCE removes sequence number generators. A sequence can only be dropped by its owner or a superuser.

Parameters

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of a sequence.

CASCADE

Automatically drop objects that depend on the sequence, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the sequence if any objects depend on it. This is the default.

Examples

To remove the sequence `serial`:

```
DROP SEQUENCE serial;
```

Compatibility

DROP SEQUENCE conforms to the SQL standard, except that the standard only allows one sequence to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

CREATE SEQUENCE, ALTER SEQUENCE

DROP SERVER

DROP SERVER — remove a foreign server descriptor

Synopsis

```
DROP SERVER [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP SERVER removes an existing foreign server descriptor. To execute this command, the current user must be the owner of the server.

Parameters

IF EXISTS

Do not throw an error if the server does not exist. A notice is issued in this case.

name

The name of an existing server.

CASCADE

Automatically drop objects that depend on the server (such as user mappings), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the server if any objects depend on it. This is the default.

Examples

Drop a server `foo` if it exists:

```
DROP SERVER IF EXISTS foo;
```

Compatibility

DROP SERVER conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a PostgreSQL extension.

See Also

CREATE SERVER, ALTER SERVER

DROP STATISTICS

DROP STATISTICS — remove extended statistics

Synopsis

```
DROP STATISTICS [ IF EXISTS ] name [ , ... ]
```

Description

DROP STATISTICS removes statistics object(s) from the database. Only the statistics object's owner, the schema owner, or a superuser can drop a statistics object.

Parameters

IF EXISTS

Do not throw an error if the statistics object does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the statistics object to drop.

Examples

To destroy two statistics objects in different schemas, without failing if they don't exist:

```
DROP STATISTICS IF EXISTS
  accounting.users_uid_creation,
  public.grants_user_role;
```

Compatibility

There is no DROP STATISTICS command in the SQL standard.

See Also

ALTER STATISTICS, CREATE STATISTICS

DROP SUBSCRIPTION

DROP SUBSCRIPTION — remove a subscription

Synopsis

```
DROP SUBSCRIPTION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP SUBSCRIPTION removes a subscription from the database cluster.

A subscription can only be dropped by a superuser.

DROP SUBSCRIPTION cannot be executed inside a transaction block if the subscription is associated with a replication slot. (You can use ALTER SUBSCRIPTION to unset the slot.)

Parameters

name

The name of a subscription to be dropped.

CASCADE
RESTRICT

These key words do not have any effect, since there are no dependencies on subscriptions.

Notes

When dropping a subscription that is associated with a replication slot on the remote host (the normal state), DROP SUBSCRIPTION will connect to the remote host and try to drop the replication slot as part of its operation. This is necessary so that the resources allocated for the subscription on the remote host are released. If this fails, either because the remote host is not reachable or because the remote replication slot cannot be dropped or does not exist or never existed, the DROP SUBSCRIPTION command will fail. To proceed in this situation, disassociate the subscription from the replication slot by executing ALTER SUBSCRIPTION ... SET (slot_name = NONE). After that, DROP SUBSCRIPTION will no longer attempt any actions on a remote host. Note that if the remote replication slot still exists, it should then be dropped manually; otherwise it will continue to reserve WAL and might eventually cause the disk to fill up. See also Section 30.2.1.

If a subscription is associated with a replication slot, then DROP SUBSCRIPTION cannot be executed inside a transaction block.

Examples

Drop a subscription:

```
DROP SUBSCRIPTION mysub;
```

Compatibility

DROP SUBSCRIPTION is a PostgreSQL extension.

See Also

CREATE SUBSCRIPTION, ALTER SUBSCRIPTION

DROP TABLE

DROP TABLE — remove a table

Synopsis

```
DROP TABLE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP TABLE removes tables from the database. Only the table owner, the schema owner, and superuser can drop a table. To empty a table of rows without destroying the table, use DELETE or TRUNCATE.

DROP TABLE always removes any indexes, rules, triggers, and constraints that exist for the target table. However, to drop a table that is referenced by a view or a foreign-key constraint of another table, CASCADE must be specified. (CASCADE will remove a dependent view entirely, but in the foreign-key case it will only remove the foreign-key constraint, not the other table entirely.)

Parameters

IF EXISTS

Do not throw an error if the table does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the table to drop.

CASCADE

Automatically drop objects that depend on the table (such as views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the table if any objects depend on it. This is the default.

Examples

To destroy two tables, `films` and `distributors`:

```
DROP TABLE films, distributors;
```

Compatibility

This command conforms to the SQL standard, except that the standard only allows one table to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER TABLE, CREATE TABLE

DROP TABLESPACE

DROP TABLESPACE — remove a tablespace

Synopsis

```
DROP TABLESPACE [ IF EXISTS ] name
```

Description

DROP TABLESPACE removes a tablespace from the system.

A tablespace can only be dropped by its owner or a superuser. The tablespace must be empty of all database objects before it can be dropped. It is possible that objects in other databases might still reside in the tablespace even if no objects in the current database are using the tablespace. Also, if the tablespace is listed in the `temp_tablespaces` setting of any active session, the DROP might fail due to temporary files residing in the tablespace.

Parameters

IF EXISTS

Do not throw an error if the tablespace does not exist. A notice is issued in this case.

name

The name of a tablespace.

Notes

DROP TABLESPACE cannot be executed inside a transaction block.

Examples

To remove tablespace `mystuff` from the system:

```
DROP TABLESPACE mystuff;
```

Compatibility

DROP TABLESPACE is a PostgreSQL extension.

See Also

CREATE TABLESPACE, ALTER TABLESPACE

DROP TEXT SEARCH CONFIGURATION

DROP TEXT SEARCH CONFIGURATION — remove a text search configuration

Synopsis

```
DROP TEXT SEARCH CONFIGURATION [ IF EXISTS ] name [ CASCADE |  
RESTRICT ]
```

Description

DROP TEXT SEARCH CONFIGURATION drops an existing text search configuration. To execute this command you must be the owner of the configuration.

Parameters

IF EXISTS

Do not throw an error if the text search configuration does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search configuration.

CASCADE

Automatically drop objects that depend on the text search configuration, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search configuration if any objects depend on it. This is the default.

Examples

Remove the text search configuration `my_english`:

```
DROP TEXT SEARCH CONFIGURATION my_english;
```

This command will not succeed if there are any existing indexes that reference the configuration in `to_tsvector` calls. Add `CASCADE` to drop such indexes along with the text search configuration.

Compatibility

There is no `DROP TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

ALTER TEXT SEARCH CONFIGURATION, CREATE TEXT SEARCH CONFIGURATION

DROP TEXT SEARCH DICTIONARY

DROP TEXT SEARCH DICTIONARY — remove a text search dictionary

Synopsis

```
DROP TEXT SEARCH DICTIONARY [ IF EXISTS ] name [ CASCADE |  
RESTRICT ]
```

Description

DROP TEXT SEARCH DICTIONARY drops an existing text search dictionary. To execute this command you must be the owner of the dictionary.

Parameters

IF EXISTS

Do not throw an error if the text search dictionary does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search dictionary.

CASCADE

Automatically drop objects that depend on the text search dictionary, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search dictionary if any objects depend on it. This is the default.

Examples

Remove the text search dictionary `english`:

```
DROP TEXT SEARCH DICTIONARY english;
```

This command will not succeed if there are any existing text search configurations that use the dictionary. Add `CASCADE` to drop such configurations along with the dictionary.

Compatibility

There is no `DROP TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

ALTER TEXT SEARCH DICTIONARY, CREATE TEXT SEARCH DICTIONARY

DROP TEXT SEARCH PARSER

DROP TEXT SEARCH PARSER — remove a text search parser

Synopsis

```
DROP TEXT SEARCH PARSER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP TEXT SEARCH PARSER drops an existing text search parser. You must be a superuser to use this command.

Parameters

IF EXISTS

Do not throw an error if the text search parser does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search parser.

CASCADE

Automatically drop objects that depend on the text search parser, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search parser if any objects depend on it. This is the default.

Examples

Remove the text search parser `my_parser`:

```
DROP TEXT SEARCH PARSER my_parser;
```

This command will not succeed if there are any existing text search configurations that use the parser. Add `CASCADE` to drop such configurations along with the parser.

Compatibility

There is no `DROP TEXT SEARCH PARSER` statement in the SQL standard.

See Also

ALTER TEXT SEARCH PARSER, CREATE TEXT SEARCH PARSER

DROP TEXT SEARCH TEMPLATE

DROP TEXT SEARCH TEMPLATE — remove a text search template

Synopsis

```
DROP TEXT SEARCH TEMPLATE [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP TEXT SEARCH TEMPLATE drops an existing text search template. You must be a superuser to use this command.

Parameters

IF EXISTS

Do not throw an error if the text search template does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search template.

CASCADE

Automatically drop objects that depend on the text search template, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the text search template if any objects depend on it. This is the default.

Examples

Remove the text search template thesaurus:

```
DROP TEXT SEARCH TEMPLATE thesaurus;
```

This command will not succeed if there are any existing text search dictionaries that use the template. Add CASCADE to drop such dictionaries along with the template.

Compatibility

There is no DROP TEXT SEARCH TEMPLATE statement in the SQL standard.

See Also

ALTER TEXT SEARCH TEMPLATE, CREATE TEXT SEARCH TEMPLATE

DROP TRANSFORM

DROP TRANSFORM — remove a transform

Synopsis

```
DROP TRANSFORM [ IF EXISTS ] FOR type_name LANGUAGE lang_name
[ CASCADE | RESTRICT ]
```

Description

DROP TRANSFORM removes a previously defined transform.

To be able to drop a transform, you must own the type and the language. These are the same privileges that are required to create a transform.

Parameters

IF EXISTS

Do not throw an error if the transform does not exist. A notice is issued in this case.

type_name

The name of the data type of the transform.

lang_name

The name of the language of the transform.

CASCADE

Automatically drop objects that depend on the transform, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the transform if any objects depend on it. This is the default.

Examples

To drop the transform for type `hstore` and language `plpythonu`:

```
DROP TRANSFORM FOR hstore LANGUAGE plpythonu;
```

Compatibility

This form of DROP TRANSFORM is a PostgreSQL extension. See CREATE TRANSFORM for details.

See Also

CREATE TRANSFORM

DROP TRIGGER

DROP TRIGGER — remove a trigger

Synopsis

```
DROP TRIGGER [ IF EXISTS ] name ON table_name [ CASCADE |  
RESTRICT ]
```

Description

DROP TRIGGER removes an existing trigger definition. To execute this command, the current user must be the owner of the table for which the trigger is defined.

Parameters

IF EXISTS

Do not throw an error if the trigger does not exist. A notice is issued in this case.

name

The name of the trigger to remove.

table_name

The name (optionally schema-qualified) of the table for which the trigger is defined.

CASCADE

Automatically drop objects that depend on the trigger, and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the trigger if any objects depend on it. This is the default.

Examples

Destroy the trigger `if_dist_exists` on the table `films`:

```
DROP TRIGGER if_dist_exists ON films;
```

Compatibility

The DROP TRIGGER statement in PostgreSQL is incompatible with the SQL standard. In the SQL standard, trigger names are not local to tables, so the command is simply DROP TRIGGER *name*.

See Also

CREATE TRIGGER

DROP TYPE

DROP TYPE — remove a data type

Synopsis

```
DROP TYPE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP TYPE removes a user-defined data type. Only the owner of a type can remove it.

Parameters

IF EXISTS

Do not throw an error if the type does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the data type to remove.

CASCADE

Automatically drop objects that depend on the type (such as table columns, functions, and operators), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the type if any objects depend on it. This is the default.

Examples

To remove the data type box:

```
DROP TYPE box;
```

Compatibility

This command is similar to the corresponding command in the SQL standard, apart from the IF EXISTS option, which is a PostgreSQL extension. But note that much of the CREATE TYPE command and the data type extension mechanisms in PostgreSQL differ from the SQL standard.

See Also

ALTER TYPE, CREATE TYPE

DROP USER

DROP USER — remove a database role

Synopsis

```
DROP USER [ IF EXISTS ] name [, ...]
```

Description

DROP USER is simply an alternate spelling of DROP ROLE.

Compatibility

The DROP USER statement is a PostgreSQL extension. The SQL standard leaves the definition of users to the implementation.

See Also

DROP ROLE

DROP USER MAPPING

DROP USER MAPPING — remove a user mapping for a foreign server

Synopsis

```
DROP USER MAPPING [ IF EXISTS ] FOR { user_name | USER |  
CURRENT_USER | PUBLIC } SERVER server_name
```

Description

DROP USER MAPPING removes an existing user mapping from foreign server.

The owner of a foreign server can drop user mappings for that server for any user. Also, a user can drop a user mapping for their own user name if USAGE privilege on the server has been granted to the user.

Parameters

IF EXISTS

Do not throw an error if the user mapping does not exist. A notice is issued in this case.

user_name

User name of the mapping. CURRENT_USER and USER match the name of the current user. PUBLIC is used to match all present and future user names in the system.

server_name

Server name of the user mapping.

Examples

Drop a user mapping bob, server foo if it exists:

```
DROP USER MAPPING IF EXISTS FOR bob SERVER foo;
```

Compatibility

DROP USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a PostgreSQL extension.

See Also

CREATE USER MAPPING, ALTER USER MAPPING

DROP VIEW

DROP VIEW — remove a view

Synopsis

```
DROP VIEW [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP VIEW drops an existing view. To execute this command you must be the owner of the view.

Parameters

IF EXISTS

Do not throw an error if the view does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the view to remove.

CASCADE

Automatically drop objects that depend on the view (such as other views), and in turn all objects that depend on those objects (see Section 5.14).

RESTRICT

Refuse to drop the view if any objects depend on it. This is the default.

Examples

This command will remove the view called `kinds`:

```
DROP VIEW kinds;
```

Compatibility

This command conforms to the SQL standard, except that the standard only allows one view to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER VIEW, CREATE VIEW

END

END — commit the current transaction

Synopsis

```
END [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

Description

END commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs. This command is a PostgreSQL extension that is equivalent to COMMIT.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use ROLLBACK to abort a transaction.

Issuing END when not inside a transaction does no harm, but it will provoke a warning message.

Examples

To commit the current transaction and make all changes permanent:

```
END ;
```

Compatibility

END is a PostgreSQL extension that provides functionality equivalent to COMMIT, which is specified in the SQL standard.

See Also

BEGIN, COMMIT, ROLLBACK

EXECUTE

EXECUTE — execute a prepared statement

Synopsis

```
EXECUTE name [ ( parameter [, ...] ) ]
```

Description

EXECUTE is used to execute a previously prepared statement. Since prepared statements only exist for the duration of a session, the prepared statement must have been created by a PREPARE statement executed earlier in the current session.

If the PREPARE statement that created the statement specified some parameters, a compatible set of parameters must be passed to the EXECUTE statement, or else an error is raised. Note that (unlike functions) prepared statements are not overloaded based on the type or number of their parameters; the name of a prepared statement must be unique within a database session.

For more information on the creation and usage of prepared statements, see PREPARE.

Parameters

name

The name of the prepared statement to execute.

parameter

The actual value of a parameter to the prepared statement. This must be an expression yielding a value that is compatible with the data type of this parameter, as was determined when the prepared statement was created.

Outputs

The command tag returned by EXECUTE is that of the prepared statement, and not EXECUTE.

Examples

Examples are given in the Examples section of the PREPARE documentation.

Compatibility

The SQL standard includes an EXECUTE statement, but it is only for use in embedded SQL. This version of the EXECUTE statement also uses a somewhat different syntax.

See Also

DEALLOCATE, PREPARE

EXPLAIN

EXPLAIN — show the execution plan of a statement

Synopsis

```
EXPLAIN [ ( option [, ...] ) ] statement
EXPLAIN [ ANALYZE ] [ VERBOSE ] statement
```

where *option* can be one of:

```
ANALYZE [ boolean ]
VERBOSE [ boolean ]
COSTS [ boolean ]
SETTINGS [ boolean ]
BUFFERS [ boolean ]
TIMING [ boolean ]
SUMMARY [ boolean ]
FORMAT { TEXT | XML | JSON | YAML }
```

Description

This command displays the execution plan that the PostgreSQL planner generates for the supplied statement. The execution plan shows how the table(s) referenced by the statement will be scanned — by plain sequential scan, index scan, etc. — and if multiple tables are referenced, what join algorithms will be used to bring together the required rows from each input table.

The most critical part of the display is the estimated statement execution cost, which is the planner's guess at how long it will take to run the statement (measured in cost units that are arbitrary, but conventionally mean disk page fetches). Actually two numbers are shown: the start-up cost before the first row can be returned, and the total cost to return all the rows. For most queries the total cost is what matters, but in contexts such as a subquery in `EXISTS`, the planner will choose the smallest start-up cost instead of the smallest total cost (since the executor will stop after getting one row, anyway). Also, if you limit the number of rows to return with a `LIMIT` clause, the planner makes an appropriate interpolation between the endpoint costs to estimate which plan is really the cheapest.

The `ANALYZE` option causes the statement to be actually executed, not only planned. Then actual run time statistics are added to the display, including the total elapsed time expended within each plan node (in milliseconds) and the total number of rows it actually returned. This is useful for seeing whether the planner's estimates are close to reality.

Important

Keep in mind that the statement is actually executed when the `ANALYZE` option is used. Although `EXPLAIN` will discard any output that a `SELECT` would return, other side effects of the statement will happen as usual. If you wish to use `EXPLAIN ANALYZE` on an `INSERT`, `UPDATE`, `DELETE`, `CREATE TABLE AS`, or `EXECUTE` statement without letting the command affect your data, use this approach:

```
BEGIN;
EXPLAIN ANALYZE ...;
ROLLBACK;
```

Only the `ANALYZE` and `VERBOSE` options can be specified, and only in that order, without surrounding the option list in parentheses. Prior to PostgreSQL 9.0, the unparenthesized syntax was the only one supported. It is expected that all new options will be supported only in the parenthesized syntax.

Parameters

ANALYZE

Carry out the command and show actual run times and other statistics. This parameter defaults to `FALSE`.

VERBOSE

Display additional information regarding the plan. Specifically, include the output column list for each node in the plan tree, schema-qualify table and function names, always label variables in expressions with their range table alias, and always print the name of each trigger for which statistics are displayed. This parameter defaults to `FALSE`.

COSTS

Include information on the estimated startup and total cost of each plan node, as well as the estimated number of rows and the estimated width of each row. This parameter defaults to `TRUE`.

SETTINGS

Include information on configuration parameters. Specifically, include options affecting query planning with value different from the built-in default value. This parameter defaults to `FALSE`.

BUFFERS

Include information on buffer usage. Specifically, include the number of shared blocks hit, read, dirtied, and written, the number of local blocks hit, read, dirtied, and written, and the number of temp blocks read and written. A *hit* means that a read was avoided because the block was found already in cache when needed. Shared blocks contain data from regular tables and indexes; local blocks contain data from temporary tables and indexes; while temp blocks contain short-term working data used in sorts, hashes, Materialize plan nodes, and similar cases. The number of blocks *dirtied* indicates the number of previously unmodified blocks that were changed by this query; while the number of blocks *written* indicates the number of previously-dirtied blocks evicted from cache by this backend during query processing. The number of blocks shown for an upper-level node includes those used by all its child nodes. In text format, only non-zero values are printed. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `FALSE`.

TIMING

Include actual startup time and time spent in each node in the output. The overhead of repeatedly reading the system clock can slow down the query significantly on some systems, so it may be useful to set this parameter to `FALSE` when only actual row counts, and not exact times, are needed. Run time of the entire statement is always measured, even when node-level timing is turned off with this option. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `TRUE`.

SUMMARY

Include summary information (e.g., totaled timing information) after the query plan. Summary information is included by default when `ANALYZE` is used but otherwise is not included by default, but can be enabled using this option. Planning time in `EXPLAIN EXECUTE` includes the time required to fetch the plan from the cache and the time required for re-planning, if necessary.

FORMAT

Specify the output format, which can be `TEXT`, `XML`, `JSON`, or `YAML`. Non-text output contains the same information as the text output format, but is easier for programs to parse. This parameter defaults to `TEXT`.

boolean

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to disable it. The *boolean* value can also be omitted, in which case `TRUE` is assumed.

statement

Any `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `VALUES`, `EXECUTE`, `DECLARE`, `CREATE TABLE AS`, or `CREATE MATERIALIZED VIEW AS statement`, whose execution plan you wish to see.

Outputs

The command's result is a textual description of the plan selected for the *statement*, optionally annotated with execution statistics. Section 14.1 describes the information provided.

Notes

In order to allow the PostgreSQL query planner to make reasonably informed decisions when optimizing queries, the `pg_statistic` data should be up-to-date for all tables used in the query. Normally the autovacuum daemon will take care of that automatically. But if a table has recently had substantial changes in its contents, you might need to do a manual `ANALYZE` rather than wait for autovacuum to catch up with the changes.

In order to measure the run-time cost of each node in the execution plan, the current implementation of `EXPLAIN ANALYZE` adds profiling overhead to query execution. As a result, running `EXPLAIN ANALYZE` on a query can sometimes take significantly longer than executing the query normally. The amount of overhead depends on the nature of the query, as well as the platform being used. The worst case occurs for plan nodes that in themselves require very little time per execution, and on machines that have relatively slow operating system calls for obtaining the time of day.

Examples

To show the plan for a simple query on a table with a single `integer` column and 10000 rows:

```
EXPLAIN SELECT * FROM foo;
```

```

                                QUERY PLAN
-----
Seq Scan on foo (cost=0.00..155.00 rows=10000 width=4)
(1 row)
```

Here is the same query, with JSON output formatting:

```
EXPLAIN (FORMAT JSON) SELECT * FROM foo;
```

```

                                QUERY PLAN
-----
[
  {
    "Plan": {
      "Node Type": "Seq Scan",
      "Relation Name": "foo",
      "Alias": "foo",
      "Startup Cost": 0.00,
      "Total Cost": 155.00,
      "Plan Rows": 10000,
      +
    }
  }
  +
]
```

EXPLAIN

```
      "Plan Width": 4      +
    }                    +
  }                      +
]
(1 row)
```

If there is an index and we use a query with an indexable WHERE condition, EXPLAIN might show a different plan:

```
EXPLAIN SELECT * FROM foo WHERE i = 4;
```

QUERY PLAN

```
-----
Index Scan using fi on foo (cost=0.00..5.98 rows=1 width=4)
  Index Cond: (i = 4)
(2 rows)
```

Here is the same query, but in YAML format:

```
EXPLAIN (FORMAT YAML) SELECT * FROM foo WHERE i='4';
```

QUERY PLAN

```
-----
- Plan:
  Node Type: "Index Scan" +
  Scan Direction: "Forward"+
  Index Name: "fi" +
  Relation Name: "foo" +
  Alias: "foo" +
  Startup Cost: 0.00 +
  Total Cost: 5.98 +
  Plan Rows: 1 +
  Plan Width: 4 +
  Index Cond: "(i = 4)"
(1 row)
```

XML format is left as an exercise for the reader.

Here is the same plan with cost estimates suppressed:

```
EXPLAIN (COSTS FALSE) SELECT * FROM foo WHERE i = 4;
```

QUERY PLAN

```
-----
Index Scan using fi on foo
  Index Cond: (i = 4)
(2 rows)
```

Here is an example of a query plan for a query using an aggregate function:

```
EXPLAIN SELECT sum(i) FROM foo WHERE i < 10;
```

QUERY PLAN

```
-----
Aggregate (cost=23.93..23.93 rows=1 width=4)
-> Index Scan using fi on foo (cost=0.00..23.92 rows=6
width=4)
```

```
      Index Cond: (i < 10)
(3 rows)
```

Here is an example of using `EXPLAIN EXECUTE` to display the execution plan for a prepared query:

```
PREPARE query(int, int) AS SELECT sum(bar) FROM test
  WHERE id > $1 AND id < $2
  GROUP BY foo;
```

```
EXPLAIN ANALYZE EXECUTE query(100, 200);
```

QUERY PLAN

```
HashAggregate  (cost=9.54..9.54 rows=1 width=8) (actual
time=0.156..0.161 rows=11 loops=1)
  Group Key: foo
    -> Index Scan using test_pkey on test  (cost=0.29..9.29 rows=50
width=8) (actual time=0.039..0.091 rows=99 loops=1)
      Index Cond: ((id > $1) AND (id < $2))
    Planning time: 0.197 ms
    Execution time: 0.225 ms
(6 rows)
```

Of course, the specific numbers shown here depend on the actual contents of the tables involved. Also note that the numbers, and even the selected query strategy, might vary between PostgreSQL releases due to planner improvements. In addition, the `ANALYZE` command uses random sampling to estimate data statistics; therefore, it is possible for cost estimates to change after a fresh run of `ANALYZE`, even if the actual distribution of data in the table has not changed.

Compatibility

There is no `EXPLAIN` statement defined in the SQL standard.

See Also

`ANALYZE`

FETCH

FETCH — retrieve rows from a query using a cursor

Synopsis

```
FETCH [ direction [ FROM | IN ] ] cursor_name
```

where *direction* can be empty or one of:

```
NEXT  
PRIOR  
FIRST  
LAST  
ABSOLUTE count  
RELATIVE count  
count  
ALL  
FORWARD  
FORWARD count  
FORWARD ALL  
BACKWARD  
BACKWARD count  
BACKWARD ALL
```

Description

FETCH retrieves rows using a previously-created cursor.

A cursor has an associated position, which is used by FETCH. The cursor position can be before the first row of the query result, on any particular row of the result, or after the last row of the result. When created, a cursor is positioned before the first row. After fetching some rows, the cursor is positioned on the row most recently retrieved. If FETCH runs off the end of the available rows then the cursor is left positioned after the last row, or before the first row if fetching backward. FETCH ALL or FETCH BACKWARD ALL will always leave the cursor positioned after the last row or before the first row.

The forms NEXT, PRIOR, FIRST, LAST, ABSOLUTE, RELATIVE fetch a single row after moving the cursor appropriately. If there is no such row, an empty result is returned, and the cursor is left positioned before the first row or after the last row as appropriate.

The forms using FORWARD and BACKWARD retrieve the indicated number of rows moving in the forward or backward direction, leaving the cursor positioned on the last-returned row (or after/before all rows, if the *count* exceeds the number of rows available).

RELATIVE 0, FORWARD 0, and BACKWARD 0 all request fetching the current row without moving the cursor, that is, re-fetching the most recently fetched row. This will succeed unless the cursor is positioned before the first row or after the last row; in which case, no row is returned.

Note

This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different — see Section 42.7.3.

Parameters

direction

direction defines the fetch direction and number of rows to fetch. It can be one of the following:

NEXT

Fetch the next row. This is the default if *direction* is omitted.

PRIOR

Fetch the prior row.

FIRST

Fetch the first row of the query (same as ABSOLUTE 1).

LAST

Fetch the last row of the query (same as ABSOLUTE -1).

ABSOLUTE *count*

Fetch the *count*'th row of the query, or the $\text{abs}(\text{count})$ 'th row from the end if *count* is negative. Position before first row or after last row if *count* is out of range; in particular, ABSOLUTE 0 positions before the first row.

RELATIVE *count*

Fetch the *count*'th succeeding row, or the $\text{abs}(\text{count})$ 'th prior row if *count* is negative. RELATIVE 0 re-fetches the current row, if any.

count

Fetch the next *count* rows (same as FORWARD *count*).

ALL

Fetch all remaining rows (same as FORWARD ALL).

FORWARD

Fetch the next row (same as NEXT).

FORWARD *count*

Fetch the next *count* rows. FORWARD 0 re-fetches the current row.

FORWARD ALL

Fetch all remaining rows.

BACKWARD

Fetch the prior row (same as PRIOR).

BACKWARD *count*

Fetch the prior *count* rows (scanning backwards). BACKWARD 0 re-fetches the current row.

BACKWARD ALL

Fetch all prior rows (scanning backwards).

count

count is a possibly-signed integer constant, determining the location or number of rows to fetch. For FORWARD and BACKWARD cases, specifying a negative *count* is equivalent to changing the sense of FORWARD and BACKWARD.

cursor_name

An open cursor's name.

Outputs

On successful completion, a FETCH command returns a command tag of the form

FETCH *count*

The *count* is the number of rows fetched (possibly zero). Note that in psql, the command tag will not actually be displayed, since psql displays the fetched rows instead.

Notes

The cursor should be declared with the SCROLL option if one intends to use any variants of FETCH other than FETCH NEXT or FETCH FORWARD with a positive count. For simple queries PostgreSQL will allow backwards fetch from cursors not declared with SCROLL, but this behavior is best not relied on. If the cursor is declared with NO SCROLL, no backward fetches are allowed.

ABSOLUTE fetches are not any faster than navigating to the desired row with a relative move: the underlying implementation must traverse all the intermediate rows anyway. Negative absolute fetches are even worse: the query must be read to the end to find the last row, and then traversed backward from there. However, rewinding to the start of the query (as with FETCH ABSOLUTE 0) is fast.

DECLARE is used to define a cursor. Use MOVE to change cursor position without retrieving data.

Examples

The following example traverses a table using a cursor:

```
BEGIN WORK;

-- Set up a cursor:
DECLARE liahona SCROLL CURSOR FOR SELECT * FROM films;

-- Fetch the first 5 rows in the cursor liahona:
FETCH FORWARD 5 FROM liahona;
```

code len	title	did	date_prod	kind
BL101 01:44	The Third Man	101	1949-12-23	Drama
BL102 01:43	The African Queen	101	1951-08-11	Romantic

```

JL201 | Une Femme est une Femme | 102 | 1961-03-12 | Romantic |
01:25
P_301 | Vertigo | 103 | 1958-11-14 | Action |
02:08
P_302 | Becket | 103 | 1964-02-03 | Drama |
02:28

-- Fetch the previous row:
FETCH PRIOR FROM liahona;

code | title | did | date_prod | kind | len
-----+-----+-----+-----+-----+-----
P_301 | Vertigo | 103 | 1958-11-14 | Action | 02:08

-- Close the cursor and end the transaction:
CLOSE liahona;
COMMIT WORK;
```

Compatibility

The SQL standard defines `FETCH` for use in embedded SQL only. The variant of `FETCH` described here returns the data as if it were a `SELECT` result rather than placing it in host variables. Other than this point, `FETCH` is fully upward-compatible with the SQL standard.

The `FETCH` forms involving `FORWARD` and `BACKWARD`, as well as the forms `FETCH count` and `FETCH ALL`, in which `FORWARD` is implicit, are PostgreSQL extensions.

The SQL standard allows only `FROM` preceding the cursor name; the option to use `IN`, or to leave them out altogether, is an extension.

See Also

`CLOSE`, `DECLARE`, `MOVE`

GRANT

GRANT — define access privileges

Synopsis

```
GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES
| TRIGGER }
  [, ...] | ALL [ PRIVILEGES ] }
  ON { [ TABLE ] table_name [, ...]
      | ALL TABLES IN SCHEMA schema_name [, ...] }
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | INSERT | UPDATE | REFERENCES } ( column_name
[, ...] )
  [, ...] | ALL [ PRIVILEGES ] ( column_name [, ...] ) }
  ON [ TABLE ] table_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { USAGE | SELECT | UPDATE }
  [, ...] | ALL [ PRIVILEGES ] }
  ON { SEQUENCE sequence_name [, ...]
      | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | CONNECT | TEMPORARY | TEMP } [, ...] | ALL
  [ PRIVILEGES ] }
  ON DATABASE database_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON DOMAIN domain_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON FOREIGN DATA WRAPPER fdw_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON FOREIGN SERVER server_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { EXECUTE | ALL [ PRIVILEGES ] }
  ON { { FUNCTION | PROCEDURE | ROUTINE } routine_name
  [ ( [ [ argmode ] [ arg_name ] arg_type [, ...] ) ] [, ...]
      | ALL { FUNCTIONS | PROCEDURES | ROUTINES } IN
  SCHEMA schema_name [, ...] }
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
  ON LANGUAGE lang_name [, ...]
  TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | UPDATE } [, ...] | ALL [ PRIVILEGES ] }
```

```

ON LARGE OBJECT loid [, ...]
TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | USAGE } [, ...] | ALL [ PRIVILEGES ] }
ON SCHEMA schema_name [, ...]
TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { CREATE | ALL [ PRIVILEGES ] }
ON TABLESPACE tablespace_name [, ...]
TO role_specification [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
ON TYPE type_name [, ...]
TO role_specification [, ...] [ WITH GRANT OPTION ]

```

where *role_specification* can be:

```

[ GROUP ] role_name
| PUBLIC
| CURRENT_USER
| SESSION_USER

```

```
GRANT role_name [, ...] TO role_name [, ...] [ WITH ADMIN OPTION ]
```

Description

The GRANT command has two basic variants: one that grants privileges on a database object (table, column, view, foreign table, sequence, database, foreign-data wrapper, foreign server, function, procedure, procedural language, schema, or tablespace), and one that grants membership in a role. These variants are similar in many ways, but they are different enough to be described separately.

GRANT on Database Objects

This variant of the GRANT command gives specific privileges on a database object to one or more roles. These privileges are added to those already granted, if any.

The key word PUBLIC indicates that the privileges are to be granted to all roles, including those that might be created later. PUBLIC can be thought of as an implicitly defined group that always includes all roles. Any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC.

If WITH GRANT OPTION is specified, the recipient of the privilege can in turn grant it to others. Without a grant option, the recipient cannot do that. Grant options cannot be granted to PUBLIC.

There is no need to grant privileges to the owner of an object (usually the user that created it), as the owner has all privileges by default. (The owner could, however, choose to revoke some of their own privileges for safety.)

The right to drop an object, or to alter its definition in any way, is not treated as a grantable privilege; it is inherent in the owner, and cannot be granted or revoked. (However, a similar effect can be obtained by granting or revoking membership in the role that owns the object; see below.) The owner implicitly has all grant options for the object, too.

The possible privileges are:

SELECT
INSERT
UPDATE
DELETE
TRUNCATE
REFERENCES
TRIGGER
CREATE
CONNECT
TEMPORARY
EXECUTE
USAGE

Specific types of privileges, as defined in Section 5.7.

TEMP

Alternative spelling for TEMPORARY.

ALL PRIVILEGES

Grant all of the privileges available for the object's type. The PRIVILEGES key word is optional in PostgreSQL, though it is required by strict SQL.

The FUNCTION syntax works for plain functions, aggregate functions, and window functions, but not for procedures; use PROCEDURE for those. Alternatively, use ROUTINE to refer to a function, aggregate function, window function, or procedure regardless of its precise type.

There is also an option to grant privileges on all objects of the same type within one or more schemas. This functionality is currently supported only for tables, sequences, functions, and procedures. ALL TABLES also affects views and foreign tables, just like the specific-object GRANT command. ALL FUNCTIONS also affects aggregate and window functions, but not procedures, again just like the specific-object GRANT command. Use ALL ROUTINES to include procedures.

GRANT on Roles

This variant of the GRANT command grants membership in a role to one or more other roles. Membership in a role is significant because it conveys the privileges granted to a role to each of its members.

If WITH ADMIN OPTION is specified, the member can in turn grant membership in the role to others, and revoke membership in the role as well. Without the admin option, ordinary users cannot do that. A role is not considered to hold WITH ADMIN OPTION on itself, but it may grant or revoke membership in itself from a database session where the session user matches the role. Database superusers can grant or revoke membership in any role to anyone. Roles having CREATEROLE privilege can grant or revoke membership in any role that is not a superuser.

Unlike the case with privileges, membership in a role cannot be granted to PUBLIC. Note also that this form of the command does not allow the noise word GROUP.

Notes

The REVOKE command is used to revoke access privileges.

Since PostgreSQL 8.1, the concepts of users and groups have been unified into a single kind of entity called a role. It is therefore no longer necessary to use the keyword GROUP to identify whether a grantee is a user or a group. GROUP is still allowed in the command, but it is a noise word.

A user may perform SELECT, INSERT, etc. on a column if they hold that privilege for either the specific column or its whole table. Granting the privilege at the table level and then revoking it for one column will not do what one might wish: the table-level grant is unaffected by a column-level operation.

When a non-owner of an object attempts to GRANT privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will grant only those privileges for which the user has grant options. The GRANT ALL PRIVILEGES forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

It should be noted that database superusers can access all objects regardless of object privilege settings. This is comparable to the rights of root in a Unix system. As with root, it's unwise to operate as a superuser except when absolutely necessary.

If a superuser chooses to issue a GRANT or REVOKE command, the command is performed as though it were issued by the owner of the affected object. In particular, privileges granted via such a command will appear to have been granted by the object owner. (For role membership, the membership appears to have been granted by the containing role itself.)

GRANT and REVOKE can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges WITH GRANT OPTION on the object. In this case the privileges will be recorded as having been granted by the role that actually owns the object or holds the privileges WITH GRANT OPTION. For example, if table t1 is owned by role g1, of which role u1 is a member, then u1 can grant privileges on t1 to u2, but those privileges will appear to have been granted directly by g1. Any other member of role g1 could revoke them later.

If the role executing GRANT holds the required privileges indirectly via more than one role membership path, it is unspecified which containing role will be recorded as having done the grant. In such cases it is best practice to use SET ROLE to become the specific role you want to do the GRANT as.

Granting permission on a table does not automatically extend permissions to any sequences used by the table, including sequences tied to SERIAL columns. Permissions on sequences must be set separately.

See Section 5.7 for more information about specific privilege types, as well as how to inspect objects' privileges.

Examples

Grant insert privilege to all users on table films:

```
GRANT INSERT ON films TO PUBLIC;
```

Grant all available privileges to user manuel on view kinds:

```
GRANT ALL PRIVILEGES ON kinds TO manuel;
```

Note that while the above will indeed grant all privileges if executed by a superuser or the owner of kinds, when executed by someone else it will only grant those permissions for which the someone else has grant options.

Grant membership in role admins to user joe:

```
GRANT admins TO joe;
```

Compatibility

According to the SQL standard, the PRIVILEGES key word in ALL PRIVILEGES is required. The SQL standard does not support setting the privileges on more than one object per command.

PostgreSQL allows an object owner to revoke their own ordinary privileges: for example, a table owner can make the table read-only to themselves by revoking their own `INSERT`, `UPDATE`, `DELETE`, and `TRUNCATE` privileges. This is not possible according to the SQL standard. The reason is that PostgreSQL treats the owner's privileges as having been granted by the owner to themselves; therefore they can revoke them too. In the SQL standard, the owner's privileges are granted by an assumed entity “`_SYSTEM`”. Not being “`_SYSTEM`”, the owner cannot revoke these rights.

According to the SQL standard, grant options can be granted to `PUBLIC`; PostgreSQL only supports granting grant options to roles.

The SQL standard provides for a `USAGE` privilege on other kinds of objects: character sets, collations, translations.

In the SQL standard, sequences only have a `USAGE` privilege, which controls the use of the `NEXT VALUE FOR` expression, which is equivalent to the function `nextval` in PostgreSQL. The sequence privileges `SELECT` and `UPDATE` are PostgreSQL extensions. The application of the sequence `USAGE` privilege to the `currval` function is also a PostgreSQL extension (as is the function itself).

Privileges on databases, tablespaces, schemas, and languages are PostgreSQL extensions.

See Also

`REVOKE`, `ALTER DEFAULT PRIVILEGES`

IMPORT FOREIGN SCHEMA

IMPORT FOREIGN SCHEMA — import table definitions from a foreign server

Synopsis

```
IMPORT FOREIGN SCHEMA remote_schema
  [ { LIMIT TO | EXCEPT } ( table_name [, ...] ) ]
  FROM SERVER server_name
  INTO local_schema
  [ OPTIONS ( option 'value' [, ...] ) ]
```

Description

IMPORT FOREIGN SCHEMA creates foreign tables that represent tables existing on a foreign server. The new foreign tables will be owned by the user issuing the command and are created with the correct column definitions and options to match the remote tables.

By default, all tables and views existing in a particular schema on the foreign server are imported. Optionally, the list of tables can be limited to a specified subset, or specific tables can be excluded. The new foreign tables are all created in the target schema, which must already exist.

To use IMPORT FOREIGN SCHEMA, the user must have USAGE privilege on the foreign server, as well as CREATE privilege on the target schema.

Parameters

remote_schema

The remote schema to import from. The specific meaning of a remote schema depends on the foreign data wrapper in use.

LIMIT TO (*table_name* [, ...])

Import only foreign tables matching one of the given table names. Other tables existing in the foreign schema will be ignored.

EXCEPT (*table_name* [, ...])

Exclude specified foreign tables from the import. All tables existing in the foreign schema will be imported except the ones listed here.

server_name

The foreign server to import from.

local_schema

The schema in which the imported foreign tables will be created.

OPTIONS (*option* 'value' [, ...])

Options to be used during the import. The allowed option names and values are specific to each foreign data wrapper.

Examples

Import table definitions from a remote schema `foreign_films` on server `film_server`, creating the foreign tables in local schema `films`:

```
IMPORT FOREIGN SCHEMA foreign_films
  FROM SERVER film_server INTO films;
```

As above, but import only the two tables `actors` and `directors` (if they exist):

```
IMPORT FOREIGN SCHEMA foreign_films LIMIT TO (actors, directors)
  FROM SERVER film_server INTO films;
```

Compatibility

The `IMPORT FOREIGN SCHEMA` command conforms to the SQL standard, except that the `OPTIONS` clause is a PostgreSQL extension.

See Also

`CREATE FOREIGN TABLE`, `CREATE SERVER`

INSERT

INSERT — create new rows in a table

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
INSERT INTO table_name [ AS alias ] [ ( column_name [, ...] ) ]
    [ OVERRIDING { SYSTEM | USER } VALUE ]
    { DEFAULT VALUES | VALUES ( { expression | DEFAULT } [, ...] )
  [, ...] | query }
    [ ON CONFLICT [ conflict_target ] conflict_action ]
    [ RETURNING * | output_expression [ [ AS ] output_name ]
  [, ...] ]
```

where *conflict_target* can be one of:

```
( { index_column_name | ( index_expression
) } [ COLLATE collation ] [ opclass ] [, ...] )
[ WHERE index_predicate ]
ON CONSTRAINT constraint_name
```

and *conflict_action* is one of:

```
DO NOTHING
DO UPDATE SET { column_name = { expression | DEFAULT } |
                ( column_name [, ...] ) = [ ROW ]
( { expression | DEFAULT } [, ...] ) |
  ( column_name [, ...] ) = ( sub-SELECT )
} [, ...]
[ WHERE condition ]
```

Description

INSERT inserts new rows into a table. One can insert one or more rows specified by value expressions, or zero or more rows resulting from a query.

The target column names can be listed in any order. If no list of column names is given at all, the default is all the columns of the table in their declared order; or the first *N* column names, if there are only *N* columns supplied by the VALUES clause or *query*. The values supplied by the VALUES clause or *query* are associated with the explicit or implicit column list left-to-right.

Each column not present in the explicit or implicit column list will be filled with a default value, either its declared default value or null if there is none.

If the expression for any column is not of the correct data type, automatic type conversion will be attempted.

ON CONFLICT can be used to specify an alternative action to raising a unique constraint or exclusion constraint violation error. (See ON CONFLICT Clause below.)

The optional RETURNING clause causes INSERT to compute and return value(s) based on each row actually inserted (or updated, if an ON CONFLICT DO UPDATE clause was used). This is primarily useful for obtaining values that were supplied by defaults, such as a serial sequence number. However, any expression using the table's columns is allowed. The syntax of the RETURNING list is identical

to that of the output list of `SELECT`. Only rows that were successfully inserted or updated will be returned. For example, if a row was locked but not updated because an `ON CONFLICT DO UPDATE . . . WHERE` clause *condition* was not satisfied, the row will not be returned.

You must have `INSERT` privilege on a table in order to insert into it. If `ON CONFLICT DO UPDATE` is present, `UPDATE` privilege on the table is also required.

If a column list is specified, you only need `INSERT` privilege on the listed columns. Similarly, when `ON CONFLICT DO UPDATE` is specified, you only need `UPDATE` privilege on the column(s) that are listed to be updated. However, `ON CONFLICT DO UPDATE` also requires `SELECT` privilege on any column whose values are read in the `ON CONFLICT DO UPDATE` expressions or *condition*.

Use of the `RETURNING` clause requires `SELECT` privilege on all columns mentioned in `RETURNING`. If you use the *query* clause to insert rows from a query, you of course need to have `SELECT` privilege on any table or column used in the query.

Parameters

Inserting

This section covers parameters that may be used when only inserting new rows. Parameters *exclusively* used with the `ON CONFLICT` clause are described separately.

with_query

The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the `INSERT` query. See Section 7.8 and `SELECT` for details.

It is possible for the *query* (`SELECT` statement) to also contain a `WITH` clause. In such a case both sets of *with_query* can be referenced within the *query*, but the second one takes precedence since it is more closely nested.

table_name

The name (optionally schema-qualified) of an existing table.

alias

A substitute name for *table_name*. When an alias is provided, it completely hides the actual name of the table. This is particularly useful when `ON CONFLICT DO UPDATE` targets a table named `excluded`, since that will otherwise be taken as the name of the special table representing rows proposed for insertion.

column_name

The name of a column in the table named by *table_name*. The column name can be qualified with a subfield name or array subscript, if needed. (Inserting into only some fields of a composite column leaves the other fields null.) When referencing a column with `ON CONFLICT DO UPDATE`, do not include the table's name in the specification of a target column. For example, `INSERT INTO table_name . . . ON CONFLICT DO UPDATE SET table_name.col = 1` is invalid (this follows the general behavior for `UPDATE`).

OVERRIDING SYSTEM VALUE

Without this clause, it is an error to specify an explicit value (other than `DEFAULT`) for an identity column defined as `GENERATED ALWAYS`. This clause overrides that restriction.

OVERRIDING USER VALUE

If this clause is specified, then any values supplied for identity columns defined as `GENERATED BY DEFAULT` are ignored and the default sequence-generated values are applied.

This clause is useful for example when copying values between tables. Writing `INSERT INTO tbl2 OVERRIDING USER VALUE SELECT * FROM tbl1` will copy from `tbl1` all columns that are not identity columns in `tbl2` while values for the identity columns in `tbl2` will be generated by the sequences associated with `tbl2`.

DEFAULT VALUES

All columns will be filled with their default values. (An `OVERRIDING` clause is not permitted in this form.)

expression

An expression or value to assign to the corresponding column.

DEFAULT

The corresponding column will be filled with its default value.

query

A query (`SELECT` statement) that supplies the rows to be inserted. Refer to the `SELECT` statement for a description of the syntax.

output_expression

An expression to be computed and returned by the `INSERT` command after each row is inserted or updated. The expression can use any column names of the table named by *table_name*. Write `*` to return all columns of the inserted or updated row(s).

output_name

A name to use for a returned column.

ON CONFLICT Clause

The optional `ON CONFLICT` clause specifies an alternative action to raising a unique violation or exclusion constraint violation error. For each individual row proposed for insertion, either the insertion proceeds, or, if an *arbiter* constraint or index specified by *conflict_target* is violated, the alternative *conflict_action* is taken. `ON CONFLICT DO NOTHING` simply avoids inserting a row as its alternative action. `ON CONFLICT DO UPDATE` updates the existing row that conflicts with the row proposed for insertion as its alternative action.

conflict_target can perform *unique index inference*. When performing inference, it consists of one or more *index_column_name* columns and/or *index_expression* expressions, and an optional *index_predicate*. All *table_name* unique indexes that, without regard to order, contain exactly the *conflict_target*-specified columns/expressions are inferred (chosen) as arbiter indexes. If an *index_predicate* is specified, it must, as a further requirement for inference, satisfy arbiter indexes. Note that this means a non-partial unique index (a unique index without a predicate) will be inferred (and thus used by `ON CONFLICT`) if such an index satisfying every other criteria is available. If an attempt at inference is unsuccessful, an error is raised.

`ON CONFLICT DO UPDATE` guarantees an atomic `INSERT` or `UPDATE` outcome; provided there is no independent error, one of those two outcomes is guaranteed, even under high concurrency. This is also known as *UPSERT* — “UPDATE or INSERT”.

conflict_target

Specifies which conflicts `ON CONFLICT` takes the alternative action on by choosing *arbiter indexes*. Either performs *unique index inference*, or names a constraint explicitly. For `ON CONFLICT DO NOTHING`, it is optional to specify a *conflict_target*; when omitted, conflicts

with all usable constraints (and unique indexes) are handled. For `ON CONFLICT DO UPDATE`, a *conflict_target must* be provided.

conflict_action

conflict_action specifies an alternative `ON CONFLICT` action. It can be either `DO NOTHING`, or a `DO UPDATE` clause specifying the exact details of the `UPDATE` action to be performed in case of a conflict. The `SET` and `WHERE` clauses in `ON CONFLICT DO UPDATE` have access to the existing row using the table's name (or an alias), and to rows proposed for insertion using the special `excluded` table. `SELECT` privilege is required on any column in the target table where corresponding `excluded` columns are read.

Note that the effects of all per-row `BEFORE INSERT` triggers are reflected in `excluded` values, since those effects may have contributed to the row being excluded from insertion.

index_column_name

The name of a *table_name* column. Used to infer arbiter indexes. Follows `CREATE INDEX` format. `SELECT` privilege on *index_column_name* is required.

index_expression

Similar to *index_column_name*, but used to infer expressions on *table_name* columns appearing within index definitions (not simple columns). Follows `CREATE INDEX` format. `SELECT` privilege on any column appearing within *index_expression* is required.

collation

When specified, mandates that corresponding *index_column_name* or *index_expression* use a particular collation in order to be matched during inference. Typically this is omitted, as collations usually do not affect whether or not a constraint violation occurs. Follows `CREATE INDEX` format.

opclass

When specified, mandates that corresponding *index_column_name* or *index_expression* use particular operator class in order to be matched during inference. Typically this is omitted, as the *equality* semantics are often equivalent across a type's operator classes anyway, or because it's sufficient to trust that the defined unique indexes have the pertinent definition of equality. Follows `CREATE INDEX` format.

index_predicate

Used to allow inference of partial unique indexes. Any indexes that satisfy the predicate (which need not actually be partial indexes) can be inferred. Follows `CREATE INDEX` format. `SELECT` privilege on any column appearing within *index_predicate* is required.

constraint_name

Explicitly specifies an arbiter *constraint* by name, rather than inferring a constraint or index.

condition

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated, although all rows will be locked when the `ON CONFLICT DO UPDATE` action is taken. Note that *condition* is evaluated last, after a conflict has been identified as a candidate to update.

Note that exclusion constraints are not supported as arbiters with `ON CONFLICT DO UPDATE`. In all cases, only `NOT DEFERRABLE` constraints and unique indexes are supported as arbiters.

INSERT with an `ON CONFLICT DO UPDATE` clause is a “deterministic” statement. This means that the command will not be allowed to affect any single existing row more than once; a cardinality violation error will be raised when this situation arises. Rows proposed for insertion should not duplicate each other in terms of attributes constrained by an arbiter index or constraint.

Note that it is currently not supported for the `ON CONFLICT DO UPDATE` clause of an INSERT applied to a partitioned table to update the partition key of a conflicting row such that it requires the row be moved to a new partition.

Tip

It is often preferable to use unique index inference rather than naming a constraint directly using `ON CONFLICT ON CONSTRAINT constraint_name`. Inference will continue to work correctly when the underlying index is replaced by another more or less equivalent index in an overlapping way, for example when using `CREATE UNIQUE INDEX ... CONCURRENTLY` before dropping the index being replaced.

Outputs

On successful completion, an INSERT command returns a command tag of the form

```
INSERT oid count
```

The *count* is the number of rows inserted or updated. *oid* is always 0 (it used to be the OID assigned to the inserted row if *count* was exactly one and the target table was declared `WITH OIDS` and 0 otherwise, but creating a table `WITH OIDS` is not supported anymore).

If the INSERT command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) inserted or updated by the command.

Notes

If the specified table is a partitioned table, each row is routed to the appropriate partition and inserted into it. If the specified table is a partition, an error will occur if one of the input rows violates the partition constraint.

Examples

Insert a single row into table `films`:

```
INSERT INTO films VALUES
 ('UA502', 'Bananas', 105, '1971-07-13', 'Comedy', '82
 minutes');
```

In this example, the `len` column is omitted and therefore it will have the default value:

```
INSERT INTO films (code, title, did, date_prod, kind)
VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

This example uses the `DEFAULT` clause for the date columns rather than specifying a value:

INSERT

```
INSERT INTO films VALUES
  ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes');
INSERT INTO films (code, title, did, date_prod, kind)
  VALUES ('T_601', 'Yojimbo', 106, DEFAULT, 'Drama');
```

To insert a row consisting entirely of default values:

```
INSERT INTO films DEFAULT VALUES;
```

To insert multiple rows using the multirow VALUES syntax:

```
INSERT INTO films (code, title, did, date_prod, kind) VALUES
  ('B6717', 'Tampopo', 110, '1985-02-10', 'Comedy'),
  ('HG120', 'The Dinner Game', 140, DEFAULT, 'Comedy');
```

This example inserts some rows into table `films` from a table `tmp_films` with the same column layout as `films`:

```
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod <
  '2004-05-07';
```

This example inserts into array columns:

```
-- Create an empty 3x3 gameboard for noughts-and-crosses
INSERT INTO tictactoe (game, board[1:3][1:3])
  VALUES (1, '{{" "," "," "},{ " "," "," "},{ " "," "," "}}');
-- The subscripts in the above example aren't really needed
INSERT INTO tictactoe (game, board)
  VALUES (2, '{{X," "," "},{ " ",O," "},{ " ",X," "}}');
```

Insert a single row into table `distributors`, returning the sequence number generated by the `DEFAULT` clause:

```
INSERT INTO distributors (did, dname) VALUES (DEFAULT, 'XYZ
  Widgets')
  RETURNING did;
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, and record the whole updated row along with current time in a log table:

```
WITH upd AS (
  UPDATE employees SET sales_count = sales_count + 1 WHERE id =
    (SELECT sales_person FROM accounts WHERE name = 'Acme
  Corporation')
  RETURNING *
)
INSERT INTO employees_log SELECT *, current_timestamp FROM upd;
```

Insert or update new distributors as appropriate. Assumes a unique index has been defined that constrains values appearing in the `did` column. Note that the special excluded table is used to reference values originally proposed for insertion:

```
INSERT INTO distributors (did, dname)
```

```
VALUES (5, 'Gizmo Transglobal'), (6, 'Associated Computing,
Inc')
ON CONFLICT (did) DO UPDATE SET dname = EXCLUDED.dname;
```

Insert a distributor, or do nothing for rows proposed for insertion when an existing, excluded row (a row with a matching constrained column or columns after before row insert triggers fire) exists. Example assumes a unique index has been defined that constrains values appearing in the `did` column:

```
INSERT INTO distributors (did, dname) VALUES (7, 'Redline GmbH')
ON CONFLICT (did) DO NOTHING;
```

Insert or update new distributors as appropriate. Example assumes a unique index has been defined that constrains values appearing in the `did` column. `WHERE` clause is used to limit the rows actually updated (any existing row not updated will still be locked, though):

```
-- Don't update existing distributors based in a certain ZIP code
INSERT INTO distributors AS d (did, dname) VALUES (8, 'Anvil
Distribution')
ON CONFLICT (did) DO UPDATE
SET dname = EXCLUDED.dname || ' (formerly ' || d.dname || ')'
WHERE d.zipcode <> '21201';
```

```
-- Name a constraint directly in the statement (uses associated
-- index to arbitrate taking the DO NOTHING action)
INSERT INTO distributors (did, dname) VALUES (9, 'Antwerp Design')
ON CONFLICT ON CONSTRAINT distributors_pkey DO NOTHING;
```

Insert new distributor if possible; otherwise `DO NOTHING`. Example assumes a unique index has been defined that constrains values appearing in the `did` column on a subset of rows where the `is_active` Boolean column evaluates to `true`:

```
-- This statement could infer a partial unique index on "did"
-- with a predicate of "WHERE is_active", but it could also
-- just use a regular unique constraint on "did"
INSERT INTO distributors (did, dname) VALUES (10, 'Conrad
International')
ON CONFLICT (did) WHERE is_active DO NOTHING;
```

Compatibility

`INSERT` conforms to the SQL standard, except that the `RETURNING` clause is a PostgreSQL extension, as is the ability to use `WITH` with `INSERT`, and the ability to specify an alternative action with `ON CONFLICT`. Also, the case in which a column name list is omitted, but not all the columns are filled from the `VALUES` clause or *query*, is disallowed by the standard.

The SQL standard specifies that `OVERRIDING SYSTEM VALUE` can only be specified if an identity column that is generated always exists. PostgreSQL allows the clause in any case and ignores it if it is not applicable.

Possible limitations of the *query* clause are documented under `SELECT`.

LISTEN

LISTEN — listen for a notification

Synopsis

```
LISTEN channel
```

Description

LISTEN registers the current session as a listener on the notification channel named *channel*. If the current session is already registered as a listener for this notification channel, nothing is done.

Whenever the command NOTIFY *channel* is invoked, either by this session or another one connected to the same database, all the sessions currently listening on that notification channel are notified, and each will in turn notify its connected client application.

A session can be unregistered for a given notification channel with the UNLISTEN command. A session's listen registrations are automatically cleared when the session ends.

The method a client application must use to detect notification events depends on which PostgreSQL application programming interface it uses. With the libpq library, the application issues LISTEN as an ordinary SQL command, and then must periodically call the function PQnotifies to find out whether any notification events have been received. Other interfaces such as libpqctl provide higher-level methods for handling notify events; indeed, with libpqctl the application programmer should not even issue LISTEN or UNLISTEN directly. See the documentation for the interface you are using for more details.

NOTIFY contains a more extensive discussion of the use of LISTEN and NOTIFY.

Parameters

channel

Name of a notification channel (any identifier).

Notes

LISTEN takes effect at transaction commit. If LISTEN or UNLISTEN is executed within a transaction that later rolls back, the set of notification channels being listened to is unchanged.

A transaction that has executed LISTEN cannot be prepared for two-phase commit.

Examples

Configure and execute a listen/notify sequence from psql:

```
LISTEN virtual;  
NOTIFY virtual;  
Asynchronous notification "virtual" received from server process  
with PID 8448.
```

Compatibility

There is no `LISTEN` statement in the SQL standard.

See Also

`NOTIFY`, `UNLISTEN`

LOAD

LOAD — load a shared library file

Synopsis

```
LOAD 'filename'
```

Description

This command loads a shared library file into the PostgreSQL server's address space. If the file has been loaded already, the command does nothing. Shared library files that contain C functions are automatically loaded whenever one of their functions is called. Therefore, an explicit LOAD is usually only needed to load a library that modifies the server's behavior through “hooks” rather than providing a set of functions.

The library file name is typically given as just a bare file name, which is sought in the server's library search path (set by `dynamic_library_path`). Alternatively it can be given as a full path name. In either case the platform's standard shared library file name extension may be omitted. See Section 37.10.1 for more information on this topic.

Non-superusers can only apply LOAD to library files located in `$libdir/plugins/` — the specified *filename* must begin with exactly that string. (It is the database administrator's responsibility to ensure that only “safe” libraries are installed there.)

Compatibility

LOAD is a PostgreSQL extension.

See Also

CREATE FUNCTION

LOCK

LOCK — lock a table

Synopsis

```
LOCK [ TABLE ] [ ONLY ] name [ * ] [, ...] [ IN lockmode MODE ]  
[ NOWAIT ]
```

where *lockmode* is one of:

```
ACCESS SHARE | ROW SHARE | ROW EXCLUSIVE | SHARE UPDATE  
EXCLUSIVE  
| SHARE | SHARE ROW EXCLUSIVE | EXCLUSIVE | ACCESS EXCLUSIVE
```

Description

LOCK TABLE obtains a table-level lock, waiting if necessary for any conflicting locks to be released. If NOWAIT is specified, LOCK TABLE does not wait to acquire the desired lock: if it cannot be acquired immediately, the command is aborted and an error is emitted. Once obtained, the lock is held for the remainder of the current transaction. (There is no UNLOCK TABLE command; locks are always released at transaction end.)

When a view is locked, all relations appearing in the view definition query are also locked recursively with the same lock mode.

When acquiring locks automatically for commands that reference tables, PostgreSQL always uses the least restrictive lock mode possible. LOCK TABLE provides for cases when you might need more restrictive locking. For example, suppose an application runs a transaction at the READ COMMITTED isolation level and needs to ensure that data in a table remains stable for the duration of the transaction. To achieve this you could obtain SHARE lock mode over the table before querying. This will prevent concurrent data changes and ensure subsequent reads of the table see a stable view of committed data, because SHARE lock mode conflicts with the ROW EXCLUSIVE lock acquired by writers, and your LOCK TABLE *name* IN SHARE MODE statement will wait until any concurrent holders of ROW EXCLUSIVE mode locks commit or roll back. Thus, once you obtain the lock, there are no uncommitted writes outstanding; furthermore none can begin until you release the lock.

To achieve a similar effect when running a transaction at the REPEATABLE READ or SERIALIZABLE isolation level, you have to execute the LOCK TABLE statement before executing any SELECT or data modification statement. A REPEATABLE READ or SERIALIZABLE transaction's view of data will be frozen when its first SELECT or data modification statement begins. A LOCK TABLE later in the transaction will still prevent concurrent writes — but it won't ensure that what the transaction reads corresponds to the latest committed values.

If a transaction of this sort is going to change the data in the table, then it should use SHARE ROW EXCLUSIVE lock mode instead of SHARE mode. This ensures that only one transaction of this type runs at a time. Without this, a deadlock is possible: two transactions might both acquire SHARE mode, and then be unable to also acquire ROW EXCLUSIVE mode to actually perform their updates. (Note that a transaction's own locks never conflict, so a transaction can acquire ROW EXCLUSIVE mode when it holds SHARE mode — but not if anyone else holds SHARE mode.) To avoid deadlocks, make sure all transactions acquire locks on the same objects in the same order, and if multiple lock modes are involved for a single object, then transactions should always acquire the most restrictive mode first.

More information about the lock modes and locking strategies can be found in Section 13.3.

Parameters

name

The name (optionally schema-qualified) of an existing table to lock. If `ONLY` is specified before the table name, only that table is locked. If `ONLY` is not specified, the table and all its descendant tables (if any) are locked. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

The command `LOCK TABLE a, b;` is equivalent to `LOCK TABLE a; LOCK TABLE b;`. The tables are locked one-by-one in the order specified in the `LOCK TABLE` command.

lockmode

The lock mode specifies which locks this lock conflicts with. Lock modes are described in Section 13.3.

If no lock mode is specified, then `ACCESS EXCLUSIVE`, the most restrictive mode, is used.

`NOWAIT`

Specifies that `LOCK TABLE` should not wait for any conflicting locks to be released: if the specified lock(s) cannot be acquired immediately without waiting, the transaction is aborted.

Notes

`LOCK TABLE ... IN ACCESS SHARE MODE` requires `SELECT` privileges on the target table. `LOCK TABLE ... IN ROW EXCLUSIVE MODE` requires `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` privileges on the target table. All other forms of `LOCK` require table-level `UPDATE`, `DELETE`, or `TRUNCATE` privileges.

The user performing the lock on the view must have the corresponding privilege on the view. In addition the view's owner must have the relevant privileges on the underlying base relations, but the user performing the lock does not need any permissions on the underlying base relations.

`LOCK TABLE` is useless outside a transaction block: the lock would remain held only to the completion of the statement. Therefore PostgreSQL reports an error if `LOCK` is used outside a transaction block. Use `BEGIN` and `COMMIT` (or `ROLLBACK`) to define a transaction block.

`LOCK TABLE` only deals with table-level locks, and so the mode names involving `ROW` are all misnomers. These mode names should generally be read as indicating the intention of the user to acquire row-level locks within the locked table. Also, `ROW EXCLUSIVE` mode is a shareable table lock. Keep in mind that all the lock modes have identical semantics so far as `LOCK TABLE` is concerned, differing only in the rules about which modes conflict with which. For information on how to acquire an actual row-level lock, see Section 13.3.2 and the `The Locking Clause` in the `SELECT` reference documentation.

Examples

Obtain a `SHARE` lock on a primary key table when going to perform inserts into a foreign key table:

```
BEGIN WORK;  
LOCK TABLE films IN SHARE MODE;  
SELECT id FROM films  
    WHERE name = 'Star Wars: Episode I - The Phantom Menace';  
-- Do ROLLBACK if record was not returned  
INSERT INTO films_user_comments VALUES  
    (_id_, 'GREAT! I was waiting for it for so long!');
```

```
COMMIT WORK;
```

Take a `SHARE ROW EXCLUSIVE` lock on a primary key table when going to perform a delete operation:

```
BEGIN WORK;  
LOCK TABLE films IN SHARE ROW EXCLUSIVE MODE;  
DELETE FROM films_user_comments WHERE id IN  
    (SELECT id FROM films WHERE rating < 5);  
DELETE FROM films WHERE rating < 5;  
COMMIT WORK;
```

Compatibility

There is no `LOCK TABLE` in the SQL standard, which instead uses `SET TRANSACTION` to specify concurrency levels on transactions. PostgreSQL supports that too; see `SET TRANSACTION` for details.

Except for `ACCESS SHARE`, `ACCESS EXCLUSIVE`, and `SHARE UPDATE EXCLUSIVE` lock modes, the PostgreSQL lock modes and the `LOCK TABLE` syntax are compatible with those present in Oracle.

MOVE

MOVE — position a cursor

Synopsis

```
MOVE [ direction [ FROM | IN ] ] cursor_name
```

where *direction* can be empty or one of:

```
NEXT  
PRIOR  
FIRST  
LAST  
ABSOLUTE count  
RELATIVE count  
count  
ALL  
FORWARD  
FORWARD count  
FORWARD ALL  
BACKWARD  
BACKWARD count  
BACKWARD ALL
```

Description

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only positions the cursor and does not return rows.

The parameters for the MOVE command are identical to those of the FETCH command; refer to FETCH for details on syntax and usage.

Outputs

On successful completion, a MOVE command returns a command tag of the form

```
MOVE count
```

The *count* is the number of rows that a FETCH command with the same parameters would have returned (possibly zero).

Examples

```
BEGIN WORK;  
DECLARE liahona CURSOR FOR SELECT * FROM films;  
  
-- Skip the first 5 rows:  
MOVE FORWARD 5 IN liahona;  
MOVE 5  
  
-- Fetch the 6th row from the cursor liahona:
```

```
FETCH 1 FROM liahona;
  code | title | did | date_prod | kind | len
-----+-----+-----+-----+-----+-----
  P_303 | 48 Hrs | 103 | 1982-10-22 | Action | 01:37
(1 row)

-- Close the cursor liahona and end the transaction:
CLOSE liahona;
COMMIT WORK;
```

Compatibility

There is no MOVE statement in the SQL standard.

See Also

CLOSE, DECLARE, FETCH

NOTIFY

NOTIFY — generate a notification

Synopsis

```
NOTIFY channel [ , payload ]
```

Description

The NOTIFY command sends a notification event together with an optional “payload” string to each client application that has previously executed LISTEN *channel* for the specified channel name in the current database. Notifications are visible to all users.

NOTIFY provides a simple interprocess communication mechanism for a collection of processes accessing the same PostgreSQL database. A payload string can be sent along with the notification, and higher-level mechanisms for passing structured data can be built by using tables in the database to pass additional data from notifier to listener(s).

The information passed to the client for a notification event includes the notification channel name, the notifying session's server process PID, and the payload string, which is an empty string if it has not been specified.

It is up to the database designer to define the channel names that will be used in a given database and what each one means. Commonly, the channel name is the same as the name of some table in the database, and the notify event essentially means, “I changed this table, take a look at it to see what's new”. But no such association is enforced by the NOTIFY and LISTEN commands. For example, a database designer could use several different channel names to signal different sorts of changes to a single table. Alternatively, the payload string could be used to differentiate various cases.

When NOTIFY is used to signal the occurrence of changes to a particular table, a useful programming technique is to put the NOTIFY in a statement trigger that is triggered by table updates. In this way, notification happens automatically when the table is changed, and the application programmer cannot accidentally forget to do it.

NOTIFY interacts with SQL transactions in some important ways. Firstly, if a NOTIFY is executed inside a transaction, the notify events are not delivered until and unless the transaction is committed. This is appropriate, since if the transaction is aborted, all the commands within it have had no effect, including NOTIFY. But it can be disconcerting if one is expecting the notification events to be delivered immediately. Secondly, if a listening session receives a notification signal while it is within a transaction, the notification event will not be delivered to its connected client until just after the transaction is completed (either committed or aborted). Again, the reasoning is that if a notification were delivered within a transaction that was later aborted, one would want the notification to be undone somehow — but the server cannot “take back” a notification once it has sent it to the client. So notification events are only delivered between transactions. The upshot of this is that applications using NOTIFY for real-time signaling should try to keep their transactions short.

If the same channel name is signaled multiple times from the same transaction with identical payload strings, the database server can decide to deliver a single notification only. On the other hand, notifications with distinct payload strings will always be delivered as distinct notifications. Similarly, notifications from different transactions will never get folded into one notification. Except for dropping later instances of duplicate notifications, NOTIFY guarantees that notifications from the same transaction get delivered in the order they were sent. It is also guaranteed that messages from different transactions are delivered in the order in which the transactions committed.

It is common for a client that executes NOTIFY to be listening on the same notification channel itself. In that case it will get back a notification event, just like all the other listening sessions. Depending on the application logic, this could result in useless work, for example, reading a database table to find the same updates that that session just wrote out. It is possible to avoid such extra work by noticing whether the notifying session's server process PID (supplied in the notification event message) is the same as one's own session's PID (available from libpq). When they are the same, the notification event is one's own work bouncing back, and can be ignored.

Parameters

channel

Name of the notification channel to be signaled (any identifier).

payload

The “payload” string to be communicated along with the notification. This must be specified as a simple string literal. In the default configuration it must be shorter than 8000 bytes. (If binary data or large amounts of information need to be communicated, it's best to put it in a database table and send the key of the record.)

Notes

There is a queue that holds notifications that have been sent but not yet processed by all listening sessions. If this queue becomes full, transactions calling NOTIFY will fail at commit. The queue is quite large (8GB in a standard installation) and should be sufficiently sized for almost every use case. However, no cleanup can take place if a session executes LISTEN and then enters a transaction for a very long time. Once the queue is half full you will see warnings in the log file pointing you to the session that is preventing cleanup. In this case you should make sure that this session ends its current transaction so that cleanup can proceed.

The function `pg_notification_queue_usage` returns the fraction of the queue that is currently occupied by pending notifications. See Section 9.25 for more information.

A transaction that has executed NOTIFY cannot be prepared for two-phase commit.

pg_notify

To send a notification you can also use the function `pg_notify(text, text)`. The function takes the channel name as the first argument and the payload as the second. The function is much easier to use than the NOTIFY command if you need to work with non-constant channel names and payloads.

Examples

Configure and execute a listen/notify sequence from psql:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process
with PID 8448.
NOTIFY virtual, 'This is the payload';
Asynchronous notification "virtual" with payload "This is the
payload" received from server process with PID 8448.

LISTEN foo;
SELECT pg_notify('fo' || 'o', 'pay' || 'load');
```

Asynchronous notification "foo" with payload "payload" received
from server process with PID 14728.

Compatibility

There is no NOTIFY statement in the SQL standard.

See Also

LISTEN, UNLISTEN

PREPARE

PREPARE — prepare a statement for execution

Synopsis

```
PREPARE name [ ( data_type [ , ... ] ) ] AS statement
```

Description

PREPARE creates a prepared statement. A prepared statement is a server-side object that can be used to optimize performance. When the PREPARE statement is executed, the specified statement is parsed, analyzed, and rewritten. When an EXECUTE command is subsequently issued, the prepared statement is planned and executed. This division of labor avoids repetitive parse analysis work, while allowing the execution plan to depend on the specific parameter values supplied.

Prepared statements can take parameters: values that are substituted into the statement when it is executed. When creating the prepared statement, refer to parameters by position, using \$1, \$2, etc. A corresponding list of parameter data types can optionally be specified. When a parameter's data type is not specified or is declared as unknown, the type is inferred from the context in which the parameter is first referenced (if possible). When executing the statement, specify the actual values for these parameters in the EXECUTE statement. Refer to EXECUTE for more information about that.

Prepared statements only last for the duration of the current database session. When the session ends, the prepared statement is forgotten, so it must be recreated before being used again. This also means that a single prepared statement cannot be used by multiple simultaneous database clients; however, each client can create their own prepared statement to use. Prepared statements can be manually cleaned up using the DEALLOCATE command.

Prepared statements potentially have the largest performance advantage when a single session is being used to execute a large number of similar statements. The performance difference will be particularly significant if the statements are complex to plan or rewrite, e.g. if the query involves a join of many tables or requires the application of several rules. If the statement is relatively simple to plan and rewrite but relatively expensive to execute, the performance advantage of prepared statements will be less noticeable.

Parameters

name

An arbitrary name given to this particular prepared statement. It must be unique within a single session and is subsequently used to execute or deallocate a previously prepared statement.

data_type

The data type of a parameter to the prepared statement. If the data type of a particular parameter is unspecified or is specified as unknown, it will be inferred from the context in which the parameter is first referenced. To refer to the parameters in the prepared statement itself, use \$1, \$2, etc.

statement

Any SELECT, INSERT, UPDATE, DELETE, or VALUES statement.

Notes

A prepared statement can be executed with either a *generic plan* or a *custom plan*. A generic plan is the same across all executions, while a custom plan is generated for a specific execution using

the parameter values given in that call. Use of a generic plan avoids planning overhead, but in some situations a custom plan will be much more efficient to execute because the planner can make use of knowledge of the parameter values. (Of course, if the prepared statement has no parameters, then this is moot and a generic plan is always used.)

By default (that is, when `plan_cache_mode` is set to `auto`), the server will automatically choose whether to use a generic or custom plan for a prepared statement that has parameters. The current rule for this is that the first five executions are done with custom plans and the average estimated cost of those plans is calculated. Then a generic plan is created and its estimated cost is compared to the average custom-plan cost. Subsequent executions use the generic plan if its cost is not so much higher than the average custom-plan cost as to make repeated replanning seem preferable.

This heuristic can be overridden, forcing the server to use either generic or custom plans, by setting `plan_cache_mode` to `force_generic_plan` or `force_custom_plan` respectively. This setting is primarily useful if the generic plan's cost estimate is badly off for some reason, allowing it to be chosen even though its actual cost is much more than that of a custom plan.

To examine the query plan PostgreSQL is using for a prepared statement, use `EXPLAIN`, for example

```
EXPLAIN EXECUTE name(parameter_values);
```

If a generic plan is in use, it will contain parameter symbols `$n`, while a custom plan will have the supplied parameter values substituted into it.

For more information on query planning and the statistics collected by PostgreSQL for that purpose, see the `ANALYZE` documentation.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, PostgreSQL will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of `search_path` changes from one use to the next, the statement will be re-parsed using the new `search_path`. (This latter behavior is new as of PostgreSQL 9.3.) These rules make use of a prepared statement semantically almost equivalent to re-submitting the same query text over and over, but with a performance benefit if no object definitions are changed, especially if the best plan remains the same across uses. An example of a case where the semantic equivalence is not perfect is that if the statement refers to a table by an unqualified name, and then a new table of the same name is created in a schema appearing earlier in the `search_path`, no automatic re-parse will occur since no object used in the statement changed. However, if some other change forces a re-parse, the new table will be referenced in subsequent uses.

You can see all prepared statements available in the session by querying the `pg_prepared_statements` system view.

Examples

Create a prepared statement for an `INSERT` statement, and then execute it:

```
PREPARE fooplan (int, text, bool, numeric) AS
  INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Create a prepared statement for a `SELECT` statement, and then execute it:

```
PREPARE usrrptplan (int) AS
  SELECT * FROM users u, logs l WHERE u.usrid=$1 AND
  u.usrid=l.usrid
  AND l.date = $2;
```

```
EXECUTE usrrptplan(1, current_date);
```

In this example, the data type of the second parameter is not specified, so it is inferred from the context in which \$2 is used.

Compatibility

The SQL standard includes a `PREPARE` statement, but it is only for use in embedded SQL. This version of the `PREPARE` statement also uses a somewhat different syntax.

See Also

DEALLOCATE, EXECUTE

PREPARE TRANSACTION

PREPARE TRANSACTION — prepare the current transaction for two-phase commit

Synopsis

```
PREPARE TRANSACTION transaction_id
```

Description

PREPARE TRANSACTION prepares the current transaction for two-phase commit. After this command, the transaction is no longer associated with the current session; instead, its state is fully stored on disk, and there is a very high probability that it can be committed successfully, even if a database crash occurs before the commit is requested.

Once prepared, a transaction can later be committed or rolled back with COMMIT PREPARED or ROLLBACK PREPARED, respectively. Those commands can be issued from any session, not only the one that executed the original transaction.

From the point of view of the issuing session, PREPARE TRANSACTION is not unlike a ROLLBACK command: after executing it, there is no active current transaction, and the effects of the prepared transaction are no longer visible. (The effects will become visible again if the transaction is committed.)

If the PREPARE TRANSACTION command fails for any reason, it becomes a ROLLBACK: the current transaction is canceled.

Parameters

transaction_id

An arbitrary identifier that later identifies this transaction for COMMIT PREPARED or ROLLBACK PREPARED. The identifier must be written as a string literal, and must be less than 200 bytes long. It must not be the same as the identifier used for any currently prepared transaction.

Notes

PREPARE TRANSACTION is not intended for use in applications or interactive sessions. Its purpose is to allow an external transaction manager to perform atomic global transactions across multiple databases or other transactional resources. Unless you're writing a transaction manager, you probably shouldn't be using PREPARE TRANSACTION.

This command must be used inside a transaction block. Use BEGIN to start one.

It is not currently allowed to PREPARE a transaction that has executed any operations involving temporary tables or the session's temporary namespace, created any cursors WITH HOLD, or executed LISTEN, UNLISTEN, or NOTIFY. Those features are too tightly tied to the current session to be useful in a transaction to be prepared.

If the transaction modified any run-time parameters with SET (without the LOCAL option), those effects persist after PREPARE TRANSACTION, and will not be affected by any later COMMIT PREPARED or ROLLBACK PREPARED. Thus, in this one respect PREPARE TRANSACTION acts more like COMMIT than ROLLBACK.

All currently available prepared transactions are listed in the pg_prepared_xacts system view.

Caution

It is unwise to leave transactions in the prepared state for a long time. This will interfere with the ability of `VACUUM` to reclaim storage, and in extreme cases could cause the database to shut down to prevent transaction ID wraparound (see Section 24.1.5). Keep in mind also that the transaction continues to hold whatever locks it held. The intended usage of the feature is that a prepared transaction will normally be committed or rolled back as soon as an external transaction manager has verified that other databases are also prepared to commit.

If you have not set up an external transaction manager to track prepared transactions and ensure they get closed out promptly, it is best to keep the prepared-transaction feature disabled by setting `max_prepared_transactions` to zero. This will prevent accidental creation of prepared transactions that might then be forgotten and eventually cause problems.

Examples

Prepare the current transaction for two-phase commit, using `foobar` as the transaction identifier:

```
PREPARE TRANSACTION 'foobar';
```

Compatibility

`PREPARE TRANSACTION` is a PostgreSQL extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

See Also

`COMMIT PREPARED`, `ROLLBACK PREPARED`

REASSIGN OWNED

REASSIGN OWNED — change the ownership of database objects owned by a database role

Synopsis

```
REASSIGN OWNED BY { old_role | CURRENT_USER | SESSION_USER }  
[, ...]  
                TO { new_role | CURRENT_USER | SESSION_USER }
```

Description

REASSIGN OWNED instructs the system to change the ownership of database objects owned by any of the *old_roles* to *new_role*.

Parameters

old_role

The name of a role. The ownership of all the objects within the current database, and of all shared objects (databases, tablespaces), owned by this role will be reassigned to *new_role*.

new_role

The name of the role that will be made the new owner of the affected objects.

Notes

REASSIGN OWNED is often used to prepare for the removal of one or more roles. Because REASSIGN OWNED does not affect objects within other databases, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.

REASSIGN OWNED requires membership on both the source role(s) and the target role.

The DROP OWNED command is an alternative that simply drops all the database objects owned by one or more roles.

The REASSIGN OWNED command does not affect any privileges granted to the *old_roles* on objects that are not owned by them. Likewise, it does not affect default privileges created with ALTER DEFAULT PRIVILEGES. Use DROP OWNED to revoke such privileges.

See Section 21.4 for more discussion.

Compatibility

The REASSIGN OWNED command is a PostgreSQL extension.

See Also

DROP OWNED, DROP ROLE, ALTER DATABASE

REFRESH MATERIALIZED VIEW

REFRESH MATERIALIZED VIEW — replace the contents of a materialized view

Synopsis

```
REFRESH MATERIALIZED VIEW [ CONCURRENTLY ] name
    [ WITH [ NO ] DATA ]
```

Description

REFRESH MATERIALIZED VIEW completely replaces the contents of a materialized view. To execute this command you must be the owner of the materialized view. The old contents are discarded. If WITH DATA is specified (or defaults) the backing query is executed to provide the new data, and the materialized view is left in a scannable state. If WITH NO DATA is specified no new data is generated and the materialized view is left in an unscannable state.

CONCURRENTLY and WITH NO DATA may not be specified together.

Parameters

CONCURRENTLY

Refresh the materialized view without locking out concurrent selects on the materialized view. Without this option a refresh which affects a lot of rows will tend to use fewer resources and complete more quickly, but could block other connections which are trying to read from the materialized view. This option may be faster in cases where a small number of rows are affected.

This option is only allowed if there is at least one UNIQUE index on the materialized view which uses only column names and includes all rows; that is, it must not be an expression index or include a WHERE clause.

This option may not be used when the materialized view is not already populated.

Even with this option only one REFRESH at a time may run against any one materialized view.

name

The name (optionally schema-qualified) of the materialized view to refresh.

Notes

While the default index for future CLUSTER operations is retained, REFRESH MATERIALIZED VIEW does not order the generated rows based on this property. If you want the data to be ordered upon generation, you must use an ORDER BY clause in the backing query.

Examples

This command will replace the contents of the materialized view called `order_summary` using the query from the materialized view's definition, and leave it in a scannable state:

```
REFRESH MATERIALIZED VIEW order_summary;
```

This command will free storage associated with the materialized view `annual_statistics_basis` and leave it in an unscannable state:

```
REFRESH MATERIALIZED VIEW annual_statistics_basis WITH NO DATA;
```

Compatibility

`REFRESH MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

`CREATE MATERIALIZED VIEW`, `ALTER MATERIALIZED VIEW`, `DROP MATERIALIZED VIEW`

REINDEX

REINDEX — rebuild indexes

Synopsis

```
REINDEX [ ( VERBOSE ) ] { INDEX | TABLE | SCHEMA | DATABASE |  
SYSTEM } [ CONCURRENTLY ] name
```

Description

REINDEX rebuilds an index using the data stored in the index's table, replacing the old copy of the index. There are several scenarios in which to use REINDEX:

- An index has become corrupted, and no longer contains valid data. Although in theory this should never happen, in practice indexes can become corrupted due to software bugs or hardware failures. REINDEX provides a recovery method.
- An index has become “bloated”, that is it contains many empty or nearly-empty pages. This can occur with B-tree indexes in PostgreSQL under certain uncommon access patterns. REINDEX provides a way to reduce the space consumption of the index by writing a new version of the index without the dead pages. See Section 24.2 for more information.
- You have altered a storage parameter (such as fillfactor) for an index, and wish to ensure that the change has taken full effect.
- If an index build fails with the CONCURRENTLY option, this index is left as “invalid”. Such indexes are useless but it can be convenient to use REINDEX to rebuild them. Note that only REINDEX INDEX is able to perform a concurrent build on an invalid index.

Parameters

INDEX

Recreate the specified index.

TABLE

Recreate all indexes of the specified table. If the table has a secondary “TOAST” table, that is reindexed as well.

SCHEMA

Recreate all indexes of the specified schema. If a table of this schema has a secondary “TOAST” table, that is reindexed as well. Indexes on shared system catalogs are also processed. This form of REINDEX cannot be executed inside a transaction block.

DATABASE

Recreate all indexes within the current database. Indexes on shared system catalogs are also processed. This form of REINDEX cannot be executed inside a transaction block.

SYSTEM

Recreate all indexes on system catalogs within the current database. Indexes on shared system catalogs are included. Indexes on user tables are not processed. This form of REINDEX cannot be executed inside a transaction block.

name

The name of the specific index, table, or database to be reindexed. Index and table names can be schema-qualified. Presently, `REINDEX DATABASE` and `REINDEX SYSTEM` can only reindex the current database, so their parameter must match the current database's name.

CONCURRENTLY

When this option is used, PostgreSQL will rebuild the index without taking any locks that prevent concurrent inserts, updates, or deletes on the table; whereas a standard index rebuild locks out writes (but not reads) on the table until it's done. There are several caveats to be aware of when using this option — see [Rebuilding Indexes Concurrently](#).

VERBOSE

Prints a progress report as each index is reindexed.

Notes

If you suspect corruption of an index on a user table, you can simply rebuild that index, or all indexes on the table, using `REINDEX INDEX` or `REINDEX TABLE`.

Things are more difficult if you need to recover from corruption of an index on a system table. In this case it's important for the system to not have used any of the suspect indexes itself. (Indeed, in this sort of scenario you might find that server processes are crashing immediately at start-up, due to reliance on the corrupted indexes.) To recover safely, the server must be started with the `-P` option, which prevents it from using indexes for system catalog lookups.

One way to do this is to shut down the server and start a single-user PostgreSQL server with the `-P` option included on its command line. Then, `REINDEX DATABASE`, `REINDEX SYSTEM`, `REINDEX TABLE`, or `REINDEX INDEX` can be issued, depending on how much you want to reconstruct. If in doubt, use `REINDEX SYSTEM` to select reconstruction of all system indexes in the database. Then quit the single-user server session and restart the regular server. See the [postgres reference page](#) for more information about how to interact with the single-user server interface.

Alternatively, a regular server session can be started with `-P` included in its command line options. The method for doing this varies across clients, but in all libpq-based clients, it is possible to set the `PGOPTIONS` environment variable to `-P` before starting the client. Note that while this method does not require locking out other clients, it might still be wise to prevent other users from connecting to the damaged database until repairs have been completed.

`REINDEX` is similar to a drop and recreate of the index in that the index contents are rebuilt from scratch. However, the locking considerations are rather different. `REINDEX` locks out writes but not reads of the index's parent table. It also takes an exclusive lock on the specific index being processed, which will block reads that attempt to use that index. In contrast, `DROP INDEX` momentarily takes an exclusive lock on the parent table, blocking both writes and reads. The subsequent `CREATE INDEX` locks out writes but not reads; since the index is not there, no read will attempt to use it, meaning that there will be no blocking but reads might be forced into expensive sequential scans.

Reindexing a single index or table requires being the owner of that index or table. Reindexing a schema or database requires being the owner of that schema or database. Note that is therefore sometimes possible for non-superusers to rebuild indexes of tables owned by other users. However, as a special exception, when `REINDEX DATABASE`, `REINDEX SCHEMA` or `REINDEX SYSTEM` is issued by a non-superuser, indexes on shared catalogs will be skipped unless the user owns the catalog (which typically won't be the case). Of course, superusers can always reindex anything.

Reindexing partitioned tables or partitioned indexes is not supported. Each individual partition can be reindexed separately instead.

Rebuilding Indexes Concurrently

Rebuilding an index can interfere with regular operation of a database. Normally PostgreSQL locks the table whose index is rebuilt against writes and performs the entire index build with a single scan of the table. Other transactions can still read the table, but if they try to insert, update, or delete rows in the table they will block until the index rebuild is finished. This could have a severe effect if the system is a live production database. Very large tables can take many hours to be indexed, and even for smaller tables, an index rebuild can lock out writers for periods that are unacceptably long for a production system.

PostgreSQL supports rebuilding indexes with minimum locking of writes. This method is invoked by specifying the `CONCURRENTLY` option of `REINDEX`. When this option is used, PostgreSQL must perform two scans of the table for each index that needs to be rebuilt and wait for termination of all existing transactions that could potentially use the index. This method requires more total work than a standard index rebuild and takes significantly longer to complete as it needs to wait for unfinished transactions that might modify the index. However, since it allows normal operations to continue while the index is being rebuilt, this method is useful for rebuilding indexes in a production environment. Of course, the extra CPU, memory and I/O load imposed by the index rebuild may slow down other operations.

The following steps occur in a concurrent reindex. Each step is run in a separate transaction. If there are multiple indexes to be rebuilt, then each step loops through all the indexes before moving to the next step.

1. A new temporary index definition is added to the catalog `pg_index`. This definition will be used to replace the old index. A `SHARE UPDATE EXCLUSIVE` lock at session level is taken on the indexes being reindexed as well as their associated tables to prevent any schema modification while processing.
2. A first pass to build the index is done for each new index. Once the index is built, its flag `pg_index.indisready` is switched to “true” to make it ready for inserts, making it visible to other sessions once the transaction that performed the build is finished. This step is done in a separate transaction for each index.
3. Then a second pass is performed to add tuples that were added while the first pass was running. This step is also done in a separate transaction for each index.
4. All the constraints that refer to the index are changed to refer to the new index definition, and the names of the indexes are changed. At this point, `pg_index.indisvalid` is switched to “true” for the new index and to “false” for the old, and a cache invalidation is done causing all sessions that referenced the old index to be invalidated.
5. The old indexes have `pg_index.indisready` switched to “false” to prevent any new tuple insertions, after waiting for running queries that might reference the old index to complete.
6. The old indexes are dropped. The `SHARE UPDATE EXCLUSIVE` session locks for the indexes and the table are released.

If a problem arises while rebuilding the indexes, such as a uniqueness violation in a unique index, the `REINDEX` command will fail but leave behind an “invalid” new index in addition to the pre-existing one. This index will be ignored for querying purposes because it might be incomplete; however it will still consume update overhead. The `psql \d` command will report such an index as `INVALID`:

```
postgres=# \d tab
          Table "public.tab"
  Column | Type   | Modifiers
  -----+-----+-----
   col   | integer |
Indexes:
  "idx" btree (col)
  "idx_ccnew" btree (col) INVALID
```

The recommended recovery method in such cases is to drop the invalid index and try again to perform `REINDEX CONCURRENTLY`. The concurrent index created during the processing has a name ending in the suffix `ccnew`, or `ccold` if it is an old index definition which we failed to drop. Invalid indexes can be dropped using `DROP INDEX`, including invalid toast indexes.

Regular index builds permit other regular index builds on the same table to occur simultaneously, but only one concurrent index build can occur on a table at a time. In both cases, no other types of schema modification on the table are allowed meanwhile. Another difference is that a regular `REINDEX TABLE` or `REINDEX INDEX` command can be performed within a transaction block, but `REINDEX CONCURRENTLY` cannot.

`REINDEX SYSTEM` does not support `CONCURRENTLY` since system catalogs cannot be reindexed concurrently.

Furthermore, indexes for exclusion constraints cannot be reindexed concurrently. If such an index is named directly in this command, an error is raised. If a table or database with exclusion constraint indexes is reindexed concurrently, those indexes will be skipped. (It is possible to reindex such indexes without the `CONCURRENTLY` option.)

Examples

Rebuild a single index:

```
REINDEX INDEX my_index;
```

Rebuild all the indexes on the table `my_table`:

```
REINDEX TABLE my_table;
```

Rebuild all indexes in a particular database, without trusting the system indexes to be valid already:

```
$ export PGOPTIONS="-P"
$ psql broken_db
...
broken_db=> REINDEX DATABASE broken_db;
broken_db=> \q
```

Rebuild indexes for a table, without blocking read and write operations on involved relations while reindexing is in progress:

```
REINDEX TABLE CONCURRENTLY my_broken_table;
```

Compatibility

There is no `REINDEX` command in the SQL standard.

See Also

`CREATE INDEX`, `DROP INDEX`, `reindexdb`

RELEASE SAVEPOINT

RELEASE SAVEPOINT — destroy a previously defined savepoint

Synopsis

```
RELEASE [ SAVEPOINT ] savepoint_name
```

Description

RELEASE SAVEPOINT destroys a savepoint previously defined in the current transaction.

Destroying a savepoint makes it unavailable as a rollback point, but it has no other user visible behavior. It does not undo the effects of commands executed after the savepoint was established. (To do that, see ROLLBACK TO SAVEPOINT.) Destroying a savepoint when it is no longer needed allows the system to reclaim some resources earlier than transaction end.

RELEASE SAVEPOINT also destroys all savepoints that were established after the named savepoint was established.

Parameters

savepoint_name

The name of the savepoint to destroy.

Notes

Specifying a savepoint name that was not previously defined is an error.

It is not possible to release a savepoint when the transaction is in an aborted state.

If multiple savepoints have the same name, only the one that was most recently defined is released.

Examples

To establish and later destroy a savepoint:

```
BEGIN;  
  INSERT INTO table1 VALUES (3);  
  SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (4);  
  RELEASE SAVEPOINT my_savepoint;  
COMMIT;
```

The above transaction will insert both 3 and 4.

Compatibility

This command conforms to the SQL standard. The standard specifies that the key word SAVEPOINT is mandatory, but PostgreSQL allows it to be omitted.

See Also

BEGIN, COMMIT, ROLLBACK, ROLLBACK TO SAVEPOINT, SAVEPOINT

RESET

RESET — restore the value of a run-time parameter to the default value

Synopsis

```
RESET configuration_parameter
RESET ALL
```

Description

RESET restores run-time parameters to their default values. RESET is an alternative spelling for

```
SET configuration_parameter TO DEFAULT
```

Refer to SET for details.

The default value is defined as the value that the parameter would have had, if no SET had ever been issued for it in the current session. The actual source of this value might be a compiled-in default, the configuration file, command-line options, or per-database or per-user default settings. This is subtly different from defining it as “the value that the parameter had at session start”, because if the value came from the configuration file, it will be reset to whatever is specified by the configuration file now. See Chapter 19 for details.

The transactional behavior of RESET is the same as SET: its effects will be undone by transaction rollback.

Parameters

configuration_parameter

Name of a settable run-time parameter. Available parameters are documented in Chapter 19 and on the SET reference page.

ALL

Resets all settable run-time parameters to default values.

Examples

Set the `timezone` configuration variable to its default value:

```
RESET timezone;
```

Compatibility

RESET is a PostgreSQL extension.

See Also

SET, SHOW

REVOKE

REVOKE — remove access privileges

Synopsis

```
REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES |
      TRIGGER }
      [, ...] | ALL [ PRIVILEGES ] }
    ON { [ TABLE ] table_name [, ...]
        | ALL TABLES IN SCHEMA schema_name [, ...] }
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | REFERENCES } ( column_name
      [, ...] )
      [, ...] | ALL [ PRIVILEGES ] ( column_name [, ...] ) }
    ON [ TABLE ] table_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { USAGE | SELECT | UPDATE }
      [, ...] | ALL [ PRIVILEGES ] }
    ON { SEQUENCE sequence_name [, ...]
        | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { { CREATE | CONNECT | TEMPORARY | TEMP } [, ...] | ALL
      [ PRIVILEGES ] }
    ON DATABASE database_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON DOMAIN domain_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN DATA WRAPPER fdw_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN SERVER server_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
```

```

[ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { EXECUTE | ALL [ PRIVILEGES ] }
    ON { { FUNCTION | PROCEDURE | ROUTINE } function_name
    [ ( [ [ argmode ] [ arg_name ] arg_type [, ...] ) ] [, ...]
        | ALL { FUNCTIONS | PROCEDURES | ROUTINES } IN
    SCHEMA schema_name [, ...] }
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON LANGUAGE lang_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { SELECT | UPDATE } [, ...] | ALL [ PRIVILEGES ] }
    ON LARGE OBJECT loid [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { CREATE | USAGE } [, ...] | ALL [ PRIVILEGES ] }
    ON SCHEMA schema_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { CREATE | ALL [ PRIVILEGES ] }
    ON TABLESPACE tablespace_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON TYPE type_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ ADMIN OPTION FOR ]
    role_name [, ...] FROM role_name [, ...]
    [ CASCADE | RESTRICT ]

```

Description

The REVOKE command revokes previously granted privileges from one or more roles. The key word PUBLIC refers to the implicitly defined group of all roles.

See the description of the GRANT command for the meaning of the privilege types.

Note that any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC. Thus, for example, revoking SELECT privilege from PUBLIC does not necessarily mean that all roles have lost SELECT privilege on the object: those who have it granted directly or via another role will still have it. Similarly, revoking SELECT from a user might not prevent that user from using SELECT if PUBLIC or another membership role still has SELECT rights.

If `GRANT OPTION FOR` is specified, only the grant option for the privilege is revoked, not the privilege itself. Otherwise, both the privilege and the grant option are revoked.

If a user holds a privilege with grant option and has granted it to other users then the privileges held by those other users are called dependent privileges. If the privilege or the grant option held by the first user is being revoked and dependent privileges exist, those dependent privileges are also revoked if `CASCADE` is specified; if it is not, the revoke action will fail. This recursive revocation only affects privileges that were granted through a chain of users that is traceable to the user that is the subject of this `REVOKE` command. Thus, the affected users might effectively keep the privilege if it was also granted through other users.

When revoking privileges on a table, the corresponding column privileges (if any) are automatically revoked on each column of the table, as well. On the other hand, if a role has been granted privileges on a table, then revoking the same privileges from individual columns will have no effect.

When revoking membership in a role, `GRANT OPTION` is instead called `ADMIN OPTION`, but the behavior is similar. Note also that this form of the command does not allow the noise word `GROUP`.

Notes

A user can only revoke privileges that were granted directly by that user. If, for example, user A has granted a privilege with grant option to user B, and user B has in turn granted it to user C, then user A cannot revoke the privilege directly from C. Instead, user A could revoke the grant option from user B and use the `CASCADE` option so that the privilege is in turn revoked from user C. For another example, if both A and B have granted the same privilege to C, A can revoke their own grant but not B's grant, so C will still effectively have the privilege.

When a non-owner of an object attempts to `REVOKE` privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will revoke only those privileges for which the user has grant options. The `REVOKE ALL PRIVILEGES` forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

If a superuser chooses to issue a `GRANT` or `REVOKE` command, the command is performed as though it were issued by the owner of the affected object. Since all privileges ultimately come from the object owner (possibly indirectly via chains of grant options), it is possible for a superuser to revoke all privileges, but this might require use of `CASCADE` as stated above.

`REVOKE` can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges `WITH GRANT OPTION` on the object. In this case the command is performed as though it were issued by the containing role that actually owns the object or holds the privileges `WITH GRANT OPTION`. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can revoke privileges on `t1` that are recorded as being granted by `g1`. This would include grants made by `u1` as well as by other members of role `g1`.

If the role executing `REVOKE` holds privileges indirectly via more than one role membership path, it is unspecified which containing role will be used to perform the command. In such cases it is best practice to use `SET ROLE` to become the specific role you want to do the `REVOKE` as. Failure to do so might lead to revoking privileges other than the ones you intended, or not revoking anything at all.

See Section 5.7 for more information about specific privilege types, as well as how to inspect objects' privileges.

Examples

Revoke insert privilege for the public on table `films`:

```
REVOKE INSERT ON films FROM PUBLIC;
```

Revoke all privileges from user manuel on view kinds:

```
REVOKE ALL PRIVILEGES ON kinds FROM manuel;
```

Note that this actually means “revoke all privileges that I granted”.

Revoke membership in role admins from user joe:

```
REVOKE admins FROM joe;
```

Compatibility

The compatibility notes of the GRANT command apply analogously to REVOKE. The keyword RESTRICT or CASCADE is required according to the standard, but PostgreSQL assumes RESTRICT by default.

See Also

GRANT, ALTER DEFAULT PRIVILEGES

ROLLBACK

ROLLBACK — abort the current transaction

Synopsis

```
ROLLBACK [ WORK | TRANSACTION ] [ AND [ NO ] CHAIN ]
```

Description

ROLLBACK rolls back the current transaction and causes all the updates made by the transaction to be discarded.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

AND CHAIN

If AND CHAIN is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use COMMIT to successfully terminate a transaction.

Issuing ROLLBACK outside of a transaction block emits a warning and otherwise has no effect. ROLLBACK AND CHAIN outside of a transaction block is an error.

Examples

To abort all changes:

```
ROLLBACK ;
```

Compatibility

The command ROLLBACK conforms to the SQL standard. The form ROLLBACK TRANSACTION is a PostgreSQL extension.

See Also

BEGIN, COMMIT, ROLLBACK TO SAVEPOINT

ROLLBACK PREPARED

ROLLBACK PREPARED — cancel a transaction that was earlier prepared for two-phase commit

Synopsis

```
ROLLBACK PREPARED transaction_id
```

Description

ROLLBACK PREPARED rolls back a transaction that is in prepared state.

Parameters

transaction_id

The transaction identifier of the transaction that is to be rolled back.

Notes

To roll back a prepared transaction, you must be either the same user that executed the transaction originally, or a superuser. But you do not have to be in the same session that executed the transaction.

This command cannot be executed inside a transaction block. The prepared transaction is rolled back immediately.

All currently available prepared transactions are listed in the `pg_prepared_xacts` system view.

Examples

Roll back the transaction identified by the transaction identifier `foobar`:

```
ROLLBACK PREPARED 'foobar';
```

Compatibility

ROLLBACK PREPARED is a PostgreSQL extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

See Also

PREPARE TRANSACTION, COMMIT PREPARED

ROLLBACK TO SAVEPOINT

ROLLBACK TO SAVEPOINT — roll back to a savepoint

Synopsis

```
ROLLBACK [ WORK | TRANSACTION ] TO [ SAVEPOINT ] savepoint_name
```

Description

Roll back all commands that were executed after the savepoint was established. The savepoint remains valid and can be rolled back to again later, if needed.

ROLLBACK TO SAVEPOINT implicitly destroys all savepoints that were established after the named savepoint.

Parameters

savepoint_name

The savepoint to roll back to.

Notes

Use RELEASE SAVEPOINT to destroy a savepoint without discarding the effects of commands executed after it was established.

Specifying a savepoint name that has not been established is an error.

Cursors have somewhat non-transactional behavior with respect to savepoints. Any cursor that is opened inside a savepoint will be closed when the savepoint is rolled back. If a previously opened cursor is affected by a FETCH or MOVE command inside a savepoint that is later rolled back, the cursor remains at the position that FETCH left it pointing to (that is, the cursor motion caused by FETCH is not rolled back). Closing a cursor is not undone by rolling back, either. However, other side-effects caused by the cursor's query (such as side-effects of volatile functions called by the query) *are* rolled back if they occur during a savepoint that is later rolled back. A cursor whose execution causes a transaction to abort is put in a cannot-execute state, so while the transaction can be restored using ROLLBACK TO SAVEPOINT, the cursor can no longer be used.

Examples

To undo the effects of the commands executed after `my_savepoint` was established:

```
ROLLBACK TO SAVEPOINT my_savepoint;
```

Cursor positions are not affected by savepoint rollback:

```
BEGIN;
```

```
DECLARE foo CURSOR FOR SELECT 1 UNION SELECT 2;
```

```
SAVEPOINT foo;
```

```
FETCH 1 FROM foo;
?column?
-----
      1

ROLLBACK TO SAVEPOINT foo;

FETCH 1 FROM foo;
?column?
-----
      2

COMMIT;
```

Compatibility

The SQL standard specifies that the key word `SAVEPOINT` is mandatory, but PostgreSQL and Oracle allow it to be omitted. SQL allows only `WORK`, not `TRANSACTION`, as a noise word after `ROLLBACK`. Also, SQL has an optional clause `AND [NO] CHAIN` which is not currently supported by PostgreSQL. Otherwise, this command conforms to the SQL standard.

See Also

`BEGIN`, `COMMIT`, `RELEASE SAVEPOINT`, `ROLLBACK`, `SAVEPOINT`

SAVEPOINT

SAVEPOINT — define a new savepoint within the current transaction

Synopsis

```
SAVEPOINT savepoint_name
```

Description

SAVEPOINT establishes a new savepoint within the current transaction.

A savepoint is a special mark inside a transaction that allows all commands that are executed after it was established to be rolled back, restoring the transaction state to what it was at the time of the savepoint.

Parameters

```
savepoint_name
```

The name to give to the new savepoint.

Notes

Use ROLLBACK TO SAVEPOINT to rollback to a savepoint. Use RELEASE SAVEPOINT to destroy a savepoint, keeping the effects of commands executed after it was established.

Savepoints can only be established when inside a transaction block. There can be multiple savepoints defined within a transaction.

Examples

To establish a savepoint and later undo the effects of all commands executed after it was established:

```
BEGIN;  
  INSERT INTO table1 VALUES (1);  
  SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (2);  
  ROLLBACK TO SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (3);  
COMMIT;
```

The above transaction will insert the values 1 and 3, but not 2.

To establish and later destroy a savepoint:

```
BEGIN;  
  INSERT INTO table1 VALUES (3);  
  SAVEPOINT my_savepoint;  
  INSERT INTO table1 VALUES (4);  
  RELEASE SAVEPOINT my_savepoint;  
COMMIT;
```

The above transaction will insert both 3 and 4.

Compatibility

SQL requires a savepoint to be destroyed automatically when another savepoint with the same name is established. In PostgreSQL, the old savepoint is kept, though only the more recent one will be used when rolling back or releasing. (Releasing the newer savepoint with `RELEASE SAVEPOINT` will cause the older one to again become accessible to `ROLLBACK TO SAVEPOINT` and `RELEASE SAVEPOINT`.) Otherwise, `SAVEPOINT` is fully SQL conforming.

See Also

`BEGIN`, `COMMIT`, `RELEASE SAVEPOINT`, `ROLLBACK`, `ROLLBACK TO SAVEPOINT`

SECURITY LABEL

SECURITY LABEL — define or change a security label applied to an object

Synopsis

```
SECURITY LABEL [ FOR provider ] ON
{
  TABLE object_name |
  COLUMN table_name.column_name |
  AGGREGATE aggregate_name ( aggregate_signature ) |
  DATABASE object_name |
  DOMAIN object_name |
  EVENT TRIGGER object_name |
  FOREIGN TABLE object_name
  FUNCTION function_name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ] |
  LARGE OBJECT large_object_oid |
  MATERIALIZED VIEW object_name |
  [ PROCEDURAL ] LANGUAGE object_name |
  PROCEDURE procedure_name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ] |
  PUBLICATION object_name |
  ROLE object_name |
  ROUTINE routine_name [ ( [ [ argmode ] [ argname ] argtype
  [, ...] ] ) ] |
  SCHEMA object_name |
  SEQUENCE object_name |
  SUBSCRIPTION object_name |
  TABLESPACE object_name |
  TYPE object_name |
  VIEW object_name
} IS 'label'
```

where *aggregate_signature* is:

```
* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ]
[ argname ] argtype [ , ... ]
```

Description

SECURITY LABEL applies a security label to a database object. An arbitrary number of security labels, one per label provider, can be associated with a given database object. Label providers are loadable modules which register themselves by using the function `register_label_provider`.

Note

`register_label_provider` is not an SQL function; it can only be called from C code loaded into the backend.

The label provider determines whether a given label is valid and whether it is permissible to assign that label to a given object. The meaning of a given label is likewise at the discretion of the label provider. PostgreSQL places no restrictions on whether or how a label provider must interpret security labels; it merely provides a mechanism for storing them. In practice, this facility is intended to allow integration with label-based mandatory access control (MAC) systems such as SE-Linux. Such systems make all access control decisions based on object labels, rather than traditional discretionary access control (DAC) concepts such as users and groups.

Parameters

object_name

table_name.column_name

aggregate_name

function_name

procedure_name

routine_name

The name of the object to be labeled. Names of tables, aggregates, domains, foreign tables, functions, procedures, routines, sequences, types, and views can be schema-qualified.

provider

The name of the provider with which this label is to be associated. The named provider must be loaded and must consent to the proposed labeling operation. If exactly one provider is loaded, the provider name may be omitted for brevity.

argmode

The mode of a function, procedure, or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that SECURITY LABEL does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of a function, procedure, or aggregate argument. Note that SECURITY LABEL does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type of a function, procedure, or aggregate argument.

large_object_oid

The OID of the large object.

PROCEDURAL

This is a noise word.

label

The new security label, written as a string literal; or NULL to drop the security label.

Examples

The following example shows how the security label of a table might be changed.

```
SECURITY LABEL FOR selinux ON TABLE mytable IS  
'system_u:object_r:sepgsql_table_t:s0';
```

Compatibility

There is no SECURITY LABEL command in the SQL standard.

See Also

sepgsql, src/test/modules/dummy_seclabel

SELECT

SELECT, TABLE, WITH — retrieve rows from a table or view

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    [ * | expression [ [ AS ] output_name ] [, ...] ]
    [ FROM from_item [, ...] ]
    [ WHERE condition ]
    [ GROUP BY grouping_element [, ...] ]
    [ HAVING condition [, ...] ]
    [ WINDOW window_name AS ( window_definition ) [, ...] ]
    [ { UNION | INTERSECT | EXCEPT } [ ALL | DISTINCT ] select ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
{ FIRST | LAST } ] [, ...] ]
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
    [ FOR { UPDATE | NO KEY UPDATE | SHARE | KEY SHARE }
[ OF table_name [, ...] ] [ NOWAIT | SKIP LOCKED ] [... ] ]
```

where *from_item* can be one of:

```
    [ ONLY ] table_name [ * ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ]
        [ TABLESAMPLE sampling_method ( argument [, ...] )
[ REPEATABLE ( seed ) ] ]
    [ LATERAL ] ( select ) [ AS ] alias [ ( column_alias
[, ...] ) ]
        with_query_name [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    [ LATERAL ] function_name ( [ argument [, ...] ] )
        [ WITH ORDINALITY ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ]
    [ LATERAL ] function_name ( [ argument [, ...] ] ) [ AS ] alias
( column_definition [, ...] )
    [ LATERAL ] function_name ( [ argument [, ...] ] ) AS
( column_definition [, ...] )
    [ LATERAL ] ROWS FROM( function_name ( [ argument [, ...] ] )
[ AS ( column_definition [, ...] ) ] [, ...] )
        [ WITH ORDINALITY ] [ [ AS ] alias [ ( column_alias
[, ...] ) ] ]
    from_item [ NATURAL ] join_type from_item [ ON join_condition |
USING ( join_column [, ...] ) ]
```

and *grouping_element* can be one of:

```
( )
expression
( expression [, ...] )
ROLLUP ( { expression | ( expression [, ...] ) } [, ...] )
CUBE ( { expression | ( expression [, ...] ) } [, ...] )
GROUPING SETS ( grouping_element [, ...] )
```

and *with_query* is:

```
with_query_name [ ( column_name [, ...] ) ] AS [ [ NOT ]
MATERIALIZED ] ( select | values | insert | update | delete )
```

```
TABLE [ ONLY ] table_name [ * ]
```

Description

SELECT retrieves rows from zero or more tables. The general processing of SELECT is as follows:

1. All queries in the WITH list are computed. These effectively serve as temporary tables that can be referenced in the FROM list. A WITH query that is referenced more than once in FROM is computed only once, unless specified otherwise with NOT MATERIALIZED. (See WITH Clause below.)
2. All elements in the FROM list are computed. (Each element in the FROM list is a real or virtual table.) If more than one element is specified in the FROM list, they are cross-joined together. (See FROM Clause below.)
3. If the WHERE clause is specified, all rows that do not satisfy the condition are eliminated from the output. (See WHERE Clause below.)
4. If the GROUP BY clause is specified, or if there are aggregate function calls, the output is combined into groups of rows that match on one or more values, and the results of aggregate functions are computed. If the HAVING clause is present, it eliminates groups that do not satisfy the given condition. (See GROUP BY Clause and HAVING Clause below.)
5. The actual output rows are computed using the SELECT output expressions for each selected row or row group. (See SELECT List below.)
6. SELECT DISTINCT eliminates duplicate rows from the result. SELECT DISTINCT ON eliminates rows that match on all the specified expressions. SELECT ALL (the default) will return all candidate rows, including duplicates. (See DISTINCT Clause below.)
7. Using the operators UNION, INTERSECT, and EXCEPT, the output of more than one SELECT statement can be combined to form a single result set. The UNION operator returns all rows that are in one or both of the result sets. The INTERSECT operator returns all rows that are strictly in both result sets. The EXCEPT operator returns the rows that are in the first result set but not in the second. In all three cases, duplicate rows are eliminated unless ALL is specified. The noise word DISTINCT can be added to explicitly specify eliminating duplicate rows. Notice that DISTINCT is the default behavior here, even though ALL is the default for SELECT itself. (See UNION Clause, INTERSECT Clause, and EXCEPT Clause below.)
8. If the ORDER BY clause is specified, the returned rows are sorted in the specified order. If ORDER BY is not given, the rows are returned in whatever order the system finds fastest to produce. (See ORDER BY Clause below.)
9. If the LIMIT (or FETCH FIRST) or OFFSET clause is specified, the SELECT statement only returns a subset of the result rows. (See LIMIT Clause below.)
10. If FOR UPDATE, FOR NO KEY UPDATE, FOR SHARE or FOR KEY SHARE is specified, the SELECT statement locks the selected rows against concurrent updates. (See The Locking Clause below.)

You must have SELECT privilege on each column used in a SELECT command. The use of FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE or FOR KEY SHARE requires UPDATE privilege as well (for at least one column of each table so selected).

Parameters

WITH Clause

The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the primary query. The subqueries effectively act as temporary tables or views for the duration of the primary query. Each subquery can be a `SELECT`, `TABLE`, `VALUES`, `INSERT`, `UPDATE` or `DELETE` statement. When writing a data-modifying statement (`INSERT`, `UPDATE` or `DELETE`) in `WITH`, it is usual to include a `RETURNING` clause. It is the output of `RETURNING`, *not* the underlying table that the statement modifies, that forms the temporary table that is read by the primary query. If `RETURNING` is omitted, the statement is still executed, but it produces no output so it cannot be referenced as a table by the primary query.

A name (without schema qualification) must be specified for each `WITH` query. Optionally, a list of column names can be specified; if this is omitted, the column names are inferred from the subquery.

If `RECURSIVE` is specified, it allows a `SELECT` subquery to reference itself by name. Such a subquery must have the form

```
non_recursive_term UNION [ ALL | DISTINCT ] recursive_term
```

where the recursive self-reference must appear on the right-hand side of the `UNION`. Only one recursive self-reference is permitted per query. Recursive data-modifying statements are not supported, but you can use the results of a recursive `SELECT` query in a data-modifying statement. See Section 7.8 for an example.

Another effect of `RECURSIVE` is that `WITH` queries need not be ordered: a query can reference another one that is later in the list. (However, circular references, or mutual recursion, are not implemented.) Without `RECURSIVE`, `WITH` queries can only reference sibling `WITH` queries that are earlier in the `WITH` list.

The primary query and the `WITH` queries are all (notionally) executed at the same time. This implies that the effects of a data-modifying statement in `WITH` cannot be seen from other parts of the query, other than by reading its `RETURNING` output. If two such data-modifying statements attempt to modify the same row, the results are unspecified.

A key property of `WITH` queries is that they are normally evaluated only once per execution of the primary query, even if the primary query refers to them more than once. In particular, data-modifying statements are guaranteed to be executed once and only once, regardless of whether the primary query reads all or any of their output.

However, a `WITH` query can be marked `NOT MATERIALIZED` to remove this guarantee. In that case, the `WITH` query can be folded into the primary query much as though it were a simple sub-`SELECT` in the primary query's `FROM` clause. This results in duplicate computations if the primary query refers to that `WITH` query more than once; but if each such use requires only a few rows of the `WITH` query's total output, `NOT MATERIALIZED` can provide a net savings by allowing the queries to be optimized jointly. `NOT MATERIALIZED` is ignored if it is attached to a `WITH` query that is recursive or is not side-effect-free (i.e., is not a plain `SELECT` containing no volatile functions).

By default, a side-effect-free `WITH` query is folded into the primary query if it is used exactly once in the primary query's `FROM` clause. This allows joint optimization of the two query levels in situations where that should be semantically invisible. However, such folding can be prevented by marking the `WITH` query as `MATERIALIZED`. That might be useful, for example, if the `WITH` query is being used as an optimization fence to prevent the planner from choosing a bad plan. PostgreSQL versions before v12 never did such folding, so queries written for older versions might rely on `WITH` to act as an optimization fence.

See Section 7.8 for additional information.

FROM Clause

The FROM clause specifies one or more source tables for the SELECT. If multiple sources are specified, the result is the Cartesian product (cross join) of all the sources. But usually qualification conditions are added (via WHERE) to restrict the returned rows to a small subset of the Cartesian product.

The FROM clause can contain the following elements:

table_name

The name (optionally schema-qualified) of an existing table or view. If ONLY is specified before the table name, only that table is scanned. If ONLY is not specified, the table and all its descendant tables (if any) are scanned. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

alias

A substitute name for the FROM item containing the alias. An alias is used for brevity or to eliminate ambiguity for self-joins (where the same table is scanned multiple times). When an alias is provided, it completely hides the actual name of the table or function; for example given FROM foo AS f, the remainder of the SELECT must refer to this FROM item as f not foo. If an alias is written, a column alias list can also be written to provide substitute names for one or more columns of the table.

```
TABLESAMPLE sampling_method ( argument [, ...] ) [ REPEATABLE ( seed ) ]
```

A TABLESAMPLE clause after a *table_name* indicates that the specified *sampling_method* should be used to retrieve a subset of the rows in that table. This sampling precedes the application of any other filters such as WHERE clauses. The standard PostgreSQL distribution includes two sampling methods, BERNOULLI and SYSTEM, and other sampling methods can be installed in the database via extensions.

The BERNOULLI and SYSTEM sampling methods each accept a single *argument* which is the fraction of the table to sample, expressed as a percentage between 0 and 100. This argument can be any real-valued expression. (Other sampling methods might accept more or different arguments.) These two methods each return a randomly-chosen sample of the table that will contain approximately the specified percentage of the table's rows. The BERNOULLI method scans the whole table and selects or ignores individual rows independently with the specified probability. The SYSTEM method does block-level sampling with each block having the specified chance of being selected; all rows in each selected block are returned. The SYSTEM method is significantly faster than the BERNOULLI method when small sampling percentages are specified, but it may return a less-random sample of the table as a result of clustering effects.

The optional REPEATABLE clause specifies a *seed* number or expression to use for generating random numbers within the sampling method. The seed value can be any non-null floating-point value. Two queries that specify the same seed and *argument* values will select the same sample of the table, if the table has not been changed meanwhile. But different seed values will usually produce different samples. If REPEATABLE is not given then a new random sample is selected for each query, based upon a system-generated seed. Note that some add-on sampling methods do not accept REPEATABLE, and will always produce new samples on each use.

select

A sub-SELECT can appear in the FROM clause. This acts as though its output were created as a temporary table for the duration of this single SELECT command. Note that the sub-SELECT must be surrounded by parentheses, and an alias *must* be provided for it. A VALUES command can also be used here.

with_query_name

A WITH query is referenced by writing its name, just as though the query's name were a table name. (In fact, the WITH query hides any real table of the same name for the purposes of the primary query. If necessary, you can refer to a real table of the same name by schema-qualifying the table's name.) An alias can be provided in the same way as for a table.

function_name

Function calls can appear in the FROM clause. (This is especially useful for functions that return result sets, but any function can be used.) This acts as though the function's output were created as a temporary table for the duration of this single SELECT command. When the optional WITH ORDINALITY clause is added to the function call, a new column is appended after all the function's output columns with numbering for each row.

An alias can be provided in the same way as for a table. If an alias is written, a column alias list can also be written to provide substitute names for one or more attributes of the function's composite return type, including the column added by ORDINALITY if present.

Multiple function calls can be combined into a single FROM-clause item by surrounding them with ROWS FROM(...). The output of such an item is the concatenation of the first row from each function, then the second row from each function, etc. If some of the functions produce fewer rows than others, null values are substituted for the missing data, so that the total number of rows returned is always the same as for the function that produced the most rows.

If the function has been defined as returning the `record` data type, then an alias or the key word AS must be present, followed by a column definition list in the form (*column_name data_type* [, ...]). The column definition list must match the actual number and types of columns returned by the function.

When using the ROWS FROM(...) syntax, if one of the functions requires a column definition list, it's preferred to put the column definition list after the function call inside ROWS FROM(...). A column definition list can be placed after the ROWS FROM(...) construct only if there's just a single function and no WITH ORDINALITY clause.

To use ORDINALITY together with a column definition list, you must use the ROWS FROM(...) syntax and put the column definition list inside ROWS FROM(...).

join_type

One of

- [INNER] JOIN
- LEFT [OUTER] JOIN
- RIGHT [OUTER] JOIN
- FULL [OUTER] JOIN
- CROSS JOIN

For the INNER and OUTER join types, a join condition must be specified, namely exactly one of NATURAL, ON *join_condition*, or USING (*join_column* [, ...]). See below for the meaning. For CROSS JOIN, none of these clauses can appear.

A JOIN clause combines two FROM items, which for convenience we will refer to as “tables”, though in reality they can be any type of FROM item. Use parentheses if necessary to determine the order of nesting. In the absence of parentheses, JOINS nest left-to-right. In any case JOIN binds more tightly than the commas separating FROM-list items.

CROSS JOIN and INNER JOIN produce a simple Cartesian product, the same result as you get from listing the two tables at the top level of FROM, but restricted by the join condition (if

any). `CROSS JOIN` is equivalent to `INNER JOIN ON (TRUE)`, that is, no rows are removed by qualification. These join types are just a notational convenience, since they do nothing you couldn't do with plain `FROM` and `WHERE`.

`LEFT OUTER JOIN` returns all rows in the qualified Cartesian product (i.e., all combined rows that pass its join condition), plus one copy of each row in the left-hand table for which there was no right-hand row that passed the join condition. This left-hand row is extended to the full width of the joined table by inserting null values for the right-hand columns. Note that only the `JOIN` clause's own condition is considered while deciding which rows have matches. Outer conditions are applied afterwards.

Conversely, `RIGHT OUTER JOIN` returns all the joined rows, plus one row for each unmatched right-hand row (extended with nulls on the left). This is just a notational convenience, since you could convert it to a `LEFT OUTER JOIN` by switching the left and right tables.

`FULL OUTER JOIN` returns all the joined rows, plus one row for each unmatched left-hand row (extended with nulls on the right), plus one row for each unmatched right-hand row (extended with nulls on the left).

`ON join_condition`

join_condition is an expression resulting in a value of type `boolean` (similar to a `WHERE` clause) that specifies which rows in a join are considered to match.

`USING (join_column [, ...])`

A clause of the form `USING (a, b, ...)` is shorthand for `ON left_table.a = right_table.a AND left_table.b = right_table.b ...`. Also, `USING` implies that only one of each pair of equivalent columns will be included in the join output, not both.

`NATURAL`

`NATURAL` is shorthand for a `USING` list that mentions all columns in the two tables that have matching names. If there are no common column names, `NATURAL` is equivalent to `ON TRUE`.

`LATERAL`

The `LATERAL` key word can precede a sub-`SELECT FROM` item. This allows the sub-`SELECT` to refer to columns of `FROM` items that appear before it in the `FROM` list. (Without `LATERAL`, each sub-`SELECT` is evaluated independently and so cannot cross-reference any other `FROM` item.)

`LATERAL` can also precede a function-call `FROM` item, but in this case it is a noise word, because the function expression can refer to earlier `FROM` items in any case.

A `LATERAL` item can appear at top level in the `FROM` list, or within a `JOIN` tree. In the latter case it can also refer to any items that are on the left-hand side of a `JOIN` that it is on the right-hand side of.

When a `FROM` item contains `LATERAL` cross-references, evaluation proceeds as follows: for each row of the `FROM` item providing the cross-referenced column(s), or set of rows of multiple `FROM` items providing the columns, the `LATERAL` item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

The column source table(s) must be `INNER` or `LEFT` joined to the `LATERAL` item, else there would not be a well-defined set of rows from which to compute each set of rows for the `LATERAL` item. Thus, although a construct such as `X RIGHT JOIN LATERAL Y` is syntactically valid, it is not actually allowed for `Y` to reference `X`.

WHERE Clause

The optional `WHERE` clause has the general form

WHERE *condition*

where *condition* is any expression that evaluates to a result of type `boolean`. Any row that does not satisfy this condition will be eliminated from the output. A row satisfies the condition if it returns `true` when the actual row values are substituted for any variable references.

GROUP BY Clause

The optional `GROUP BY` clause has the general form

```
GROUP BY grouping_element [, ...]
```

`GROUP BY` will condense into a single row all selected rows that share the same values for the grouped expressions. An *expression* used inside a *grouping_element* can be an input column name, or the name or ordinal number of an output column (`SELECT` list item), or an arbitrary expression formed from input-column values. In case of ambiguity, a `GROUP BY` name will be interpreted as an input-column name rather than an output column name.

If any of `GROUPING SETS`, `ROLLUP` or `CUBE` are present as grouping elements, then the `GROUP BY` clause as a whole defines some number of independent *grouping sets*. The effect of this is equivalent to constructing a `UNION ALL` between subqueries with the individual grouping sets as their `GROUP BY` clauses. For further details on the handling of grouping sets see Section 7.2.4.

Aggregate functions, if any are used, are computed across all rows making up each group, producing a separate value for each group. (If there are aggregate functions but no `GROUP BY` clause, the query is treated as having a single group comprising all the selected rows.) The set of rows fed to each aggregate function can be further filtered by attaching a `FILTER` clause to the aggregate function call; see Section 4.2.7 for more information. When a `FILTER` clause is present, only those rows matching it are included in the input to that aggregate function.

When `GROUP BY` is present, or any aggregate functions are present, it is not valid for the `SELECT` list expressions to refer to ungrouped columns except within aggregate functions or when the ungrouped column is functionally dependent on the grouped columns, since there would otherwise be more than one possible value to return for an ungrouped column. A functional dependency exists if the grouped columns (or a subset thereof) are the primary key of the table containing the ungrouped column.

Keep in mind that all aggregate functions are evaluated before evaluating any “scalar” expressions in the `HAVING` clause or `SELECT` list. This means that, for example, a `CASE` expression cannot be used to skip evaluation of an aggregate function; see Section 4.2.14.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `GROUP BY`.

HAVING Clause

The optional `HAVING` clause has the general form

```
HAVING condition
```

where *condition* is the same as specified for the `WHERE` clause.

`HAVING` eliminates group rows that do not satisfy the condition. `HAVING` is different from `WHERE`: `WHERE` filters individual rows before the application of `GROUP BY`, while `HAVING` filters group rows created by `GROUP BY`. Each column referenced in *condition* must unambiguously reference a grouping column, unless the reference appears within an aggregate function or the ungrouped column is functionally dependent on the grouping columns.

The presence of `HAVING` turns a query into a grouped query even if there is no `GROUP BY` clause. This is the same as what happens when the query contains aggregate functions but no `GROUP BY` clause. All the selected rows are considered to form a single group, and the `SELECT` list and `HAVING` clause can only reference table columns from within aggregate functions. Such a query will emit a single row if the `HAVING` condition is true, zero rows if it is not true.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `HAVING`.

WINDOW Clause

The optional `WINDOW` clause has the general form

```
WINDOW window_name AS ( window_definition ) [, ...]
```

where *window_name* is a name that can be referenced from `OVER` clauses or subsequent window definitions, and *window_definition* is

```
[ existing_window_name ]
[ PARTITION BY expression [, ...] ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
  { FIRST | LAST } ] [, ...] ]
[ frame_clause ]
```

If an *existing_window_name* is specified it must refer to an earlier entry in the `WINDOW` list; the new window copies its partitioning clause from that entry, as well as its ordering clause if any. In this case the new window cannot specify its own `PARTITION BY` clause, and it can specify `ORDER BY` only if the copied window does not have one. The new window always uses its own frame clause; the copied window must not specify a frame clause.

The elements of the `PARTITION BY` list are interpreted in much the same fashion as elements of a `GROUP BY` Clause, except that they are always simple expressions and never the name or number of an output column. Another difference is that these expressions can contain aggregate function calls, which are not allowed in a regular `GROUP BY` clause. They are allowed here because windowing occurs after grouping and aggregation.

Similarly, the elements of the `ORDER BY` list are interpreted in much the same fashion as elements of an `ORDER BY` Clause, except that the expressions are always taken as simple expressions and never the name or number of an output column.

The optional *frame_clause* defines the *window frame* for window functions that depend on the frame (not all do). The window frame is a set of related rows for each row of the query (called the *current row*). The *frame_clause* can be one of

```
{ RANGE | ROWS | GROUPS } frame_start [ frame_exclusion ]
{ RANGE | ROWS | GROUPS } BETWEEN frame_start AND frame_end
[ frame_exclusion ]
```

where *frame_start* and *frame_end* can be one of

```
UNBOUNDED PRECEDING
offset PRECEDING
CURRENT ROW
offset FOLLOWING
UNBOUNDED FOLLOWING
```

and *frame_exclusion* can be one of

```
EXCLUDE CURRENT ROW
EXCLUDE GROUP
EXCLUDE TIES
EXCLUDE NO OTHERS
```

If *frame_end* is omitted it defaults to `CURRENT ROW`. Restrictions are that *frame_start* cannot be `UNBOUNDED FOLLOWING`, *frame_end* cannot be `UNBOUNDED PRECEDING`, and the *frame_end* choice cannot appear earlier in the above list of *frame_start* and *frame_end* options than the *frame_start* choice does — for example `RANGE BETWEEN CURRENT ROW AND offset PRECEDING` is not allowed.

The default framing option is `RANGE UNBOUNDED PRECEDING`, which is the same as `RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW`; it sets the frame to be all rows from the partition start up through the current row's last *peer* (a row that the window's `ORDER BY` clause considers equivalent to the current row; all rows are peers if there is no `ORDER BY`). In general, `UNBOUNDED PRECEDING` means that the frame starts with the first row of the partition, and similarly `UNBOUNDED FOLLOWING` means that the frame ends with the last row of the partition, regardless of `RANGE`, `ROWS` or `GROUPS` mode. In `ROWS` mode, `CURRENT ROW` means that the frame starts or ends with the current row; but in `RANGE` or `GROUPS` mode it means that the frame starts or ends with the current row's first or last peer in the `ORDER BY` ordering. The *offset* `PRECEDING` and *offset* `FOLLOWING` options vary in meaning depending on the frame mode. In `ROWS` mode, the *offset* is an integer indicating that the frame starts or ends that many rows before or after the current row. In `GROUPS` mode, the *offset* is an integer indicating that the frame starts or ends that many peer groups before or after the current row's peer group, where a *peer group* is a group of rows that are equivalent according to the window's `ORDER BY` clause. In `RANGE` mode, use of an *offset* option requires that there be exactly one `ORDER BY` column in the window definition. Then the frame contains those rows whose ordering column value is no more than *offset* less than (for `PRECEDING`) or more than (for `FOLLOWING`) the current row's ordering column value. In these cases the data type of the *offset* expression depends on the data type of the ordering column. For numeric ordering columns it is typically of the same type as the ordering column, but for datetime ordering columns it is an interval. In all these cases, the value of the *offset* must be non-null and non-negative. Also, while the *offset* does not have to be a simple constant, it cannot contain variables, aggregate functions, or window functions.

The *frame_exclusion* option allows rows around the current row to be excluded from the frame, even if they would be included according to the frame start and frame end options. `EXCLUDE CURRENT ROW` excludes the current row from the frame. `EXCLUDE GROUP` excludes the current row and its ordering peers from the frame. `EXCLUDE TIES` excludes any peers of the current row from the frame, but not the current row itself. `EXCLUDE NO OTHERS` simply specifies explicitly the default behavior of not excluding the current row or its peers.

Beware that the `ROWS` mode can produce unpredictable results if the `ORDER BY` ordering does not order the rows uniquely. The `RANGE` and `GROUPS` modes are designed to ensure that rows that are peers in the `ORDER BY` ordering are treated alike: all rows of a given peer group will be in the frame or excluded from it.

The purpose of a `WINDOW` clause is to specify the behavior of *window functions* appearing in the query's `SELECT` List or `ORDER BY` Clause. These functions can reference the `WINDOW` clause entries by name in their `OVER` clauses. A `WINDOW` clause entry does not have to be referenced anywhere, however; if it is not used in the query it is simply ignored. It is possible to use window functions without any `WINDOW` clause at all, since a window function call can specify its window definition directly in its `OVER` clause. However, the `WINDOW` clause saves typing when the same window definition is needed for more than one window function.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `WINDOW`.

Window functions are described in detail in Section 3.5, Section 4.2.8, and Section 7.2.5.

SELECT List

The `SELECT` list (between the key words `SELECT` and `FROM`) specifies expressions that form the output rows of the `SELECT` statement. The expressions can (and usually do) refer to columns computed in the `FROM` clause.

Just as in a table, every output column of a `SELECT` has a name. In a simple `SELECT` this name is just used to label the column for display, but when the `SELECT` is a sub-query of a larger query, the name is seen by the larger query as the column name of the virtual table produced by the sub-query. To specify the name to use for an output column, write `AS output_name` after the column's expression. (You can omit `AS`, but only if the desired output name does not match any PostgreSQL keyword (see Appendix C). For protection against possible future keyword additions, it is recommended that you always either write `AS` or double-quote the output name.) If you do not specify a column name, a name is chosen automatically by PostgreSQL. If the column's expression is a simple column reference then the chosen name is the same as that column's name. In more complex cases a function or type name may be used, or the system may fall back on a generated name such as `?column?`.

An output column's name can be used to refer to the column's value in `ORDER BY` and `GROUP BY` clauses, but not in the `WHERE` or `HAVING` clauses; there you must write out the expression instead.

Instead of an expression, `*` can be written in the output list as a shorthand for all the columns of the selected rows. Also, you can write `table_name.*` as a shorthand for the columns coming from just that table. In these cases it is not possible to specify new names with `AS`; the output column names will be the same as the table columns' names.

According to the SQL standard, the expressions in the output list should be computed before applying `DISTINCT`, `ORDER BY`, or `LIMIT`. This is obviously necessary when using `DISTINCT`, since otherwise it's not clear what values are being made distinct. However, in many cases it is convenient if output expressions are computed after `ORDER BY` and `LIMIT`; particularly if the output list contains any volatile or expensive functions. With that behavior, the order of function evaluations is more intuitive and there will not be evaluations corresponding to rows that never appear in the output. PostgreSQL will effectively evaluate output expressions after sorting and limiting, so long as those expressions are not referenced in `DISTINCT`, `ORDER BY` or `GROUP BY`. (As a counterexample, `SELECT f(x) FROM tab ORDER BY 1` clearly must evaluate `f(x)` before sorting.) Output expressions that contain set-returning functions are effectively evaluated after sorting and before limiting, so that `LIMIT` will act to cut off the output from a set-returning function.

Note

PostgreSQL versions before 9.6 did not provide any guarantees about the timing of evaluation of output expressions versus sorting and limiting; it depended on the form of the chosen query plan.

DISTINCT Clause

If `SELECT DISTINCT` is specified, all duplicate rows are removed from the result set (one row is kept from each group of duplicates). `SELECT ALL` specifies the opposite: all rows are kept; that is the default.

`SELECT DISTINCT ON (expression [, ...])` keeps only the first row of each set of rows where the given expressions evaluate to equal. The `DISTINCT ON` expressions are interpreted using the same rules as for `ORDER BY` (see above). Note that the “first row” of each set is unpredictable unless `ORDER BY` is used to ensure that the desired row appears first. For example:

```
SELECT DISTINCT ON (location) location, time, report
FROM weather_reports
ORDER BY location, time DESC;
```

retrieves the most recent weather report for each location. But if we had not used `ORDER BY` to force descending order of time values for each location, we'd have gotten a report from an unpredictable time for each location.

The `DISTINCT ON` expression(s) must match the leftmost `ORDER BY` expression(s). The `ORDER BY` clause will normally contain additional expression(s) that determine the desired precedence of rows within each `DISTINCT ON` group.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `DISTINCT`.

UNION Clause

The `UNION` clause has this general form:

```
select_statement UNION [ ALL | DISTINCT ] select_statement
```

select_statement is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause. (`ORDER BY` and `LIMIT` can be attached to a subexpression if it is enclosed in parentheses. Without parentheses, these clauses will be taken to apply to the result of the `UNION`, not to its right-hand input expression.)

The `UNION` operator computes the set union of the rows returned by the involved `SELECT` statements. A row is in the set union of two result sets if it appears in at least one of the result sets. The two `SELECT` statements that represent the direct operands of the `UNION` must produce the same number of columns, and corresponding columns must be of compatible data types.

The result of `UNION` does not contain any duplicate rows unless the `ALL` option is specified. `ALL` prevents elimination of duplicates. (Therefore, `UNION ALL` is usually significantly quicker than `UNION`; use `ALL` when you can.) `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `UNION` operators in the same `SELECT` statement are evaluated left to right, unless otherwise indicated by parentheses.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified either for a `UNION` result or for any input of a `UNION`.

INTERSECT Clause

The `INTERSECT` clause has this general form:

```
select_statement INTERSECT [ ALL | DISTINCT ] select_statement
```

select_statement is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause.

The `INTERSECT` operator computes the set intersection of the rows returned by the involved `SELECT` statements. A row is in the intersection of two result sets if it appears in both result sets.

The result of `INTERSECT` does not contain any duplicate rows unless the `ALL` option is specified. With `ALL`, a row that has m duplicates in the left table and n duplicates in the right table will appear $\min(m,n)$ times in the result set. `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple INTERSECT operators in the same SELECT statement are evaluated left to right, unless parentheses dictate otherwise. INTERSECT binds more tightly than UNION. That is, A UNION B INTERSECT C will be read as A UNION (B INTERSECT C).

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified either for an INTERSECT result or for any input of an INTERSECT.

EXCEPT Clause

The EXCEPT clause has this general form:

```
select_statement EXCEPT [ ALL | DISTINCT ] select_statement
```

select_statement is any SELECT statement without an ORDER BY, LIMIT, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, or FOR KEY SHARE clause.

The EXCEPT operator computes the set of rows that are in the result of the left SELECT statement but not in the result of the right one.

The result of EXCEPT does not contain any duplicate rows unless the ALL option is specified. With ALL, a row that has m duplicates in the left table and n duplicates in the right table will appear $\max(m-n, 0)$ times in the result set. DISTINCT can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple EXCEPT operators in the same SELECT statement are evaluated left to right, unless parentheses dictate otherwise. EXCEPT binds at the same level as UNION.

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified either for an EXCEPT result or for any input of an EXCEPT.

ORDER BY Clause

The optional ORDER BY clause has this general form:

```
ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [, ...]
```

The ORDER BY clause causes the result rows to be sorted according to the specified expression(s). If two rows are equal according to the leftmost expression, they are compared according to the next expression and so on. If they are equal according to all specified expressions, they are returned in an implementation-dependent order.

Each *expression* can be the name or ordinal number of an output column (SELECT list item), or it can be an arbitrary expression formed from input-column values.

The ordinal number refers to the ordinal (left-to-right) position of the output column. This feature makes it possible to define an ordering on the basis of a column that does not have a unique name. This is never absolutely necessary because it is always possible to assign a name to an output column using the AS clause.

It is also possible to use arbitrary expressions in the ORDER BY clause, including columns that do not appear in the SELECT output list. Thus the following statement is valid:

```
SELECT name FROM distributors ORDER BY code;
```

A limitation of this feature is that an ORDER BY clause applying to the result of a UNION, INTERSECT, or EXCEPT clause can only specify an output column name or number, not an expression.

If an `ORDER BY` expression is a simple name that matches both an output column name and an input column name, `ORDER BY` will interpret it as the output column name. This is the opposite of the choice that `GROUP BY` will make in the same situation. This inconsistency is made to be compatible with the SQL standard.

Optionally one can add the key word `ASC` (ascending) or `DESC` (descending) after any expression in the `ORDER BY` clause. If not specified, `ASC` is assumed by default. Alternatively, a specific ordering operator name can be specified in the `USING` clause. An ordering operator must be a less-than or greater-than member of some B-tree operator family. `ASC` is usually equivalent to `USING <` and `DESC` is usually equivalent to `USING >`. (But the creator of a user-defined data type can define exactly what the default sort ordering is, and it might correspond to operators with other names.)

If `NULLS LAST` is specified, null values sort after all non-null values; if `NULLS FIRST` is specified, null values sort before all non-null values. If neither is specified, the default behavior is `NULLS LAST` when `ASC` is specified or implied, and `NULLS FIRST` when `DESC` is specified (thus, the default is to act as though nulls are larger than non-nulls). When `USING` is specified, the default nulls ordering depends on whether the operator is a less-than or greater-than operator.

Note that ordering options apply only to the expression they follow; for example `ORDER BY x, y DESC` does not mean the same thing as `ORDER BY x DESC, y DESC`.

Character-string data is sorted according to the collation that applies to the column being sorted. That can be overridden at need by including a `COLLATE` clause in the *expression*, for example `ORDER BY mycolumn COLLATE "en_US"`. For more information see Section 4.2.10 and Section 23.2.

LIMIT Clause

The `LIMIT` clause consists of two independent sub-clauses:

```
LIMIT { count | ALL }
OFFSET start
```

count specifies the maximum number of rows to return, while *start* specifies the number of rows to skip before starting to return rows. When both are specified, *start* rows are skipped before starting to count the *count* rows to be returned.

If the *count* expression evaluates to `NULL`, it is treated as `LIMIT ALL`, i.e., no limit. If *start* evaluates to `NULL`, it is treated the same as `OFFSET 0`.

SQL:2008 introduced a different syntax to achieve the same result, which PostgreSQL also supports. It is:

```
OFFSET start { ROW | ROWS }
FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY
```

In this syntax, the *start* or *count* value is required by the standard to be a literal constant, a parameter, or a variable name; as a PostgreSQL extension, other expressions are allowed, but will generally need to be enclosed in parentheses to avoid ambiguity. If *count* is omitted in a `FETCH` clause, it defaults to 1. `ROW` and `ROWS` as well as `FIRST` and `NEXT` are noise words that don't influence the effects of these clauses. According to the standard, the `OFFSET` clause must come before the `FETCH` clause if both are present; but PostgreSQL is laxer and allows either order.

When using `LIMIT`, it is a good idea to use an `ORDER BY` clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows — you might be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? You don't know what ordering unless you specify `ORDER BY`.

The query planner takes `LIMIT` into account when generating a query plan, so you are very likely to get different plans (yielding different row orders) depending on what you use for `LIMIT` and `OFFSET`.

Thus, using different `LIMIT/OFFSET` values to select different subsets of a query result *will give inconsistent results* unless you enforce a predictable result ordering with `ORDER BY`. This is not a bug; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless `ORDER BY` is used to constrain the order.

It is even possible for repeated executions of the same `LIMIT` query to return different subsets of the rows of a table, if there is not an `ORDER BY` to enforce selection of a deterministic subset. Again, this is not a bug; determinism of the results is simply not guaranteed in such a case.

The Locking Clause

`FOR UPDATE`, `FOR NO KEY UPDATE`, `FOR SHARE` and `FOR KEY SHARE` are *locking clauses*; they affect how `SELECT` locks rows as they are obtained from the table.

The locking clause has the general form

```
FOR lock_strength [ OF table_name [, ...] ] [ NOWAIT | SKIP  
LOCKED ]
```

where *lock_strength* can be one of

```
UPDATE  
NO KEY UPDATE  
SHARE  
KEY SHARE
```

For more information on each row-level lock mode, refer to Section 13.3.2.

To prevent the operation from waiting for other transactions to commit, use either the `NOWAIT` or `SKIP LOCKED` option. With `NOWAIT`, the statement reports an error, rather than waiting, if a selected row cannot be locked immediately. With `SKIP LOCKED`, any selected rows that cannot be immediately locked are skipped. Skipping locked rows provides an inconsistent view of the data, so this is not suitable for general purpose work, but can be used to avoid lock contention with multiple consumers accessing a queue-like table. Note that `NOWAIT` and `SKIP LOCKED` apply only to the row-level lock(s) — the required `ROW SHARE` table-level lock is still taken in the ordinary way (see Chapter 13). You can use `LOCK` with the `NOWAIT` option first, if you need to acquire the table-level lock without waiting.

If specific tables are named in a locking clause, then only rows coming from those tables are locked; any other tables used in the `SELECT` are simply read as usual. A locking clause without a table list affects all tables used in the statement. If a locking clause is applied to a view or sub-query, it affects all tables used in the view or sub-query. However, these clauses do not apply to `WITH` queries referenced by the primary query. If you want row locking to occur within a `WITH` query, specify a locking clause within the `WITH` query.

Multiple locking clauses can be written if it is necessary to specify different locking behavior for different tables. If the same table is mentioned (or implicitly affected) by more than one locking clause, then it is processed as if it was only specified by the strongest one. Similarly, a table is processed as `NOWAIT` if that is specified in any of the clauses affecting it. Otherwise, it is processed as `SKIP LOCKED` if that is specified in any of the clauses affecting it.

The locking clauses cannot be used in contexts where returned rows cannot be clearly identified with individual table rows; for example they cannot be used with aggregation.

When a locking clause appears at the top level of a `SELECT` query, the rows that are locked are exactly those that are returned by the query; in the case of a join query, the rows locked are those that contribute to returned join rows. In addition, rows that satisfied the query conditions as of the query snapshot will be locked, although they will not be returned if they were updated after the snapshot and

no longer satisfy the query conditions. If a `LIMIT` is used, locking stops once enough rows have been returned to satisfy the limit (but note that rows skipped over by `OFFSET` will get locked). Similarly, if a locking clause is used in a cursor's query, only rows actually fetched or stepped past by the cursor will be locked.

When a locking clause appears in a sub-`SELECT`, the rows locked are those returned to the outer query by the sub-query. This might involve fewer rows than inspection of the sub-query alone would suggest, since conditions from the outer query might be used to optimize execution of the sub-query. For example,

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss WHERE coll = 5;
```

will lock only rows having `coll = 5`, even though that condition is not textually within the sub-query.

Previous releases failed to preserve a lock which is upgraded by a later savepoint. For example, this code:

```
BEGIN;
SELECT * FROM mytable WHERE key = 1 FOR UPDATE;
SAVEPOINT s;
UPDATE mytable SET ... WHERE key = 1;
ROLLBACK TO s;
```

would fail to preserve the `FOR UPDATE` lock after the `ROLLBACK TO`. This has been fixed in release 9.3.

Caution

It is possible for a `SELECT` command running at the `READ COMMITTED` transaction isolation level and using `ORDER BY` and a locking clause to return rows out of order. This is because `ORDER BY` is applied first. The command sorts the result, but might then block trying to obtain a lock on one or more of the rows. Once the `SELECT` unblocks, some of the ordering column values might have been modified, leading to those rows appearing to be out of order (though they are in order in terms of the original column values). This can be worked around at need by placing the `FOR UPDATE/SHARE` clause in a sub-query, for example

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss
ORDER BY column1;
```

Note that this will result in locking all rows of `mytable`, whereas `FOR UPDATE` at the top level would lock only the actually returned rows. This can make for a significant performance difference, particularly if the `ORDER BY` is combined with `LIMIT` or other restrictions. So this technique is recommended only if concurrent updates of the ordering columns are expected and a strictly sorted result is required.

At the `REPEATABLE READ` or `SERIALIZABLE` transaction isolation level this would cause a serialization failure (with a `SQLSTATE` of '40001'), so there is no possibility of receiving rows out of order under these isolation levels.

TABLE Command

The command

TABLE *name*

is equivalent to

```
SELECT * FROM name
```

It can be used as a top-level command or as a space-saving syntax variant in parts of complex queries. Only the WITH, UNION, INTERSECT, EXCEPT, ORDER BY, LIMIT, OFFSET, FETCH and FOR locking clauses can be used with TABLE; the WHERE clause and any form of aggregation cannot be used.

Examples

To join the table `films` with the table `distributors`:

```
SELECT f.title, f.did, d.name, f.date_prod, f.kind
   FROM distributors d, films f
   WHERE f.did = d.did
```

title	did	name	date_prod	kind
The Third Man	101	British Lion	1949-12-23	Drama
The African Queen	101	British Lion	1951-08-11	Romantic
...				

To sum the column `len` of all films and group the results by kind:

```
SELECT kind, sum(len) AS total FROM films GROUP BY kind;
```

kind	total
Action	07:34
Comedy	02:58
Drama	14:28
Musical	06:42
Romantic	04:38

To sum the column `len` of all films, group the results by kind and show those group totals that are less than 5 hours:

```
SELECT kind, sum(len) AS total
   FROM films
   GROUP BY kind
   HAVING sum(len) < interval '5 hours';
```

kind	total
Comedy	02:58
Romantic	04:38

The following two examples are identical ways of sorting the individual results according to the contents of the second column (`name`):

SELECT

```
SELECT * FROM distributors ORDER BY name;
SELECT * FROM distributors ORDER BY 2;
```

did	name
109	20th Century Fox
110	Bavaria Atelier
101	British Lion
107	Columbia
102	Jean Luc Godard
113	Luso films
104	Mosfilm
103	Paramount
106	Toho
105	United Artists
111	Walt Disney
112	Warner Bros.
108	Westward

The next example shows how to obtain the union of the tables `distributors` and `actors`, restricting the results to those that begin with the letter `W` in each table. Only distinct rows are wanted, so the key word `ALL` is omitted.

distributors:		actors:	
did	name	id	name
108	Westward	1	Woody Allen
111	Walt Disney	2	Warren Beatty
112	Warner Bros.	3	Walter Matthau
...		...	

```
SELECT distributors.name
      FROM distributors
      WHERE distributors.name LIKE 'W%'
UNION
SELECT actors.name
      FROM actors
      WHERE actors.name LIKE 'W%';
```

name
Walt Disney
Walter Matthau
Warner Bros.
Warren Beatty
Westward
Woody Allen

This example shows how to use a function in the `FROM` clause, both with and without a column definition list:

```
CREATE FUNCTION distributors(int) RETURNS SETOF distributors AS $$
      SELECT * FROM distributors WHERE did = $1;
$$ LANGUAGE SQL;

SELECT * FROM distributors(111);
did | name
```

SELECT

```
-----+-----
111 | Walt Disney

CREATE FUNCTION distributors_2(int) RETURNS SETOF record AS $$
    SELECT * FROM distributors WHERE did = $1;
$$ LANGUAGE SQL;

SELECT * FROM distributors_2(111) AS (f1 int, f2 text);
f1 | f2
-----+-----
111 | Walt Disney
```

Here is an example of a function with an ordinality column added:

```
SELECT * FROM unnest(ARRAY['a','b','c','d','e','f']) WITH
ORDINALITY;
unnest | ordinality
-----+-----
a      |          1
b      |          2
c      |          3
d      |          4
e      |          5
f      |          6
(6 rows)
```

This example shows how to use a simple WITH clause:

```
WITH t AS (
    SELECT random() as x FROM generate_series(1, 3)
)
SELECT * FROM t
UNION ALL
SELECT * FROM t

          x
-----+-----
0.534150459803641
0.520092216785997
0.0735620250925422
0.534150459803641
0.520092216785997
0.0735620250925422
```

Notice that the WITH query was evaluated only once, so that we got two sets of the same three random values.

This example uses WITH RECURSIVE to find all subordinates (direct or indirect) of the employee Mary, and their level of indirectness, from a table that shows only direct subordinates:

```
WITH RECURSIVE employee_recursive(distance, employee_name,
manager_name) AS (
    SELECT 1, employee_name, manager_name
    FROM employee
    WHERE manager_name = 'Mary'
    UNION ALL
```

```

SELECT er.distance + 1, e.employee_name, e.manager_name
FROM employee_recursive er, employee e
WHERE er.employee_name = e.manager_name
)
SELECT distance, employee_name FROM employee_recursive;

```

Notice the typical form of recursive queries: an initial condition, followed by UNION, followed by the recursive part of the query. Be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. (See Section 7.8 for more examples.)

This example uses LATERAL to apply a set-returning function `get_product_names()` for each row of the `manufacturers` table:

```

SELECT m.name AS mname, pname
FROM manufacturers m, LATERAL get_product_names(m.id) pname;

```

Manufacturers not currently having any products would not appear in the result, since it is an inner join. If we wished to include the names of such manufacturers in the result, we could do:

```

SELECT m.name AS mname, pname
FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id)
pname ON true;

```

Compatibility

Of course, the SELECT statement is compatible with the SQL standard. But there are some extensions and some missing features.

Omitted FROM Clauses

PostgreSQL allows one to omit the FROM clause. It has a straightforward use to compute the results of simple expressions:

```

SELECT 2+2;

?column?
-----
      4

```

Some other SQL databases cannot do this except by introducing a dummy one-row table from which to do the SELECT.

Note that if a FROM clause is not specified, the query cannot reference any database tables. For example, the following query is invalid:

```

SELECT distributors.* WHERE distributors.name = 'Westward';

```

PostgreSQL releases prior to 8.1 would accept queries of this form, and add an implicit entry to the query's FROM clause for each table referenced by the query. This is no longer allowed.

Empty SELECT Lists

The list of output expressions after SELECT can be empty, producing a zero-column result table. This is not valid syntax according to the SQL standard. PostgreSQL allows it to be consistent with allowing zero-column tables. However, an empty list is not allowed when DISTINCT is used.

Omitting the AS Key Word

In the SQL standard, the optional key word `AS` can be omitted before an output column name whenever the new column name is a valid column name (that is, not the same as any reserved keyword). PostgreSQL is slightly more restrictive: `AS` is required if the new column name matches any keyword at all, reserved or not. Recommended practice is to use `AS` or double-quote output column names, to prevent any possible conflict against future keyword additions.

In `FROM` items, both the standard and PostgreSQL allow `AS` to be omitted before an alias that is an unreserved keyword. But this is impractical for output column names, because of syntactic ambiguities.

ONLY and Inheritance

The SQL standard requires parentheses around the table name when writing `ONLY`, for example `SELECT * FROM ONLY (tab1), ONLY (tab2) WHERE ...`. PostgreSQL considers these parentheses to be optional.

PostgreSQL allows a trailing `*` to be written to explicitly specify the non-`ONLY` behavior of including child tables. The standard does not allow this.

(These points apply equally to all SQL commands supporting the `ONLY` option.)

TABLESAMPLE Clause Restrictions

The `TABLESAMPLE` clause is currently accepted only on regular tables and materialized views. According to the SQL standard it should be possible to apply it to any `FROM` item.

Function Calls in FROM

PostgreSQL allows a function call to be written directly as a member of the `FROM` list. In the SQL standard it would be necessary to wrap such a function call in a sub-`SELECT`; that is, the syntax `FROM func(...) alias` is approximately equivalent to `FROM LATERAL (SELECT func(...)) alias`. Note that `LATERAL` is considered to be implicit; this is because the standard requires `LATERAL` semantics for an `UNNEST()` item in `FROM`. PostgreSQL treats `UNNEST()` the same as other set-returning functions.

Namespace Available to GROUP BY and ORDER BY

In the SQL-92 standard, an `ORDER BY` clause can only use output column names or numbers, while a `GROUP BY` clause can only use expressions based on input column names. PostgreSQL extends each of these clauses to allow the other choice as well (but it uses the standard's interpretation if there is ambiguity). PostgreSQL also allows both clauses to specify arbitrary expressions. Note that names appearing in an expression will always be taken as input-column names, not as output-column names.

SQL:1999 and later use a slightly different definition which is not entirely upward compatible with SQL-92. In most cases, however, PostgreSQL will interpret an `ORDER BY` or `GROUP BY` expression the same way SQL:1999 does.

Functional Dependencies

PostgreSQL recognizes functional dependency (allowing columns to be omitted from `GROUP BY`) only when a table's primary key is included in the `GROUP BY` list. The SQL standard specifies additional conditions that should be recognized.

LIMIT and OFFSET

The clauses `LIMIT` and `OFFSET` are PostgreSQL-specific syntax, also used by MySQL. The SQL:2008 standard has introduced the clauses `OFFSET ... FETCH {FIRST|NEXT} ...` for

the same functionality, as shown above in `LIMIT` Clause. This syntax is also used by IBM DB2. (Applications written for Oracle frequently use a workaround involving the automatically generated `rownum` column, which is not available in PostgreSQL, to implement the effects of these clauses.)

FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, FOR KEY SHARE

Although `FOR UPDATE` appears in the SQL standard, the standard allows it only as an option of `DECLARE CURSOR`. PostgreSQL allows it in any `SELECT` query as well as in sub-`SELECT`s, but this is an extension. The `FOR NO KEY UPDATE`, `FOR SHARE` and `FOR KEY SHARE` variants, as well as the `NOWAIT` and `SKIP LOCKED` options, do not appear in the standard.

Data-Modifying Statements in WITH

PostgreSQL allows `INSERT`, `UPDATE`, and `DELETE` to be used as `WITH` queries. This is not found in the SQL standard.

Nonstandard Clauses

`DISTINCT ON (...)` is an extension of the SQL standard.

`ROWS FROM(...)` is an extension of the SQL standard.

The `MATERIALIZED` and `NOT MATERIALIZED` options of `WITH` are extensions of the SQL standard.

SELECT INTO

SELECT INTO — define a new table from the results of a query

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    * | expression [ [ AS ] output_name ] [, ...]
INTO [ TEMPORARY | TEMP | UNLOGGED ] [ TABLE ] new_table
[ FROM from_item [, ...] ]
[ WHERE condition ]
[ GROUP BY expression [, ...] ]
[ HAVING condition [, ...] ]
[ WINDOW window_name AS ( window_definition ) [, ...] ]
[ { UNION | INTERSECT | EXCEPT } [ ALL | DISTINCT ] select ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS
{ FIRST | LAST } ] [, ...] ]
[ LIMIT { count | ALL } ]
[ OFFSET start [ ROW | ROWS ] ]
[ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
[ FOR { UPDATE | SHARE } [ OF table_name [, ...] ] [ NOWAIT ]
[ ... ] ]
```

Description

SELECT INTO creates a new table and fills it with data computed by a query. The data is not returned to the client, as it is with a normal SELECT. The new table's columns have the names and data types associated with the output columns of the SELECT.

Parameters

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED

If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

new_table

The name (optionally schema-qualified) of the table to be created.

All other parameters are described in detail under SELECT.

Notes

CREATE TABLE AS is functionally similar to SELECT INTO. CREATE TABLE AS is the recommended syntax, since this form of SELECT INTO is not available in ECPG or PL/pgSQL, because they interpret the INTO clause differently. Furthermore, CREATE TABLE AS offers a superset of the functionality provided by SELECT INTO.

In contrast to CREATE TABLE AS, SELECT INTO does not allow to specify properties like a table's access method with USING *method* or the table's tablespace with TABLESPACE *table-*

space_name. Use `CREATE TABLE AS` if necessary. Therefore, the default table access method is chosen for the new table. See `default_table_access_method` for more information.

Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
SELECT * INTO films_recent FROM films WHERE date_prod >=
'2002-01-01';
```

Compatibility

The SQL standard uses `SELECT INTO` to represent selecting values into scalar variables of a host program, rather than creating a new table. This indeed is the usage found in ECPG (see Chapter 35) and PL/pgSQL (see Chapter 42). The PostgreSQL usage of `SELECT INTO` to represent table creation is historical. It is best to use `CREATE TABLE AS` for this purpose in new code.

See Also

`CREATE TABLE AS`

SET

SET — change a run-time parameter

Synopsis

```
SET [ SESSION | LOCAL ] configuration_parameter { TO | = } { value
| 'value' | DEFAULT }
SET [ SESSION | LOCAL ] TIME ZONE { timezone | LOCAL | DEFAULT }
```

Description

The SET command changes run-time configuration parameters. Many of the run-time parameters listed in Chapter 19 can be changed on-the-fly with SET. (But some require superuser privileges to change, and others cannot be changed after server or session start.) SET only affects the value used by the current session.

If SET (or equivalently SET SESSION) is issued within a transaction that is later aborted, the effects of the SET command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another SET.

The effects of SET LOCAL last only till the end of the current transaction, whether committed or not. A special case is SET followed by SET LOCAL within a single transaction: the SET LOCAL value will be seen until the end of the transaction, but afterwards (if the transaction is committed) the SET value will take effect.

The effects of SET or SET LOCAL are also canceled by rolling back to a savepoint that is earlier than the command.

If SET LOCAL is used within a function that has a SET option for the same variable (see CREATE FUNCTION), the effects of the SET LOCAL command disappear at function exit; that is, the value in effect when the function was called is restored anyway. This allows SET LOCAL to be used for dynamic or repeated changes of a parameter within a function, while still having the convenience of using the SET option to save and restore the caller's value. However, a regular SET command overrides any surrounding function's SET option; its effects will persist unless rolled back.

Note

In PostgreSQL versions 8.0 through 8.2, the effects of a SET LOCAL would be canceled by releasing an earlier savepoint, or by successful exit from a PL/pgSQL exception block. This behavior has been changed because it was deemed unintuitive.

Parameters

SESSION

Specifies that the command takes effect for the current session. (This is the default if neither SESSION nor LOCAL appears.)

LOCAL

Specifies that the command takes effect for only the current transaction. After COMMIT or ROLLBACK, the session-level setting takes effect again. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

configuration_parameter

Name of a settable run-time parameter. Available parameters are documented in Chapter 19 and below.

value

New value of parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. DEFAULT can be written to specify resetting the parameter to its default value (that is, whatever value it would have had if no SET had been executed in the current session).

Besides the configuration parameters documented in Chapter 19, there are a few that can only be adjusted using the SET command or that have a special syntax:

SCHEMA

SET SCHEMA *value* is an alias for SET search_path TO *value*. Only one schema can be specified using this syntax.

NAMES

SET NAMES *value* is an alias for SET client_encoding TO *value*.

SEED

Sets the internal seed for the random number generator (the function random). Allowed values are floating-point numbers between -1 and 1, which are then multiplied by $2^{31}-1$.

The seed can also be set by invoking the function setseed:

```
SELECT setseed(value);
```

TIME ZONE

SET TIME ZONE *value* is an alias for SET timezone TO *value*. The syntax SET TIME ZONE allows special syntax for the time zone specification. Here are examples of valid values:

```
'PST8PDT'
```

The time zone for Berkeley, California.

```
'Europe/Rome'
```

The time zone for Italy.

```
-7
```

The time zone 7 hours west from UTC (equivalent to PDT). Positive values are east from UTC.

```
INTERVAL '-08:00' HOUR TO MINUTE
```

The time zone 8 hours west from UTC (equivalent to PST).

LOCAL

DEFAULT

Set the time zone to your local time zone (that is, the server's default value of timezone).

Timezone settings given as numbers or intervals are internally translated to POSIX timezone syntax. For example, after SET TIME ZONE -7, SHOW TIME ZONE would report <-07>+07.

See Section 8.5.3 for more information about time zones.

Notes

The function `set_config` provides equivalent functionality; see Section 9.26. Also, it is possible to UPDATE the `pg_settings` system view to perform the equivalent of SET.

Examples

Set the schema search path:

```
SET search_path TO my_schema, public;
```

Set the style of date to traditional POSTGRES with “day before month” input convention:

```
SET datestyle TO postgres, dmy;
```

Set the time zone for Berkeley, California:

```
SET TIME ZONE 'PST8PDT';
```

Set the time zone for Italy:

```
SET TIME ZONE 'Europe/Rome';
```

Compatibility

SET TIME ZONE extends syntax defined in the SQL standard. The standard allows only numeric time zone offsets while PostgreSQL allows more flexible time-zone specifications. All other SET features are PostgreSQL extensions.

See Also

RESET, SHOW

SET CONSTRAINTS

SET CONSTRAINTS — set constraint check timing for the current transaction

Synopsis

```
SET CONSTRAINTS { ALL | name [, ...] } { DEFERRED | IMMEDIATE }
```

Description

SET CONSTRAINTS sets the behavior of constraint checking within the current transaction. IMMEDIATE constraints are checked at the end of each statement. DEFERRED constraints are not checked until transaction commit. Each constraint has its own IMMEDIATE or DEFERRED mode.

Upon creation, a constraint is given one of three characteristics: DEFERRABLE INITIALLY DEFERRED, DEFERRABLE INITIALLY IMMEDIATE, or NOT DEFERRABLE. The third class is always IMMEDIATE and is not affected by the SET CONSTRAINTS command. The first two classes start every transaction in the indicated mode, but their behavior can be changed within a transaction by SET CONSTRAINTS.

SET CONSTRAINTS with a list of constraint names changes the mode of just those constraints (which must all be deferrable). Each constraint name can be schema-qualified. The current schema search path is used to find the first matching name if no schema name is specified. SET CONSTRAINTS ALL changes the mode of all deferrable constraints.

When SET CONSTRAINTS changes the mode of a constraint from DEFERRED to IMMEDIATE, the new mode takes effect retroactively: any outstanding data modifications that would have been checked at the end of the transaction are instead checked during the execution of the SET CONSTRAINTS command. If any such constraint is violated, the SET CONSTRAINTS fails (and does not change the constraint mode). Thus, SET CONSTRAINTS can be used to force checking of constraints to occur at a specific point in a transaction.

Currently, only UNIQUE, PRIMARY KEY, REFERENCES (foreign key), and EXCLUDE constraints are affected by this setting. NOT NULL and CHECK constraints are always checked immediately when a row is inserted or modified (*not* at the end of the statement). Uniqueness and exclusion constraints that have not been declared DEFERRABLE are also checked immediately.

The firing of triggers that are declared as “constraint triggers” is also controlled by this setting — they fire at the same time that the associated constraint should be checked.

Notes

Because PostgreSQL does not require constraint names to be unique within a schema (but only per-table), it is possible that there is more than one match for a specified constraint name. In this case SET CONSTRAINTS will act on all matches. For a non-schema-qualified name, once a match or matches have been found in some schema in the search path, schemas appearing later in the path are not searched.

This command only alters the behavior of constraints within the current transaction. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

Compatibility

This command complies with the behavior defined in the SQL standard, except for the limitation that, in PostgreSQL, it does not apply to NOT NULL and CHECK constraints. Also, PostgreSQL checks non-deferrable uniqueness constraints immediately, not at end of statement as the standard would suggest.

SET ROLE

SET ROLE — set the current user identifier of the current session

Synopsis

```
SET [ SESSION | LOCAL ] ROLE role_name
SET [ SESSION | LOCAL ] ROLE NONE
RESET ROLE
```

Description

This command sets the current user identifier of the current SQL session to be *role_name*. The role name can be written as either an identifier or a string literal. After SET ROLE, permissions checking for SQL commands is carried out as though the named role were the one that had logged in originally.

The specified *role_name* must be a role that the current session user is a member of. (If the session user is a superuser, any role can be selected.)

The SESSION and LOCAL modifiers act the same as for the regular SET command.

The NONE and RESET forms reset the current user identifier to be the current session user identifier. These forms can be executed by any user.

Notes

Using this command, it is possible to either add privileges or restrict one's privileges. If the session user role has the INHERIT attribute, then it automatically has all the privileges of every role that it could SET ROLE to; in this case SET ROLE effectively drops all the privileges assigned directly to the session user and to the other roles it is a member of, leaving only the privileges available to the named role. On the other hand, if the session user role has the NOINHERIT attribute, SET ROLE drops the privileges assigned directly to the session user and instead acquires the privileges available to the named role.

In particular, when a superuser chooses to SET ROLE to a non-superuser role, they lose their superuser privileges.

SET ROLE has effects comparable to SET SESSION AUTHORIZATION, but the privilege checks involved are quite different. Also, SET SESSION AUTHORIZATION determines which roles are allowable for later SET ROLE commands, whereas changing roles with SET ROLE does not change the set of roles allowed to a later SET ROLE.

SET ROLE does not process session variables as specified by the role's ALTER ROLE settings; this only happens during login.

SET ROLE cannot be used within a SECURITY DEFINER function.

Examples

```
SELECT SESSION_USER, CURRENT_USER;

 session_user | current_user
-----+-----
```

```
peter          | peter
SET ROLE 'paul';

SELECT SESSION_USER, CURRENT_USER;

session_user | current_user
-----+-----
peter       | paul
```

Compatibility

PostgreSQL allows identifier syntax (*rolename*), while the SQL standard requires the role name to be written as a string literal. SQL does not allow this command during a transaction; PostgreSQL does not make this restriction because there is no reason to. The `SESSION` and `LOCAL` modifiers are a PostgreSQL extension, as is the `RESET` syntax.

See Also

SET SESSION AUTHORIZATION

SET SESSION AUTHORIZATION

SET SESSION AUTHORIZATION — set the session user identifier and the current user identifier of the current session

Synopsis

```
SET [ SESSION | LOCAL ] SESSION AUTHORIZATION user_name
SET [ SESSION | LOCAL ] SESSION AUTHORIZATION DEFAULT
RESET SESSION AUTHORIZATION
```

Description

This command sets the session user identifier and the current user identifier of the current SQL session to be *user_name*. The user name can be written as either an identifier or a string literal. Using this command, it is possible, for example, to temporarily become an unprivileged user and later switch back to being a superuser.

The session user identifier is initially set to be the (possibly authenticated) user name provided by the client. The current user identifier is normally equal to the session user identifier, but might change temporarily in the context of SECURITY DEFINER functions and similar mechanisms; it can also be changed by SET ROLE. The current user identifier is relevant for permission checking.

The session user identifier can be changed only if the initial session user (the *authenticated user*) had the superuser privilege. Otherwise, the command is accepted only if it specifies the authenticated user name.

The SESSION and LOCAL modifiers act the same as for the regular SET command.

The DEFAULT and RESET forms reset the session and current user identifiers to be the originally authenticated user name. These forms can be executed by any user.

Notes

SET SESSION AUTHORIZATION cannot be used within a SECURITY DEFINER function.

Examples

```
SELECT SESSION_USER, CURRENT_USER;
```

```
  session_user | current_user
-----+-----
  peter       | peter
```

```
SET SESSION AUTHORIZATION 'paul';
```

```
SELECT SESSION_USER, CURRENT_USER;
```

```
  session_user | current_user
-----+-----
  paul        | paul
```

Compatibility

The SQL standard allows some other expressions to appear in place of the literal *user_name*, but these options are not important in practice. PostgreSQL allows identifier syntax ("*username*"), which SQL does not. SQL does not allow this command during a transaction; PostgreSQL does not make this restriction because there is no reason to. The `SESSION` and `LOCAL` modifiers are a PostgreSQL extension, as is the `RESET` syntax.

The privileges necessary to execute this command are left implementation-defined by the standard.

See Also

SET ROLE

SET TRANSACTION

SET TRANSACTION — set the characteristics of the current transaction

Synopsis

```
SET TRANSACTION transaction_mode [, ...]
SET TRANSACTION SNAPSHOT snapshot_id
SET SESSION CHARACTERISTICS AS TRANSACTION transaction_mode [, ...]
```

where *transaction_mode* is one of:

```
ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ
COMMITTED | READ UNCOMMITTED }
READ WRITE | READ ONLY
[ NOT ] DEFERRABLE
```

Description

The SET TRANSACTION command sets the characteristics of the current transaction. It has no effect on any subsequent transactions. SET SESSION CHARACTERISTICS sets the default transaction characteristics for subsequent transactions of a session. These defaults can be overridden by SET TRANSACTION for an individual transaction.

The available transaction characteristics are the transaction isolation level, the transaction access mode (read/write or read-only), and the deferrable mode. In addition, a snapshot can be selected, though only for the current transaction, not as a session default.

The isolation level of a transaction determines what data the transaction can see when other transactions are running concurrently:

READ COMMITTED

A statement can only see rows committed before it began. This is the default.

REPEATABLE READ

All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction.

SERIALIZABLE

All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction. If a pattern of reads and writes among concurrent serializable transactions would create a situation which could not have occurred for any serial (one-at-a-time) execution of those transactions, one of them will be rolled back with a `serialization_failure` error.

The SQL standard defines one additional level, READ UNCOMMITTED. In PostgreSQL READ UNCOMMITTED is treated as READ COMMITTED.

The transaction isolation level cannot be changed after the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of a transaction has been executed. See Chapter 13 for more information about transaction isolation and concurrency control.

The transaction access mode determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: INSERT,

UPDATE, DELETE, and COPY FROM if the table they would write to is not a temporary table; all CREATE, ALTER, and DROP commands; COMMENT, GRANT, REVOKE, TRUNCATE; and EXPLAIN ANALYZE and EXECUTE if the command they would execute is among those listed. This is a high-level notion of read-only that does not prevent all writes to disk.

The DEFERRABLE transaction property has no effect unless the transaction is also SERIALIZABLE and READ ONLY. When all three of these properties are selected for a transaction, the transaction may block when first acquiring its snapshot, after which it is able to run without the normal overhead of a SERIALIZABLE transaction and without any risk of contributing to or being canceled by a serialization failure. This mode is well suited for long-running reports or backups.

The SET TRANSACTION SNAPSHOT command allows a new transaction to run with the same *snapshot* as an existing transaction. The pre-existing transaction must have exported its snapshot with the pg_export_snapshot function (see Section 9.26.5). That function returns a snapshot identifier, which must be given to SET TRANSACTION SNAPSHOT to specify which snapshot is to be imported. The identifier must be written as a string literal in this command, for example '000003A1-1'. SET TRANSACTION SNAPSHOT can only be executed at the start of a transaction, before the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of the transaction. Furthermore, the transaction must already be set to SERIALIZABLE or REPEATABLE READ isolation level (otherwise, the snapshot would be discarded immediately, since READ COMMITTED mode takes a new snapshot for each command). If the importing transaction uses SERIALIZABLE isolation level, then the transaction that exported the snapshot must also use that isolation level. Also, a non-read-only serializable transaction cannot import a snapshot from a read-only transaction.

Notes

If SET TRANSACTION is executed without a prior START TRANSACTION or BEGIN, it emits a warning and otherwise has no effect.

It is possible to dispense with SET TRANSACTION by instead specifying the desired *transaction_modes* in BEGIN or START TRANSACTION. But that option is not available for SET TRANSACTION SNAPSHOT.

The session default transaction modes can also be set by setting the configuration parameters default_transaction_isolation, default_transaction_read_only, and default_transaction_deferrable. (In fact SET SESSION CHARACTERISTICS is just a verbose equivalent for setting these variables with SET.) This means the defaults can be set in the configuration file, via ALTER DATABASE, etc. Consult Chapter 19 for more information.

Examples

To begin a new transaction with the same snapshot as an already existing transaction, first export the snapshot from the existing transaction. That will return the snapshot identifier, for example:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SELECT pg_export_snapshot();
       pg_export_snapshot
-----
00000003-0000001B-1
(1 row)
```

Then give the snapshot identifier in a SET TRANSACTION SNAPSHOT command at the beginning of the newly opened transaction:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SET TRANSACTION SNAPSHOT '00000003-0000001B-1';
```

Compatibility

These commands are defined in the SQL standard, except for the `DEFERRABLE` transaction mode and the `SET TRANSACTION SNAPSHOT` form, which are PostgreSQL extensions.

`SERIALIZABLE` is the default transaction isolation level in the standard. In PostgreSQL the default is ordinarily `READ COMMITTED`, but you can change it as mentioned above.

In the SQL standard, there is one other transaction characteristic that can be set with these commands: the size of the diagnostics area. This concept is specific to embedded SQL, and therefore is not implemented in the PostgreSQL server.

The SQL standard requires commas between successive *transaction_modes*, but for historical reasons PostgreSQL allows the commas to be omitted.

SHOW

SHOW — show the value of a run-time parameter

Synopsis

```
SHOW name
SHOW ALL
```

Description

SHOW will display the current setting of run-time parameters. These variables can be set using the SET statement, by editing the `postgresql.conf` configuration file, through the `PGOPTIONS` environmental variable (when using libpq or a libpq-based application), or through command-line flags when starting the `postgres` server. See Chapter 19 for details.

Parameters

name

The name of a run-time parameter. Available parameters are documented in Chapter 19 and on the SET reference page. In addition, there are a few parameters that can be shown but not set:

SERVER_VERSION

Shows the server's version number.

SERVER_ENCODING

Shows the server-side character set encoding. At present, this parameter can be shown but not set, because the encoding is determined at database creation time.

LC_COLLATE

Shows the database's locale setting for collation (text ordering). At present, this parameter can be shown but not set, because the setting is determined at database creation time.

LC_CTYPE

Shows the database's locale setting for character classification. At present, this parameter can be shown but not set, because the setting is determined at database creation time.

IS_SUPERUSER

True if the current role has superuser privileges.

ALL

Show the values of all configuration parameters, with descriptions.

Notes

The function `current_setting` produces equivalent output; see Section 9.26. Also, the `pg_settings` system view produces the same information.

Examples

Show the current setting of the parameter `DateStyle`:

```
SHOW DateStyle;
DateStyle
-----
ISO, MDY
(1 row)
```

Show the current setting of the parameter `geqo`:

```
SHOW geqo;
geqo
-----
on
(1 row)
```

Show all settings:

```
SHOW ALL;
          name          | setting | description
-----+-----
allow_system_table_mods | off     | Allows modifications of the
structure of ...
.
.
.
xmloption               | content | Sets whether XML data in
implicit parsing ...
zero_damaged_pages      | off     | Continues processing past
damaged page headers.
(196 rows)
```

Compatibility

The `SHOW` command is a PostgreSQL extension.

See Also

SET, RESET

START TRANSACTION

START TRANSACTION — start a transaction block

Synopsis

```
START TRANSACTION [ transaction_mode [, ...] ]
```

where *transaction_mode* is one of:

```
ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ  
COMMITTED | READ UNCOMMITTED }  
READ WRITE | READ ONLY  
[ NOT ] DEFERRABLE
```

Description

This command begins a new transaction block. If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed. This is the same as the BEGIN command.

Parameters

Refer to SET TRANSACTION for information on the meaning of the parameters to this statement.

Compatibility

In the standard, it is not necessary to issue START TRANSACTION to start a transaction block: any SQL command implicitly begins a block. PostgreSQL's behavior can be seen as implicitly issuing a COMMIT after each command that does not follow START TRANSACTION (or BEGIN), and it is therefore often called “autocommit”. Other relational database systems might offer an autocommit feature as a convenience.

The DEFERRABLE *transaction_mode* is a PostgreSQL language extension.

The SQL standard requires commas between successive *transaction_modes*, but for historical reasons PostgreSQL allows the commas to be omitted.

See also the compatibility section of SET TRANSACTION.

See Also

BEGIN, COMMIT, ROLLBACK, SAVEPOINT, SET TRANSACTION

TRUNCATE

TRUNCATE — empty a table or set of tables

Synopsis

```
TRUNCATE [ TABLE ] [ ONLY ] name [ * ] [ , ... ]  
        [ RESTART IDENTITY | CONTINUE IDENTITY ] [ CASCADE | RESTRICT ]
```

Description

TRUNCATE quickly removes all rows from a set of tables. It has the same effect as an unqualified DELETE on each table, but since it does not actually scan the tables it is faster. Furthermore, it reclaims disk space immediately, rather than requiring a subsequent VACUUM operation. This is most useful on large tables.

Parameters

name

The name (optionally schema-qualified) of a table to truncate. If ONLY is specified before the table name, only that table is truncated. If ONLY is not specified, the table and all its descendant tables (if any) are truncated. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

RESTART IDENTITY

Automatically restart sequences owned by columns of the truncated table(s).

CONTINUE IDENTITY

Do not change the values of sequences. This is the default.

CASCADE

Automatically truncate all tables that have foreign-key references to any of the named tables, or to any tables added to the group due to CASCADE.

RESTRICT

Refuse to truncate if any of the tables have foreign-key references from tables that are not listed in the command. This is the default.

Notes

You must have the TRUNCATE privilege on a table to truncate it.

TRUNCATE acquires an ACCESS EXCLUSIVE lock on each table it operates on, which blocks all other concurrent operations on the table. When RESTART IDENTITY is specified, any sequences that are to be restarted are likewise locked exclusively. If concurrent access to a table is required, then the DELETE command should be used instead.

TRUNCATE cannot be used on a table that has foreign-key references from other tables, unless all such tables are also truncated in the same command. Checking validity in such cases would require table scans, and the whole point is not to do one. The CASCADE option can be used to automatically

include all dependent tables — but be very careful when using this option, or else you might lose data you did not intend to!

TRUNCATE will not fire any ON DELETE triggers that might exist for the tables. But it will fire ON TRUNCATE triggers. If ON TRUNCATE triggers are defined for any of the tables, then all BEFORE TRUNCATE triggers are fired before any truncation happens, and all AFTER TRUNCATE triggers are fired after the last truncation is performed and any sequences are reset. The triggers will fire in the order that the tables are to be processed (first those listed in the command, and then any that were added due to cascading).

TRUNCATE is not MVCC-safe. After truncation, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the truncation occurred. See Section 13.5 for more details.

TRUNCATE is transaction-safe with respect to the data in the tables: the truncation will be safely rolled back if the surrounding transaction does not commit.

When RESTART IDENTITY is specified, the implied ALTER SEQUENCE RESTART operations are also done transactionally; that is, they will be rolled back if the surrounding transaction does not commit. This is unlike the normal behavior of ALTER SEQUENCE RESTART. Be aware that if any additional sequence operations are done on the restarted sequences before the transaction rolls back, the effects of these operations on the sequences will be rolled back, but not their effects on `currval()`; that is, after the transaction `currval()` will continue to reflect the last sequence value obtained inside the failed transaction, even though the sequence itself may no longer be consistent with that. This is similar to the usual behavior of `currval()` after a failed transaction.

TRUNCATE is not currently supported for foreign tables. This implies that if a specified table has any descendant tables that are foreign, the command will fail.

Examples

Truncate the tables `bigtable` and `fattable`:

```
TRUNCATE bigtable, fattable;
```

The same, and also reset any associated sequence generators:

```
TRUNCATE bigtable, fattable RESTART IDENTITY;
```

Truncate the table `othertable`, and cascade to any tables that reference `othertable` via foreign-key constraints:

```
TRUNCATE othertable CASCADE;
```

Compatibility

The SQL:2008 standard includes a TRUNCATE command with the syntax `TRUNCATE TABLE tablename`. The clauses `CONTINUE IDENTITY/RESTART IDENTITY` also appear in that standard, but have slightly different though related meanings. Some of the concurrency behavior of this command is left implementation-defined by the standard, so the above notes should be considered and compared with other implementations if necessary.

See Also

DELETE

UNLISTEN

UNLISTEN — stop listening for a notification

Synopsis

```
UNLISTEN { channel | * }
```

Description

UNLISTEN is used to remove an existing registration for NOTIFY events. UNLISTEN cancels any existing registration of the current PostgreSQL session as a listener on the notification channel named *channel*. The special wildcard *** cancels all listener registrations for the current session.

NOTIFY contains a more extensive discussion of the use of LISTEN and NOTIFY.

Parameters

channel

Name of a notification channel (any identifier).

*

All current listen registrations for this session are cleared.

Notes

You can unlisten something you were not listening for; no warning or error will appear.

At the end of each session, UNLISTEN *** is automatically executed.

A transaction that has executed UNLISTEN cannot be prepared for two-phase commit.

Examples

To make a registration:

```
LISTEN virtual;  
NOTIFY virtual;  
Asynchronous notification "virtual" received from server process  
with PID 8448.
```

Once UNLISTEN has been executed, further NOTIFY messages will be ignored:

```
UNLISTEN virtual;  
NOTIFY virtual;  
-- no NOTIFY event is received
```

Compatibility

There is no UNLISTEN command in the SQL standard.

See Also

LISTEN, NOTIFY

UPDATE

UPDATE — update rows of a table

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
UPDATE [ ONLY ] table_name [ * ] [ [ AS ] alias ]
    SET { column_name = { expression | DEFAULT } |
        ( column_name [, ...] ) = [ ROW ] ( { expression |
DEFAULT } [, ...] ) |
        ( column_name [, ...] ) = ( sub-SELECT )
    } [, ...]
    [ FROM from_list ]
    [ WHERE condition | WHERE CURRENT OF cursor_name ]
    [ RETURNING * | output_expression [ [ AS ] output_name ]
    [, ...] ]
```

Description

UPDATE changes the values of the specified columns in all rows that satisfy the condition. Only the columns to be modified need be mentioned in the SET clause; columns not explicitly modified retain their previous values.

There are two ways to modify a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the FROM clause. Which technique is more appropriate depends on the specific circumstances.

The optional RETURNING clause causes UPDATE to compute and return value(s) based on each row actually updated. Any expression using the table's columns, and/or columns of other tables mentioned in FROM, can be computed. The new (post-update) values of the table's columns are used. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have the UPDATE privilege on the table, or at least on the column(s) that are listed to be updated. You must also have the SELECT privilege on any column whose values are read in the *expressions* or *condition*.

Parameters

with_query

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the UPDATE query. See Section 7.8 and SELECT for details.

table_name

The name (optionally schema-qualified) of the table to update. If ONLY is specified before the table name, matching rows are updated in the named table only. If ONLY is not specified, matching rows are also updated in any tables inheriting from the named table. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

alias

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given UPDATE *f○○* AS *f*, the remainder of the UPDATE statement must refer to this table as *f* not *f○○*.

column_name

The name of a column in the table named by *table_name*. The column name can be qualified with a subfield name or array subscript, if needed. Do not include the table's name in the specification of a target column — for example, `UPDATE table_name SET table_name.col = 1` is invalid.

expression

An expression to assign to the column. The expression can use the old values of this and other columns in the table.

DEFAULT

Set the column to its default value (which will be NULL if no specific default expression has been assigned to it).

sub-SELECT

A SELECT sub-query that produces as many output columns as are listed in the parenthesized column list preceding it. The sub-query must yield no more than one row when executed. If it yields one row, its column values are assigned to the target columns; if it yields no rows, NULL values are assigned to the target columns. The sub-query can refer to old values of the current row of the table being updated.

from_list

A list of table expressions, allowing columns from other tables to appear in the WHERE condition and the update expressions. This is similar to the list of tables that can be specified in the FROM Clause of a SELECT statement. Note that the target table must not appear in the *from_list*, unless you intend a self-join (in which case it must appear with an alias in the *from_list*).

condition

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated.

cursor_name

The name of the cursor to use in a WHERE CURRENT OF condition. The row to be updated is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the UPDATE's target table. Note that WHERE CURRENT OF cannot be specified together with a Boolean condition. See DECLARE for more information about using cursors with WHERE CURRENT OF.

output_expression

An expression to be computed and returned by the UPDATE command after each row is updated. The expression can use any column names of the table named by *table_name* or table(s) listed in FROM. Write `*` to return all columns.

output_name

A name to use for a returned column.

Outputs

On successful completion, an UPDATE command returns a command tag of the form

UPDATE *count*

The *count* is the number of rows updated, including matched rows whose values did not change. Note that the number may be less than the number of rows that matched the *condition* when updates were suppressed by a BEFORE UPDATE trigger. If *count* is 0, no rows were updated by the query (this is not considered an error).

If the UPDATE command contains a RETURNING clause, the result will be similar to that of a SELECT statement containing the columns and values defined in the RETURNING list, computed over the row(s) updated by the command.

Notes

When a FROM clause is present, what essentially happens is that the target table is joined to the tables mentioned in the *from_list*, and each output row of the join represents an update operation for the target table. When using FROM you should ensure that the join produces at most one output row for each row to be modified. In other words, a target row shouldn't join to more than one row from the other table(s). If it does, then only one of the join rows will be used to update the target row, but which one will be used is not readily predictable.

Because of this indeterminacy, referencing other tables only within sub-selects is safer, though often harder to read and slower than using a join.

In the case of a partitioned table, updating a row might cause it to no longer satisfy the partition constraint of the containing partition. In that case, if there is some other partition in the partition tree for which this row satisfies its partition constraint, then the row is moved to that partition. If there is no such partition, an error will occur. Behind the scenes, the row movement is actually a DELETE and INSERT operation.

There is a possibility that a concurrent UPDATE or DELETE on the row being moved will get a serialization failure error. Suppose session 1 is performing an UPDATE on a partition key, and meanwhile a concurrent session 2 for which this row is visible performs an UPDATE or DELETE operation on this row. In such case, session 2's UPDATE or DELETE will detect the row movement and raise a serialization failure error (which always returns with an SQLSTATE code '40001'). Applications may wish to retry the transaction if this occurs. In the usual case where the table is not partitioned, or where there is no row movement, session 2 would have identified the newly updated row and carried out the UPDATE/DELETE on this new row version.

Note that while rows can be moved from local partitions to a foreign-table partition (provided the foreign data wrapper supports tuple routing), they cannot be moved from a foreign-table partition to another partition.

Examples

Change the word Drama to Dramatic in the column kind of the table films:

```
UPDATE films SET kind = 'Dramatic' WHERE kind = 'Drama';
```

Adjust temperature entries and reset precipitation to its default value in one row of the table weather:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp
= DEFAULT
WHERE city = 'San Francisco' AND date = '2003-07-03';
```

Perform the same operation and return the updated entries:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp
= DEFAULT
```

UPDATE

```
WHERE city = 'San Francisco' AND date = '2003-07-03'  
RETURNING temp_lo, temp_hi, prcp;
```

Use the alternative column-list syntax to do the same update:

```
UPDATE weather SET (temp_lo, temp_hi, prcp) = (temp_lo+1, temp_lo  
+15, DEFAULT)  
WHERE city = 'San Francisco' AND date = '2003-07-03';
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, using the FROM clause syntax:

```
UPDATE employees SET sales_count = sales_count + 1 FROM accounts  
WHERE accounts.name = 'Acme Corporation'  
AND employees.id = accounts.sales_person;
```

Perform the same operation, using a sub-select in the WHERE clause:

```
UPDATE employees SET sales_count = sales_count + 1 WHERE id =  
(SELECT sales_person FROM accounts WHERE name = 'Acme  
Corporation');
```

Update contact names in an accounts table to match the currently assigned salesmen:

```
UPDATE accounts SET (contact_first_name, contact_last_name) =  
(SELECT first_name, last_name FROM salesmen  
WHERE salesmen.id = accounts.sales_id);
```

A similar result could be accomplished with a join:

```
UPDATE accounts SET contact_first_name = first_name,  
contact_last_name = last_name  
FROM salesmen WHERE salesmen.id = accounts.sales_id;
```

However, the second query may give unexpected results if `salesmen.id` is not a unique key, whereas the first query is guaranteed to raise an error if there are multiple `id` matches. Also, if there is no match for a particular `accounts.sales_id` entry, the first query will set the corresponding name fields to NULL, whereas the second query will not update that row at all.

Update statistics in a summary table to match the current data:

```
UPDATE summary s SET (sum_x, sum_y, avg_x, avg_y) =  
(SELECT sum(x), sum(y), avg(x), avg(y) FROM data d  
WHERE d.group_id = s.group_id);
```

Attempt to insert a new stock item along with the quantity of stock. If the item already exists, instead update the stock count of the existing item. To do this without failing the entire transaction, use savepoints:

```
BEGIN;  
-- other operations  
SAVEPOINT sp1;  
INSERT INTO wines VALUES('Chateau Lafite 2003', '24');  
-- Assume the above fails because of a unique key violation,
```

```
-- so now we issue these commands:  
ROLLBACK TO sp1;  
UPDATE wines SET stock = stock + 24 WHERE winename = 'Chateau  
  Lafite 2003';  
-- continue with other operations, and eventually  
COMMIT;
```

Change the kind column of the table `films` in the row on which the cursor `c_films` is currently positioned:

```
UPDATE films SET kind = 'Dramatic' WHERE CURRENT OF c_films;
```

Compatibility

This command conforms to the SQL standard, except that the `FROM` and `RETURNING` clauses are PostgreSQL extensions, as is the ability to use `WITH` with `UPDATE`.

Some other database systems offer a `FROM` option in which the target table is supposed to be listed again within `FROM`. That is not how PostgreSQL interprets `FROM`. Be careful when porting applications that use this extension.

According to the standard, the source value for a parenthesized sub-list of target column names can be any row-valued expression yielding the correct number of columns. PostgreSQL only allows the source value to be a row constructor or a sub-`SELECT`. An individual column's updated value can be specified as `DEFAULT` in the row-constructor case, but not inside a sub-`SELECT`.

VACUUM

VACUUM — garbage-collect and optionally analyze a database

Synopsis

```
VACUUM [ ( option [, ...] ) ] [ table_and_columns [, ...] ]  
VACUUM [ FULL ] [ FREEZE ] [ VERBOSE ] [ ANALYZE ]  
    [ table_and_columns [, ...] ]
```

where *option* can be one of:

```
FULL [ boolean ]  
FREEZE [ boolean ]  
VERBOSE [ boolean ]  
ANALYZE [ boolean ]  
DISABLE_PAGE_SKIPPING [ boolean ]  
SKIP_LOCKED [ boolean ]  
INDEX_CLEANUP [ boolean ]  
TRUNCATE [ boolean ]
```

and *table_and_columns* is:

```
table_name [ ( column_name [, ...] ) ]
```

Description

VACUUM reclaims storage occupied by dead tuples. In normal PostgreSQL operation, tuples that are deleted or obsoleted by an update are not physically removed from their table; they remain present until a VACUUM is done. Therefore it's necessary to do VACUUM periodically, especially on frequently-updated tables.

Without a *table_and_columns* list, VACUUM processes every table and materialized view in the current database that the current user has permission to vacuum. With a list, VACUUM processes only those table(s).

VACUUM ANALYZE performs a VACUUM and then an ANALYZE for each selected table. This is a handy combination form for routine maintenance scripts. See ANALYZE for more details about its processing.

Plain VACUUM (without FULL) simply reclaims space and makes it available for re-use. This form of the command can operate in parallel with normal reading and writing of the table, as an exclusive lock is not obtained. However, extra space is not returned to the operating system (in most cases); it's just kept available for re-use within the same table. VACUUM FULL rewrites the entire contents of the table into a new disk file with no extra space, allowing unused space to be returned to the operating system. This form is much slower and requires an exclusive lock on each table while it is being processed.

When the option list is surrounded by parentheses, the options can be written in any order. Without parentheses, options must be specified in exactly the order shown above. The parenthesized syntax was added in PostgreSQL 9.0; the unparenthesized syntax is deprecated.

Parameters

FULL

Selects “full” vacuum, which can reclaim more space, but takes much longer and exclusively locks the table. This method also requires extra disk space, since it writes a new copy of the table and doesn't release the old copy until the operation is complete. Usually this should only be used when a significant amount of space needs to be reclaimed from within the table.

FREEZE

Selects aggressive “freezing” of tuples. Specifying `FREEZE` is equivalent to performing `VACUUM` with the `vacuum_freeze_min_age` and `vacuum_freeze_table_age` parameters set to zero. Aggressive freezing is always performed when the table is rewritten, so this option is redundant when `FULL` is specified.

VERBOSE

Prints a detailed vacuum activity report for each table.

ANALYZE

Updates statistics used by the planner to determine the most efficient way to execute a query.

DISABLE_PAGE_SKIPPING

Normally, `VACUUM` will skip pages based on the visibility map. Pages where all tuples are known to be frozen can always be skipped, and those where all tuples are known to be visible to all transactions may be skipped except when performing an aggressive vacuum. Furthermore, except when performing an aggressive vacuum, some pages may be skipped in order to avoid waiting for other sessions to finish using them. This option disables all page-skipping behavior, and is intended to be used only when the contents of the visibility map are suspect, which should happen only if there is a hardware or software issue causing database corruption.

SKIP_LOCKED

Specifies that `VACUUM` should not wait for any conflicting locks to be released when beginning work on a relation: if a relation cannot be locked immediately without waiting, the relation is skipped. Note that even with this option, `VACUUM` may still block when opening the relation's indexes. Additionally, `VACUUM ANALYZE` may still block when acquiring sample rows from partitions, table inheritance children, and some types of foreign tables. Also, while `VACUUM` ordinarily processes all partitions of specified partitioned tables, this option will cause `VACUUM` to skip all partitions if there is a conflicting lock on the partitioned table.

INDEX_CLEANUP

Specifies that `VACUUM` should attempt to remove index entries pointing to dead tuples. This is normally the desired behavior and is the default unless the `vacuum_index_cleanup` option has been set to false for the table to be vacuumed. Setting this option to false may be useful when it is necessary to make vacuum run as quickly as possible, for example to avoid imminent transaction ID wraparound (see Section 24.1.5). However, if index cleanup is not performed regularly, performance may suffer, because as the table is modified, indexes will accumulate dead tuples and the table itself will accumulate dead line pointers that cannot be removed until index cleanup is completed. This option has no effect for tables that do not have an index and is ignored if the `FULL` option is used.

TRUNCATE

Specifies that `VACUUM` should attempt to truncate off any empty pages at the end of the table and allow the disk space for the truncated pages to be returned to the operating system. This is normally the desired behavior and is the default unless the `vacuum_truncate` option has

been set to false for the table to be vacuumed. Setting this option to false may be useful to avoid `ACCESS EXCLUSIVE` lock on the table that the truncation requires. This option is ignored if the `FULL` option is used.

boolean

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to disable it. The *boolean* value can also be omitted, in which case `TRUE` is assumed.

table_name

The name (optionally schema-qualified) of a specific table or materialized view to vacuum. If the specified table is a partitioned table, all of its leaf partitions are vacuumed.

column_name

The name of a specific column to analyze. Defaults to all columns. If a column list is specified, `ANALYZE` must also be specified.

Outputs

When `VERBOSE` is specified, `VACUUM` emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

Notes

To vacuum a table, one must ordinarily be the table's owner or a superuser. However, database owners are allowed to vacuum all tables in their databases, except shared catalogs. (The restriction for shared catalogs means that a true database-wide `VACUUM` can only be performed by a superuser.) `VACUUM` will skip over any tables that the calling user does not have permission to vacuum.

`VACUUM` cannot be executed inside a transaction block.

For tables with GIN indexes, `VACUUM` (in any form) also completes any pending index insertions, by moving pending index entries to the appropriate places in the main GIN index structure. See Section 66.4.1 for details.

We recommend that active production databases be vacuumed frequently (at least nightly), in order to remove dead rows. After adding or deleting a large number of rows, it might be a good idea to issue a `VACUUM ANALYZE` command for the affected table. This will update the system catalogs with the results of all recent changes, and allow the PostgreSQL query planner to make better choices in planning queries.

The `FULL` option is not recommended for routine use, but might be useful in special cases. An example is when you have deleted or updated most of the rows in a table and would like the table to physically shrink to occupy less disk space and allow faster table scans. `VACUUM FULL` will usually shrink the table more than a plain `VACUUM` would.

`VACUUM` causes a substantial increase in I/O traffic, which might cause poor performance for other active sessions. Therefore, it is sometimes advisable to use the cost-based vacuum delay feature. See Section 19.4.4 for details.

PostgreSQL includes an “autovacuum” facility which can automate routine vacuum maintenance. For more information about automatic and manual vacuuming, see Section 24.1.

Examples

To clean a single table `onek`, analyze it for the optimizer and print a detailed vacuum activity report:

```
VACUUM (VERBOSE, ANALYZE) onek;
```

Compatibility

There is no VACUUM statement in the SQL standard.

See Also

[vacuumdb](#), [Section 19.4.4](#), [Section 24.1.6](#)

VALUES

VALUES — compute a set of rows

Synopsis

```
VALUES ( expression [, ...] ) [, ...]
  [ ORDER BY sort_expression [ ASC | DESC | USING operator ]
  [, ...] ]
  [ LIMIT { count | ALL } ]
  [ OFFSET start [ ROW | ROWS ] ]
  [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
```

Description

VALUES computes a row value or set of row values specified by value expressions. It is most commonly used to generate a “constant table” within a larger command, but it can be used on its own.

When more than one row is specified, all the rows must have the same number of elements. The data types of the resulting table's columns are determined by combining the explicit or inferred types of the expressions appearing in that column, using the same rules as for UNION (see Section 10.5).

Within larger commands, VALUES is syntactically allowed anywhere that SELECT is. Because it is treated like a SELECT by the grammar, it is possible to use the ORDER BY, LIMIT (or equivalently FETCH FIRST), and OFFSET clauses with a VALUES command.

Parameters

expression

A constant or expression to compute and insert at the indicated place in the resulting table (set of rows). In a VALUES list appearing at the top level of an INSERT, an *expression* can be replaced by DEFAULT to indicate that the destination column's default value should be inserted. DEFAULT cannot be used when VALUES appears in other contexts.

sort_expression

An expression or integer constant indicating how to sort the result rows. This expression can refer to the columns of the VALUES result as `column1`, `column2`, etc. For more details see ORDER BY Clause.

operator

A sorting operator. For details see ORDER BY Clause.

count

The maximum number of rows to return. For details see LIMIT Clause.

start

The number of rows to skip before starting to return rows. For details see LIMIT Clause.

Notes

VALUES lists with very large numbers of rows should be avoided, as you might encounter out-of-memory failures or poor performance. VALUES appearing within INSERT is a special case (because

the desired column types are known from the `INSERT`'s target table, and need not be inferred by scanning the `VALUES` list), so it can handle larger lists than are practical in other contexts.

Examples

A bare `VALUES` command:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

This will return a table of two columns and three rows. It's effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

More usually, `VALUES` is used within a larger SQL command. The most common use is in `INSERT`:

```
INSERT INTO films (code, title, did, date_prod, kind)
VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

In the context of `INSERT`, entries of a `VALUES` list can be `DEFAULT` to indicate that the column default should be used here instead of specifying a value:

```
INSERT INTO films VALUES
('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes'),
('T_601', 'Yojimbo', 106, DEFAULT, 'Drama', DEFAULT);
```

`VALUES` can also be used where a sub-`SELECT` might be written, for example in a `FROM` clause:

```
SELECT f.*
FROM films f, (VALUES('MGM', 'Horror'), ('UA', 'Sci-Fi')) AS t
(studio, kind)
WHERE f.studio = t.studio AND f.kind = t.kind;
```

```
UPDATE employees SET salary = salary * v.increase
FROM (VALUES(1, 200000, 1.2), (2, 400000, 1.4)) AS v (depno,
target, increase)
WHERE employees.depno = v.depno AND employees.sales >= v.target;
```

Note that an `AS` clause is required when `VALUES` is used in a `FROM` clause, just as is true for `SELECT`. It is not required that the `AS` clause specify names for all the columns, but it's good practice to do so. (The default column names for `VALUES` are `column1`, `column2`, etc in PostgreSQL, but these names might be different in other database systems.)

When `VALUES` is used in `INSERT`, the values are all automatically coerced to the data type of the corresponding destination column. When it's used in other contexts, it might be necessary to specify the correct data type. If the entries are all quoted literal constants, coercing the first is sufficient to determine the assumed type for all:

```
SELECT * FROM machines
WHERE ip_address IN (VALUES('192.168.0.1'::inet), ('192.168.0.10'),
('192.168.1.43'));
```

Tip

For simple IN tests, it's better to rely on the list-of-scalars form of IN than to write a VALUES query as shown above. The list of scalars method requires less writing and is often more efficient.

Compatibility

VALUES conforms to the SQL standard. LIMIT and OFFSET are PostgreSQL extensions; see also under SELECT.

See Also

INSERT, SELECT

PostgreSQL Client Applications

This part contains reference information for PostgreSQL client applications and utilities. Not all of these commands are of general utility; some might require special privileges. The common feature of these applications is that they can be run on any host, independent of where the database server resides.

When specified on the command line, user and database names have their case preserved — the presence of spaces or special characters might require quoting. Table names and other identifiers do not have their case preserved, except where documented, and might require quoting.

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clusterdb

clusterdb — cluster a PostgreSQL database

Synopsis

```
clusterdb [connection-option...] [ --verbose | -v ] [ --table | -t table ] ... [db-name]
```

```
clusterdb [connection-option...] [ --verbose | -v ] --all | -a
```

Description

clusterdb is a utility for recluster tables in a PostgreSQL database. It finds tables that have previously been clustered, and clusters them again on the same index that was last used. Tables that have never been clustered are not affected.

clusterdb is a wrapper around the SQL command CLUSTER. There is no effective difference between clustering databases via this utility and via other methods for accessing the server.

Options

clusterdb accepts the following command-line arguments:

-a
--all

Cluster all databases.

[-d] *dbname*
[--dbname=] *dbname*

Specifies the name of the database to be clustered. If this is not specified and -a (or --all) is not used, the database name is read from the environment variable PGDATABASE. If that is not set, the user name specified for the connection is used.

-e
--echo

Echo the commands that clusterdb generates and sends to the server.

-q
--quiet

Do not display progress messages.

-t *table*
--table=*table*

Cluster *table* only. Multiple tables can be clustered by writing multiple -t switches.

-v
--verbose

Print detailed information during processing.

`-V`
`--version`

Print the clusterdb version and exit.

`-?`
`--help`

Show help about clusterdb command line arguments, and exit.

clusterdb also accepts the following command-line arguments for connection parameters:

`-h host`
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force clusterdb to prompt for a password before connecting to a database.

This option is never essential, since clusterdb will automatically prompt for a password if the server demands password authentication. However, clusterdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to discover what other databases should be clustered. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

Environment

PGDATABASE
PGHOST
PGPORT
PGUSER

Default connection parameters

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Diagnostics

In case of difficulty, see `CLUSTER` and `psql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Examples

To cluster the database `test`:

```
$ clusterdb test
```

To cluster a single table `foo` in a database named `xyzzzy`:

```
$ clusterdb --table=foo xyzzzy
```

See Also

`CLUSTER`

createdb

createdb — create a new PostgreSQL database

Synopsis

```
createdb [connection-option...] [option...] [dbname [description]]
```

Description

createdb creates a new PostgreSQL database.

Normally, the database user who executes this command becomes the owner of the new database. However, a different owner can be specified via the `-O` option, if the executing user has appropriate privileges.

createdb is a wrapper around the SQL command `CREATE DATABASE`. There is no effective difference between creating databases via this utility and via other methods for accessing the server.

Options

createdb accepts the following command-line arguments:

dbname

Specifies the name of the database to be created. The name must be unique among all PostgreSQL databases in this cluster. The default is to create a database with the same name as the current system user.

description

Specifies a comment to be associated with the newly created database.

`-D tablespace`

`--tablespace=tablespace`

Specifies the default tablespace for the database. (This name is processed as a double-quoted identifier.)

`-e`

`--echo`

Echo the commands that createdb generates and sends to the server.

`-E encoding`

`--encoding=encoding`

Specifies the character encoding scheme to be used in this database. The character sets supported by the PostgreSQL server are described in Section 23.3.1.

`-l locale`

`--locale=locale`

Specifies the locale to be used in this database. This is equivalent to specifying both `--lc-collate` and `--lc-ctype`.

`--lc-collate=locale`

Specifies the `LC_COLLATE` setting to be used in this database.

`--lc-ctype=locale`

Specifies the LC_CTYPE setting to be used in this database.

`-O owner`

`--owner=owner`

Specifies the database user who will own the new database. (This name is processed as a double-quoted identifier.)

`-T template`

`--template=template`

Specifies the template database from which to build this database. (This name is processed as a double-quoted identifier.)

`-V`

`--version`

Print the createdb version and exit.

`-?`

`--help`

Show help about createdb command line arguments, and exit.

The options `-D`, `-l`, `-E`, `-O`, and `-T` correspond to options of the underlying SQL command `CREATE DATABASE`; see there for more information about them.

createdb also accepts the following command-line arguments for connection parameters:

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`

`--port=port`

Specifies the TCP port or the local Unix domain socket file extension on which the server is listening for connections.

`-U username`

`--username=username`

User name to connect as.

`-w`

`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`

`--password`

Force createdb to prompt for a password before connecting to a database.

This option is never essential, since createdb will automatically prompt for a password if the server demands password authentication. However, createdb will waste a connection attempt finding out

that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to when creating the new database. If not specified, the `postgres` database will be used; if that does not exist (or if it is the name of the new database being created), `template1` will be used.

Environment

`PGDATABASE`

If set, the name of the database to create, unless overridden on the command line.

`PGHOST`

`PGPORT`

`PGUSER`

Default connection parameters. `PGUSER` also determines the name of the database to create, if it is not specified on the command line or by `PGDATABASE`.

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Diagnostics

In case of difficulty, see `CREATE DATABASE` and `psql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Examples

To create the database `demo` using the default database server:

```
$ createdb demo
```

To create the database `demo` using the server on host `eden`, port `5000`, using the `template0` template database, here is the command-line command and the underlying SQL command:

```
$ createdb -p 5000 -h eden -T template0 -e demo  
CREATE DATABASE demo TEMPLATE template0;
```

See Also

`dropdb`, `CREATE DATABASE`

createuser

createuser — define a new PostgreSQL user account

Synopsis

```
createuser [connection-option...] [option...] [username]
```

Description

createuser creates a new PostgreSQL user (or more precisely, a role). Only superusers and users with CREATEROLE privilege can create new users, so createuser must be invoked by someone who can connect as a superuser or a user with CREATEROLE privilege.

If you wish to create a new superuser, you must connect as a superuser, not merely with CREATEROLE privilege. Being a superuser implies the ability to bypass all access permission checks within the database, so superuserdom should not be granted lightly.

createuser is a wrapper around the SQL command CREATE ROLE. There is no effective difference between creating users via this utility and via other methods for accessing the server.

Options

createuser accepts the following command-line arguments:

username

Specifies the name of the PostgreSQL user to be created. This name must be different from all existing roles in this PostgreSQL installation.

-c *number*

--connection-limit=*number*

Set a maximum number of connections for the new user. The default is to set no limit.

-d

--createdb

The new user will be allowed to create databases.

-D

--no-createdb

The new user will not be allowed to create databases. This is the default.

-e

--echo

Echo the commands that createuser generates and sends to the server.

-E

--encrypted

This option is obsolete but still accepted for backward compatibility.

-g *role*

--role=*role*

Indicates role to which this role will be added immediately as a new member. Multiple roles to which this role will be added as a member can be specified by writing multiple -g switches.

`-i`
`--inherit`

The new role will automatically inherit privileges of roles it is a member of. This is the default.

`-I`
`--no-inherit`

The new role will not automatically inherit privileges of roles it is a member of.

`--interactive`

Prompt for the user name if none is specified on the command line, and also prompt for whichever of the options `-d/-D`, `-r/-R`, `-s/-S` is not specified on the command line. (This was the default behavior up to PostgreSQL 9.1.)

`-l`
`--login`

The new user will be allowed to log in (that is, the user name can be used as the initial session user identifier). This is the default.

`-L`
`--no-login`

The new user will not be allowed to log in. (A role without login privilege is still useful as a means of managing database permissions.)

`-P`
`--pwprompt`

If given, `createuser` will issue a prompt for the password of the new user. This is not necessary if you do not plan on using password authentication.

`-r`
`--createrole`

The new user will be allowed to create new roles (that is, this user will have `CREATEROLE` privilege).

`-R`
`--no-createrole`

The new user will not be allowed to create new roles. This is the default.

`-s`
`--superuser`

The new user will be a superuser.

`-S`
`--no-superuser`

The new user will not be a superuser. This is the default.

`-V`
`--version`

Print the `createuser` version and exit.

`--replication`

The new user will have the `REPLICATION` privilege, which is described more fully in the documentation for `CREATE ROLE`.

`--no-replication`

The new user will not have the `REPLICATION` privilege, which is described more fully in the documentation for `CREATE ROLE`.

`-?`

`--help`

Show help about createuser command line arguments, and exit.

createuser also accepts the following command-line arguments for connection parameters:

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`

`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`

`--username=username`

User name to connect as (not the user name to create).

`-w`

`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`

`--password`

Force createuser to prompt for a password (for connecting to the server, not for the password of the new user).

This option is never essential, since createuser will automatically prompt for a password if the server demands password authentication. However, createuser will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

`PGHOST`

`PGPORT`

`PGUSER`

Default connection parameters

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 33.14).

Diagnostics

In case of difficulty, see CREATE ROLE and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To create a user `joe` on the default database server:

```
$ createuser joe
```

To create a user `joe` on the default database server with prompting for some additional attributes:

```
$ createuser --interactive joe
Shall the new role be a superuser? (y/n) n
Shall the new role be allowed to create databases? (y/n) n
Shall the new role be allowed to create more new roles? (y/n) n
```

To create the same user `joe` using the server on host `eden`, port `5000`, with attributes explicitly specified, taking a look at the underlying command:

```
$ createuser -h eden -p 5000 -s -D -R -e joe
CREATE ROLE joe NOSUPERUSER NOCREATEDB NOCREATEROLE INHERIT LOGIN;
```

To create the user `joe` as a superuser, and assign a password immediately:

```
$ createuser -P -s -e joe
Enter password for new role: xyzzy
Enter it again: xyzzy
CREATE ROLE joe PASSWORD 'md5b5f5ba1a423792b526f799ae4eb3d59e'
SUPERUSER CREATEDB CREATEROLE INHERIT LOGIN;
```

In the above example, the new password isn't actually echoed when typed, but we show what was typed for clarity. As you see, the password is encrypted before it is sent to the client.

See Also

dropuser, CREATE ROLE

dropdb

dropdb — remove a PostgreSQL database

Synopsis

```
dropdb [connection-option...] [option...] dbname
```

Description

dropdb destroys an existing PostgreSQL database. The user who executes this command must be a database superuser or the owner of the database.

dropdb is a wrapper around the SQL command DROP DATABASE. There is no effective difference between dropping databases via this utility and via other methods for accessing the server.

Options

dropdb accepts the following command-line arguments:

dbname

Specifies the name of the database to be removed.

-e
--echo

Echo the commands that dropdb generates and sends to the server.

-i
--interactive

Issues a verification prompt before doing anything destructive.

-V
--version

Print the dropdb version and exit.

--if-exists

Do not throw an error if the database does not exist. A notice is issued in this case.

-?
--help

Show help about dropdb command line arguments, and exit.

dropdb also accepts the following command-line arguments for connection parameters:

-h *host*
--host=*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force dropdb to prompt for a password before connecting to a database.

This option is never essential, since dropdb will automatically prompt for a password if the server demands password authentication. However, dropdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to in order to drop the target database. If not specified, the `postgres` database will be used; if that does not exist (or is the database being dropped), `template1` will be used.

Environment

PGHOST
PGPORT
PGUSER

Default connection parameters

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 33.14).

Diagnostics

In case of difficulty, see `DROP DATABASE` and `psql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To destroy the database `demo` on the default database server:

```
$ dropdb demo
```

To destroy the database `demo` using the server on host `eden`, port `5000`, with verification and a peek at the underlying command:

```
$ dropdb -p 5000 -h eden -i -e demo
Database "demo" will be permanently deleted.
Are you sure? (y/n) y
DROP DATABASE demo;
```

See Also

`createdb`, `DROP DATABASE`

dropuser

dropuser — remove a PostgreSQL user account

Synopsis

```
dropuser [connection-option...] [option...] [username]
```

Description

dropuser removes an existing PostgreSQL user. Only superusers and users with the CREATEROLE privilege can remove PostgreSQL users. (To remove a superuser, you must yourself be a superuser.)

dropuser is a wrapper around the SQL command DROP ROLE. There is no effective difference between dropping users via this utility and via other methods for accessing the server.

Options

dropuser accepts the following command-line arguments:

username

Specifies the name of the PostgreSQL user to be removed. You will be prompted for a name if none is specified on the command line and the `-i/--interactive` option is used.

`-e`
`--echo`

Echo the commands that dropuser generates and sends to the server.

`-i`
`--interactive`

Prompt for confirmation before actually removing the user, and prompt for the user name if none is specified on the command line.

`-V`
`--version`

Print the dropuser version and exit.

`--if-exists`

Do not throw an error if the user does not exist. A notice is issued in this case.

`-?`
`--help`

Show help about dropuser command line arguments, and exit.

dropuser also accepts the following command-line arguments for connection parameters:

`-h host`
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`
`--username=username`

User name to connect as (not the user name to drop).

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force dropuser to prompt for a password before connecting to a database.

This option is never essential, since dropuser will automatically prompt for a password if the server demands password authentication. However, dropuser will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

PGHOST
PGPORT
PGUSER

Default connection parameters

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 33.14).

Diagnostics

In case of difficulty, see `DROP ROLE` and `psql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To remove user `joe` from the default database server:

```
$ dropuser joe
```

To remove user `joe` using the server on host `eden`, port `5000`, with verification and a peek at the underlying command:

```
$ dropuser -p 5000 -h eden -i -e joe
Role "joe" will be permanently removed.
Are you sure? (y/n) y
DROP ROLE joe;
```

See Also

createuser, DROP ROLE

ecpg

ecpg — embedded SQL C preprocessor

Synopsis

ecpg [*option...*] *file...*

Description

ecpg is the embedded SQL preprocessor for C programs. It converts C programs with embedded SQL statements to normal C code by replacing the SQL invocations with special function calls. The output files can then be processed with any C compiler tool chain.

ecpg will convert each input file given on the command line to the corresponding C output file. Input files preferably have the extension `.pgc`. The extension will be replaced by `.c` to determine the output file name. The output file name can also be overridden using the `-o` option.

This reference page does not describe the embedded SQL language. See Chapter 35 for more information on that topic.

Options

ecpg accepts the following command-line arguments:

`-c`

Automatically generate certain C code from SQL code. Currently, this works for EXEC SQL TYPE.

`-C mode`

Set a compatibility mode. *mode* can be INFORMIX, INFORMIX_SE, or ORACLE.

`-D symbol`

Define a C preprocessor symbol.

`-i`

Parse system include files as well.

`-I directory`

Specify an additional include path, used to find files included via EXEC SQL INCLUDE. Defaults are `.` (current directory), `/usr/local/include`, the PostgreSQL include directory which is defined at compile time (default: `/usr/local/pgsql/include`), and `/usr/include`, in that order.

`-o filename`

Specifies that ecpg should write all its output to the given *filename*.

`-r option`

Selects run-time behavior. *Option* can be one of the following:

no_indicator

Do not use indicators but instead use special values to represent null values. Historically there have been databases using this approach.

prepare

Prepare all statements before using them. Libecpg will keep a cache of prepared statements and reuse a statement if it gets executed again. If the cache runs full, libecpg will free the least used statement.

questionmarks

Allow question mark as placeholder for compatibility reasons. This used to be the default long ago.

-t

Turn on autocommit of transactions. In this mode, each SQL command is automatically committed unless it is inside an explicit transaction block. In the default mode, commands are committed only when EXEC SQL COMMIT is issued.

-v

Print additional information including the version and the "include" path.

--version

Print the ecpg version and exit.

-?**--help**

Show help about ecpg command line arguments, and exit.

Notes

When compiling the preprocessed C code files, the compiler needs to be able to find the ECPG header files in the PostgreSQL include directory. Therefore, you might have to use the `-I` option when invoking the compiler (e.g., `-I/usr/local/pgsql/include`).

Programs using C code with embedded SQL have to be linked against the `libecpg` library, for example using the linker options `-L/usr/local/pgsql/lib -lecpg`.

The value of either of these directories that is appropriate for the installation can be found out using `pg_config`.

Examples

If you have an embedded SQL C source file named `prog1.pgc`, you can create an executable program using the following sequence of commands:

```
ecpg prog1.pgc
cc -I/usr/local/pgsql/include -c prog1.c
cc -o prog1 prog1.o -L/usr/local/pgsql/lib -lecpg
```

pg_basebackup

pg_basebackup — take a base backup of a PostgreSQL cluster

Synopsis

```
pg_basebackup [option...]
```

Description

pg_basebackup is used to take base backups of a running PostgreSQL database cluster. These are taken without affecting other clients to the database, and can be used both for point-in-time recovery (see Section 25.3) and as the starting point for a log shipping or streaming replication standby servers (see Section 26.2).

pg_basebackup makes a binary copy of the database cluster files, while making sure the system is put in and out of backup mode automatically. Backups are always taken of the entire database cluster; it is not possible to back up individual databases or database objects. For individual database backups, a tool such as pg_dump must be used.

The backup is made over a regular PostgreSQL connection, and uses the replication protocol. The connection must be made with a superuser or a user having REPLICATION permissions (see Section 21.2), and pg_hba.conf must explicitly permit the replication connection. The server must also be configured with max_wal_senders set high enough to leave at least one session available for the backup and one for WAL streaming (if used).

There can be multiple pg_basebackups running at the same time, but it is better from a performance point of view to take only one backup, and copy the result.

pg_basebackup can make a base backup from not only the master but also the standby. To take a backup from the standby, set up the standby so that it can accept replication connections (that is, set max_wal_senders and hot_standby, and configure host-based authentication). You will also need to enable full_page_writes on the master.

Note that there are some limitations in an online backup from the standby:

- The backup history file is not created in the database cluster backed up.
- If you are using `-X none`, there is no guarantee that all WAL files required for the backup are archived at the end of backup.
- If the standby is promoted to the master during online backup, the backup fails.
- All WAL records required for the backup must contain sufficient full-page writes, which requires you to enable `full_page_writes` on the master and not to use a tool like `pg_compresslog` as `archive_command` to remove full-page writes from WAL files.

Options

The following command-line options control the location and format of the output.

```
-D directory  
--pgdata=directory
```

Directory to write the output to. pg_basebackup will create the directory and any parent directories if necessary. The directory may already exist, but it is an error if the directory already exists and is not empty.

When the backup is in tar mode, and the directory is specified as - (dash), the tar file will be written to `stdout`.

This option is required.

`-F format`
`--format=format`

Selects the format for the output. *format* can be one of the following:

`p`
`plain`

Write the output as plain files, with the same layout as the current data directory and tablespaces. When the cluster has no additional tablespaces, the whole database will be placed in the target directory. If the cluster contains additional tablespaces, the main data directory will be placed in the target directory, but all other tablespaces will be placed in the same absolute path as they have on the server.

This is the default format.

`t`
`tar`

Write the output as tar files in the target directory. The main data directory will be written to a file named `base.tar`, and all other tablespaces will be named after the tablespace OID.

If the value - (dash) is specified as target directory, the tar contents will be written to standard output, suitable for piping to for example `gzip`. This is only possible if the cluster has no additional tablespaces and WAL streaming is not used.

`-r rate`
`--max-rate=rate`

The maximum transfer rate of data transferred from the server. Values are in kilobytes per second. Use a suffix of `M` to indicate megabytes per second. A suffix of `k` is also accepted, and has no effect. Valid values are between 32 kilobytes per second and 1024 megabytes per second.

The purpose is to limit the impact of `pg_basebackup` on the running server.

This option always affects transfer of the data directory. Transfer of WAL files is only affected if the collection method is `fetch`.

`-R`
`--write-recovery-conf`

Create `standby.signal` and append connection settings to `postgresql.auto.conf` in the output directory (or into the base archive file when using tar format) to ease setting up a standby server. The `postgresql.auto.conf` file will record the connection settings and, if specified, the replication slot that `pg_basebackup` is using, so that the streaming replication will use the same settings later on.

`-T olddir=newdir`
`--tablespace-mapping=olddir=newdir`

Relocate the tablespace in directory *olddir* to *newdir* during the backup. To be effective, *olddir* must exactly match the path specification of the tablespace as it is currently defined. (But it is not an error if there is no tablespace in *olddir* contained in the backup.) Both *olddir* and *newdir* must be absolute paths. If a path happens to contain a = sign, escape it with a backslash. This option can be specified multiple times for multiple tablespaces. See examples below.

If a tablespace is relocated in this way, the symbolic links inside the main data directory are updated to point to the new location. So the new data directory is ready to be used for a new server instance with all tablespaces in the updated locations.

`--waldir=waldir`

Specifies the location for the write-ahead log directory. *waldir* must be an absolute path. The write-ahead log directory can only be specified when the backup is in plain mode.

`-X method`

`--wal-method=method`

Includes the required write-ahead log files (WAL files) in the backup. This will include all write-ahead logs generated during the backup. Unless the method *none* is specified, it is possible to start a postmaster directly in the extracted directory without the need to consult the log archive, thus making this a completely standalone backup.

The following methods for collecting the write-ahead logs are supported:

n

none

Don't include write-ahead log in the backup.

f

fetch

The write-ahead log files are collected at the end of the backup. Therefore, it is necessary for the *wal_keep_segments* parameter to be set high enough that the log is not removed before the end of the backup. If the log has been rotated when it's time to transfer it, the backup will fail and be unusable.

When tar format mode is used, the write-ahead log files will be written to the *base.tar* file.

s

stream

Stream the write-ahead log while the backup is created. This will open a second connection to the server and start streaming the write-ahead log in parallel while running the backup. Therefore, it will use up two connections configured by the *max_wal_senders* parameter. As long as the client can keep up with write-ahead log received, using this mode requires no extra write-ahead logs to be saved on the master.

When tar format mode is used, the write-ahead log files will be written to a separate file named *pg_wal.tar* (if the server is a version earlier than 10, the file will be named *pg_xlog.tar*).

This value is the default.

`-z`

`--gzip`

Enables gzip compression of tar file output, with the default compression level. Compression is only available when using the tar format, and the suffix *.gz* will automatically be added to all tar filenames.

`-Z level`

`--compress=level`

Enables gzip compression of tar file output, and specifies the compression level (0 through 9, 0 being no compression and 9 being best compression). Compression is only available when using the tar format, and the suffix *.gz* will automatically be added to all tar filenames.

The following command-line options control the generation of the backup and the running of the program.

`-c fast/spread`
`--checkpoint=fast/spread`

Sets checkpoint mode to fast (immediate) or spread (default) (see Section 25.3.3).

`-C`
`--create-slot`

This option causes creation of a replication slot named by the `--slot` option before starting the backup. An error is raised if the slot already exists.

`-l label`
`--label=label`

Sets the label for the backup. If none is specified, a default value of “pg_basebackup base backup” will be used.

`-n`
`--no-clean`

By default, when `pg_basebackup` aborts with an error, it removes any directories it might have created before discovering that it cannot finish the job (for example, data directory and write-ahead log directory). This option inhibits tidying-up and is thus useful for debugging.

Note that tablespace directories are not cleaned up either way.

`-N`
`--no-sync`

By default, `pg_basebackup` will wait for all files to be written safely to disk. This option causes `pg_basebackup` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the base backup corrupt. Generally, this option is useful for testing but should not be used when creating a production installation.

`-P`
`--progress`

Enables progress reporting. Turning this on will deliver an approximate progress report during the backup. Since the database may change during the backup, this is only an approximation and may not end at exactly 100%. In particular, when WAL log is included in the backup, the total amount of data cannot be estimated in advance, and in this case the estimated target size will increase once it passes the total estimate without WAL.

When this is enabled, the backup will start by enumerating the size of the entire database, and then go back and send the actual contents. This may make the backup take slightly longer, and in particular it will take longer before the first data is sent.

`-S slotname`
`--slot=slotname`

This option can only be used together with `-X stream`. It causes the WAL streaming to use the specified replication slot. If the base backup is intended to be used as a streaming replication standby using replication slots, it should then use the same replication slot name in `primary_slot_name`. That way, it is ensured that the server does not remove any necessary WAL data in the time between the end of the base backup and the start of streaming replication.

The specified replication slot has to exist unless the option `-C` is also used.

If this option is not specified and the server supports temporary replication slots (version 10 and later), then a temporary replication slot is automatically used for WAL streaming.

`-v`
`--verbose`

Enables verbose mode. Will output some extra steps during startup and shutdown, as well as show the exact file name that is currently being processed if progress reporting is also enabled.

`--no-slot`

This option prevents the creation of a temporary replication slot during the backup even if it's supported by the server.

Temporary replication slots are created by default if no slot name is given with the option `-S` when using log streaming.

The main purpose of this option is to allow taking a base backup when the server is out of free replication slots. Using replication slots is almost always preferred, because it prevents needed WAL from being removed by the server during the backup.

`--no-verify-checksums`

Disables verification of checksums, if they are enabled on the server the base backup is taken from.

By default, checksums are verified and checksum failures will result in a non-zero exit status. However, the base backup will not be removed in such a case, as if the `--no-clean` option had been used. Checksum verifications failures will also be reported in the `pg_stat_database` view.

The following command-line options control the database connection parameters.

`-d connstr`
`--dbname=connstr`

Specifies parameters used to connect to the server, as a connection string. See Section 33.1.1 for more information.

The option is called `--dbname` for consistency with other client applications, but because `pg_basebackup` doesn't connect to any particular database in the cluster, database name in the connection string will be ignored.

`-h host`
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-s interval`
`--status-interval=interval`

Specifies the number of seconds between status packets sent back to the server. This allows for easier monitoring of the progress from server. A value of zero disables the periodic status updates completely, although an update will still be sent when requested by the server, to avoid timeout disconnect. The default value is 10 seconds.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force `pg_basebackup` to prompt for a password before connecting to a database.

This option is never essential, since `pg_basebackup` will automatically prompt for a password if the server demands password authentication. However, `pg_basebackup` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Other options are also available:

`-V`
`--version`

Print the `pg_basebackup` version and exit.

`-?`
`--help`

Show help about `pg_basebackup` command line arguments, and exit.

Environment

This utility, like most other PostgreSQL utilities, uses the environment variables supported by `libpq` (see Section 33.14).

The environment variable `PG_COLOR` specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

At the beginning of the backup, a checkpoint needs to be written on the server the backup is taken from. Especially if the option `--checkpoint=fast` is not used, this can take some time during which `pg_basebackup` will appear to be idle.

The backup will include all files in the data directory and tablespaces, including the configuration files and any additional files placed in the directory by third parties, except certain temporary files managed by PostgreSQL. But only regular files and directories are copied, except that symbolic links used for tablespaces are preserved. Symbolic links pointing to certain directories known to PostgreSQL are copied as empty directories. Other symbolic links and special device files are skipped. See Section 52.4 for the precise details.

Tablespaces will in plain format by default be backed up to the same path they have on the server, unless the option `--tablespace-mapping` is used. Without this option, running a plain format base backup on the same host as the server will not work if tablespaces are in use, because the backup would have to be written to the same directory locations as the original tablespaces.

When tar format mode is used, it is the user's responsibility to unpack each tar file before starting the PostgreSQL server. If there are additional tablespaces, the tar files for them need to be unpacked in the correct locations. In this case the symbolic links for those tablespaces will be created by the server according to the contents of the `tablespace_map` file that is included in the `base.tar` file.

`pg_basebackup` works with servers of the same or an older major version, down to 9.1. However, WAL streaming mode (`-X stream`) only works with server version 9.3 and later, and tar format mode (`--format=tar`) of the current version only works with server version 9.5 or later.

`pg_basebackup` will preserve group permissions in both the `plain` and `tar` formats if group permissions are enabled on the source cluster.

Examples

To create a base backup of the server at `mydbserver` and store it in the local directory `/usr/local/pgsql/data`:

```
$ pg_basebackup -h mydbserver -D /usr/local/pgsql/data
```

To create a backup of the local server with one compressed tar file for each tablespace, and store it in the directory `backup`, showing a progress report while running:

```
$ pg_basebackup -D backup -Ft -z -P
```

To create a backup of a single-tablespace local database and compress this with `bzip2`:

```
$ pg_basebackup -D - -Ft -X fetch | bzip2 > backup.tar.bz2
```

(This command will fail if there are multiple tablespaces in the database.)

To create a backup of a local database where the tablespace in `/opt/ts` is relocated to `./backup/ts`:

```
$ pg_basebackup -D backup/data -T /opt/ts=$(pwd)/backup/ts
```

See Also

`pg_dump`

pgbench

pgbench — run a benchmark test on PostgreSQL

Synopsis

```
pgbench -i [option...] [dbname]
```

```
pgbench [option...] [dbname]
```

Description

pgbench is a simple program for running benchmark tests on PostgreSQL. It runs the same sequence of SQL commands over and over, possibly in multiple concurrent database sessions, and then calculates the average transaction rate (transactions per second). By default, pgbench tests a scenario that is loosely based on TPC-B, involving five `SELECT`, `UPDATE`, and `INSERT` commands per transaction. However, it is easy to test other cases by writing your own transaction script files.

Typical output from pgbench looks like:

```
transaction type: <builtin: TPC-B (sort of)>
scaling factor: 10
query mode: simple
number of clients: 10
number of threads: 1
number of transactions per client: 1000
number of transactions actually processed: 10000/10000
tps = 85.184871 (including connections establishing)
tps = 85.296346 (excluding connections establishing)
```

The first six lines report some of the most important parameter settings. The next line reports the number of transactions completed and intended (the latter being just the product of number of clients and number of transactions per client); these will be equal unless the run failed before completion. (In `-T` mode, only the actual number of transactions is printed.) The last two lines report the number of transactions per second, figured with and without counting the time to start database sessions.

The default TPC-B-like transaction test requires specific tables to be set up beforehand. pgbench should be invoked with the `-i` (initialize) option to create and populate these tables. (When you are testing a custom script, you don't need this step, but will instead need to do whatever setup your test needs.) Initialization looks like:

```
pgbench -i [ other-options ] dbname
```

where *dbname* is the name of the already-created database to test in. (You may also need `-h`, `-p`, and/or `-U` options to specify how to connect to the database server.)

Caution

pgbench `-i` creates four tables `pgbench_accounts`, `pgbench_branches`, `pgbench_history`, and `pgbench_tellers`, destroying any existing tables of these names. Be very careful to use another database if you have tables having these names!

At the default “scale factor” of 1, the tables initially contain this many rows:

table	# of rows
-----	-----
pgbench_branches	1
pgbench_tellers	10
pgbench_accounts	100000
pgbench_history	0

You can (and, for most purposes, probably should) increase the number of rows by using the `-s` (scale factor) option. The `-F` (fillfactor) option might also be used at this point.

Once you have done the necessary setup, you can run your benchmark with a command that doesn't include `-i`, that is

```
pgbench [ options ] dbname
```

In nearly all cases, you'll need some options to make a useful test. The most important options are `-c` (number of clients), `-t` (number of transactions), `-T` (time limit), and `-f` (specify a custom script file). See below for a full list.

Options

The following is divided into three subsections. Different options are used during database initialization and while running benchmarks, but some options are useful in both cases.

Initialization Options

pgbench accepts the following command-line initialization arguments:

```
-i  
--initialize
```

Required to invoke initialization mode.

```
-I init_steps  
--init-steps=init_steps
```

Perform just a selected set of the normal initialization steps. *init_steps* specifies the initialization steps to be performed, using one character per step. Each step is invoked in the specified order. The default is `dtgvp`. The available steps are:

d (Drop)

Drop any existing pgbench tables.

t (create Tables)

Create the tables used by the standard pgbench scenario, namely `pgbench_accounts`, `pgbench_branches`, `pgbench_history`, and `pgbench_tellers`.

g (Generate data)

Generate data and load it into the standard tables, replacing any data already present.

v (Vacuum)

Invoke `VACUUM` on the standard tables.

`p` (create Primary keys)

Create primary key indexes on the standard tables.

`f` (create Foreign keys)

Create foreign key constraints between the standard tables. (Note that this step is not performed by default.)

`-F fillfactor`

`--fillfactor=fillfactor`

Create the `pgbench_accounts`, `pgbench_tellers` and `pgbench_branches` tables with the given fillfactor. Default is 100.

`-n`

`--no-vacuum`

Perform no vacuuming during initialization. (This option suppresses the `v` initialization step, even if it was specified in `-I`.)

`-q`

`--quiet`

Switch logging to quiet mode, producing only one progress message per 5 seconds. The default logging prints one message each 100000 rows, which often outputs many lines per second (especially on good hardware).

`-s scale_factor`

`--scale=scale_factor`

Multiply the number of rows generated by the scale factor. For example, `-s 100` will create 10,000,000 rows in the `pgbench_accounts` table. Default is 1. When the scale is 20,000 or larger, the columns used to hold account identifiers (`aid` columns) will switch to using larger integers (`bigint`), in order to be big enough to hold the range of account identifiers.

`--foreign-keys`

Create foreign key constraints between the standard tables. (This option adds the `f` step to the initialization step sequence, if it is not already present.)

`--index-tablespace=index_tablespace`

Create indexes in the specified tablespace, rather than the default tablespace.

`--tablespace=tablespace`

Create tables in the specified tablespace, rather than the default tablespace.

`--unlogged-tables`

Create all tables as unlogged tables, rather than permanent tables.

Benchmarking Options

pgbench accepts the following command-line benchmarking arguments:

`-b scriptname[@weight]`

`--builtin=scriptname[@weight]`

Add the specified built-in script to the list of executed scripts. An optional integer weight after `@` allows to adjust the probability of drawing the script. If not specified, it is set to 1. Available built-

in scripts are: `tpcb-like`, `simple-update` and `select-only`. Unambiguous prefixes of built-in names are accepted. With special name `list`, show the list of built-in scripts and exit immediately.

`-c clients`
`--client=clients`

Number of clients simulated, that is, number of concurrent database sessions. Default is 1.

`-C`
`--connect`

Establish a new connection for each transaction, rather than doing it just once per client session. This is useful to measure the connection overhead.

`-d`
`--debug`

Print debugging output.

`-D varname=value`
`--define=varname=value`

Define a variable for use by a custom script (see below). Multiple `-D` options are allowed.

`-f filename[@weight]`
`--file=filename[@weight]`

Add a transaction script read from `filename` to the list of executed scripts. An optional integer weight after `@` allows to adjust the probability of drawing the test. See below for details.

`-j threads`
`--jobs=threads`

Number of worker threads within `pgbench`. Using more than one thread can be helpful on multi-CPU machines. Clients are distributed as evenly as possible among available threads. Default is 1.

`-l`
`--log`

Write information about each transaction to a log file. See below for details.

`-L limit`
`--latency-limit=limit`

Transactions that last more than `limit` milliseconds are counted and reported separately, as *late*.

When throttling is used (`--rate=...`), transactions that lag behind schedule by more than `limit` ms, and thus have no hope of meeting the latency limit, are not sent to the server at all. They are counted and reported separately as *skipped*.

`-M querymode`
`--protocol=querymode`

Protocol to use for submitting queries to the server:

- `simple`: use simple query protocol.
- `extended`: use extended query protocol.
- `prepared`: use extended query protocol with prepared statements.

In the `prepared` mode, `pgbench` reuses the parse analysis result starting from the second query iteration, so `pgbench` runs faster than in other modes.

The default is simple query protocol. (See Chapter 52 for more information.)

`-n`
`--no-vacuum`

Perform no vacuuming before running the test. This option is *necessary* if you are running a custom test scenario that does not include the standard tables `pgbench_accounts`, `pgbench_branches`, `pgbench_history`, and `pgbench_tellers`.

`-N`
`--skip-some-updates`

Run built-in simple-update script. Shorthand for `-b simple-update`.

`-P sec`
`--progress=sec`

Show progress report every `sec` seconds. The report includes the time since the beginning of the run, the TPS since the last report, and the transaction latency average and standard deviation since the last report. Under throttling (`-R`), the latency is computed with respect to the transaction scheduled start time, not the actual transaction beginning time, thus it also includes the average schedule lag time.

`-r`
`--report-latencies`

Report the average per-statement latency (execution time from the perspective of the client) of each command after the benchmark finishes. See below for details.

`-R rate`
`--rate=rate`

Execute transactions targeting the specified rate instead of running as fast as possible (the default). The rate is given in transactions per second. If the targeted rate is above the maximum possible rate, the rate limit won't impact the results.

The rate is targeted by starting transactions along a Poisson-distributed schedule time line. The expected start time schedule moves forward based on when the client first started, not when the previous transaction ended. That approach means that when transactions go past their original scheduled end time, it is possible for later ones to catch up again.

When throttling is active, the transaction latency reported at the end of the run is calculated from the scheduled start times, so it includes the time each transaction had to wait for the previous transaction to finish. The wait time is called the schedule lag time, and its average and maximum are also reported separately. The transaction latency with respect to the actual transaction start time, i.e. the time spent executing the transaction in the database, can be computed by subtracting the schedule lag time from the reported latency.

If `--latency-limit` is used together with `--rate`, a transaction can lag behind so much that it is already over the latency limit when the previous transaction ends, because the latency is calculated from the scheduled start time. Such transactions are not sent to the server, but are skipped altogether and counted separately.

A high schedule lag time is an indication that the system cannot process transactions at the specified rate, with the chosen number of clients and threads. When the average transaction execution time is longer than the scheduled interval between each transaction, each successive transaction will fall further behind, and the schedule lag time will keep increasing the longer the test run is. When that happens, you will have to reduce the specified transaction rate.

`-s scale_factor`
`--scale=scale_factor`

Report the specified scale factor in pgbench's output. With the built-in tests, this is not necessary; the correct scale factor will be detected by counting the number of rows in the `pgbench_branches` table. However, when testing only custom benchmarks (`-f` option), the scale factor will be reported as 1 unless this option is used.

`-S`
`--select-only`

Run built-in select-only script. Shorthand for `-b select-only`.

`-t transactions`
`--transactions=transactions`

Number of transactions each client runs. Default is 10.

`-T seconds`
`--time=seconds`

Run the test for this many seconds, rather than a fixed number of transactions per client. `-t` and `-T` are mutually exclusive.

`-v`
`--vacuum-all`

Vacuum all four standard tables before running the test. With neither `-n` nor `-v`, pgbench will vacuum the `pgbench_tellers` and `pgbench_branches` tables, and will truncate `pgbench_history`.

`--aggregate-interval=seconds`

Length of aggregation interval (in seconds). May be used only with `-l` option. With this option, the log contains per-interval summary data, as described below.

`--log-prefix=prefix`

Set the filename prefix for the log files created by `--log`. The default is `pgbench_log`.

`--progress-timestamp`

When showing progress (option `-P`), use a timestamp (Unix epoch) instead of the number of seconds since the beginning of the run. The unit is in seconds, with millisecond precision after the dot. This helps compare logs generated by various tools.

`--random-seed=SEED`

Set random generator seed. Seeds the system random number generator, which then produces a sequence of initial generator states, one for each thread. Values for `SEED` may be: `time` (the default, the seed is based on the current time), `rand` (use a strong random source, failing if none is available), or an unsigned decimal integer value. The random generator is invoked explicitly from a pgbench script (`random. . .` functions) or implicitly (for instance option `--rate` uses it to schedule transactions). When explicitly set, the value used for seeding is shown on the terminal. Any value allowed for `SEED` may also be provided through the environment variable `PGBENCH_RANDOM_SEED`. To ensure that the provided seed impacts all possible uses, put this option first or use the environment variable.

Setting the seed explicitly allows to reproduce a pgbench run exactly, as far as random numbers are concerned. As the random state is managed per thread, this means the exact same pgbench run for an identical invocation if there is one client per thread and there are no external or data dependencies. From a statistical viewpoint reproducing runs exactly is a bad idea because it can

hide the performance variability or improve performance unduly, e.g. by hitting the same pages as a previous run. However, it may also be of great help for debugging, for instance re-running a tricky case which leads to an error. Use wisely.

`--sampling-rate=rate`

Sampling rate, used when writing data into the log, to reduce the amount of log generated. If this option is given, only the specified fraction of transactions are logged. 1.0 means all transactions will be logged, 0.05 means only 5% of the transactions will be logged.

Remember to take the sampling rate into account when processing the log file. For example, when computing TPS values, you need to multiply the numbers accordingly (e.g. with 0.01 sample rate, you'll only get 1/100 of the actual TPS).

Common Options

pgbench accepts the following command-line common arguments:

`-h hostname`

`--host=hostname`

The database server's host name

`-p port`

`--port=port`

The database server's port number

`-U login`

`--username=login`

The user name to connect as

`-v`

`--version`

Print the pgbench version and exit.

`-?`

`--help`

Show help about pgbench command line arguments, and exit.

Exit Status

A successful run will exit with status 0. Exit status 1 indicates static problems such as invalid command-line options. Errors during the run such as database errors or problems in the script will result in exit status 2. In the latter case, pgbench will print partial results.

Notes

What Is the “Transaction” Actually Performed in pgbench?

pgbench executes test scripts chosen randomly from a specified list. They include built-in scripts with `-b` and user-provided custom scripts with `-f`. Each script may be given a relative weight specified after a `@` so as to change its drawing probability. The default weight is 1. Scripts with a weight of 0 are ignored.

The default built-in transaction script (also invoked with `-b tpcb-like`) issues seven commands per transaction over randomly chosen `aid`, `tid`, `bid` and `delta`. The scenario is inspired by the TPC-B benchmark, but is not actually TPC-B, hence the name.

```

1. BEGIN;
2. UPDATE pgbench_accounts SET abalance = abalance + :delta WHERE aid
   = :aid;
3. SELECT abalance FROM pgbench_accounts WHERE aid = :aid;
4. UPDATE pgbench_tellers SET tbalance = tbalance + :delta WHERE tid
   = :tid;
5. UPDATE pgbench_branches SET bbalance = bbalance + :delta WHERE bid
   = :bid;
6. INSERT INTO pgbench_history (tid, bid, aid, delta, mtime) VALUES
   (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);
7. END;

```

If you select the `simple-update` built-in (also `-N`), steps 4 and 5 aren't included in the transaction. This will avoid update contention on these tables, but it makes the test case even less like TPC-B.

If you select the `select-only` built-in (also `-S`), only the `SELECT` is issued.

Custom Scripts

pgbench has support for running custom benchmark scenarios by replacing the default transaction script (described above) with a transaction script read from a file (`-f` option). In this case a “transaction” counts as one execution of a script file.

A script file contains one or more SQL commands terminated by semicolons. Empty lines and lines beginning with `--` are ignored. Script files can also contain “meta commands”, which are interpreted by pgbench itself, as described below.

Note

Before PostgreSQL 9.6, SQL commands in script files were terminated by newlines, and so they could not be continued across lines. Now a semicolon is *required* to separate consecutive SQL commands (though a SQL command does not need one if it is followed by a meta command). If you need to create a script file that works with both old and new versions of pgbench, be sure to write each SQL command on a single line ending with a semicolon.

There is a simple variable-substitution facility for script files. Variable names must consist of letters (including non-Latin letters), digits, and underscores. Variables can be set by the command-line `-D` option, explained above, or by the meta commands explained below. In addition to any variables preset by `-D` command-line options, there are a few variables that are preset automatically, listed in Table 257. A value specified for these variables using `-D` takes precedence over the automatic presets. Once set, a variable's value can be inserted into a SQL command by writing `:variablename`. When running more than one client session, each session has its own set of variables. pgbench supports up to 255 variable uses in one statement.

Table 257. Automatic Variables

Variable	Description
<code>client_id</code>	unique number identifying the client session (starts from zero)
<code>default_seed</code>	seed used in hash functions by default

Variable	Description
random_seed	random generator seed (unless overwritten with -D)
scale	current scale factor

Script file meta commands begin with a backslash (\) and normally extend to the end of the line, although they can be continued to additional lines by writing backslash-return. Arguments to a meta command are separated by white space. These meta commands are supported:

```
\gset [prefix]
```

This command may be used to end SQL queries, taking the place of the terminating semicolon (;).

When this command is used, the preceding SQL query is expected to return one row, the columns of which are stored into variables named after column names, and prefixed with *prefix* if provided.

The following example puts the final account balance from the first query into variable *abalance*, and fills variables *p_two* and *p_three* with integers from the third query. The result of the second query is discarded.

```
UPDATE pgbench_accounts
  SET abalance = abalance + :delta
  WHERE aid = :aid
  RETURNING abalance \gset
-- compound of two queries
SELECT 1 \;
SELECT 2 AS two, 3 AS three \gset p_
```

```
\if expression
\elif expression
\else
\endif
```

This group of commands implements nestable conditional blocks, similarly to `psql`'s `\if expression`. Conditional expressions are identical to those with `\set`, with non-zero values interpreted as true.

```
\set varname expression
```

Sets variable *varname* to a value calculated from *expression*. The expression may contain the NULL constant, Boolean constants TRUE and FALSE, integer constants such as 5432, double constants such as 3.14159, references to variables `:variablename`, operators with their usual SQL precedence and associativity, function calls, SQL CASE generic conditional expressions and parentheses.

Functions and most operators return NULL on NULL input.

For conditional purposes, non zero numerical values are TRUE, zero numerical values and NULL are FALSE.

Too large or small integer and double constants, as well as integer arithmetic operators (+, -, * and /) raise errors on overflows.

When no final ELSE clause is provided to a CASE, the default value is NULL.

Examples:

```
\set ntellers 10 * :scale
\set aid (1021 * random(1, 100000 * :scale)) % \
        (100000 * :scale) + 1
\set divx CASE WHEN :x <> 0 THEN :y/:x ELSE NULL END
```

```
\sleep number [ us | ms | s ]
```

Causes script execution to sleep for the specified duration in microseconds (*us*), milliseconds (*ms*) or seconds (*s*). If the unit is omitted then seconds are the default. *number* can be either an integer constant or a *:variablename* reference to a variable having an integer value.

Example:

```
\sleep 10 ms
```

```
\setshell varname command [ argument ... ]
```

Sets variable *varname* to the result of the shell command *command* with the given *argument*(s). The command must return an integer value through its standard output.

command and each *argument* can be either a text constant or a *:variablename* reference to a variable. If you want to use an *argument* starting with a colon, write an additional colon at the beginning of *argument*.

Example:

```
\setshell variable_to_be_assigned command
        literal_argument :variable ::literal_starting_with_colon
```

```
\shell command [ argument ... ]
```

Same as `\setshell`, but the result of the command is discarded.

Example:

```
\shell command
        literal_argument :variable ::literal_starting_with_colon
```

Built-in Operators

The arithmetic, bitwise, comparison and logical operators listed in Table 258 are built into pgbench and may be used in expressions appearing in `\set`.

Table 258. pgbench Operators by Increasing Precedence

Operator	Description	Example	Result
OR	logical or	5 or 0	TRUE
AND	logical and	3 and 0	FALSE
NOT	logical not	not false	TRUE
IS [NOT] (NULL TRUE FALSE)	value tests	1 is null	FALSE
ISNULL NOTNULL	null tests	1 notnull	TRUE
=	is equal	5 = 4	FALSE
<>	is not equal	5 <> 4	TRUE
!=	is not equal	5 != 5	FALSE

Operator	Description	Example	Result
<	lower than	5 < 4	FALSE
<=	lower or equal	5 <= 4	FALSE
>	greater than	5 > 4	TRUE
>=	greater or equal	5 >= 4	TRUE
	integer bitwise OR	1 2	3
#	integer bitwise XOR	1 # 3	2
&	integer bitwise AND	1 & 3	1
~	integer bitwise NOT	~ 1	-2
<<	integer bitwise shift left	1 << 2	4
>>	integer bitwise shift right	8 >> 2	2
+	addition	5 + 4	9
-	subtraction	3 - 2.0	1.0
*	multiplication	5 * 4	20
/	division (integer truncates the results)	5 / 3	1
%	modulo	3 % 2	1
-	opposite	- 2.0	-2.0

Built-In Functions

The functions listed in Table 259 are built into pgbench and may be used in expressions appearing in `\set`.

Table 259. pgbench Functions

Function	Return Type	Description	Example	Result
<code>abs(a)</code>	same as <i>a</i>	absolute value	<code>abs(-17)</code>	17
<code>debug(a)</code>	same as <i>a</i>	print <i>a</i> to stderr, and return <i>a</i>	<code>debug(5432.1)</code>	5432.1
<code>double(i)</code>	double	cast to double	<code>double(5432)</code>	5432.0
<code>exp(x)</code>	double	exponential	<code>exp(1.0)</code>	2.718281828459045
<code>greatest(a [, ...])</code>	double if any <i>a</i> is double, else integer	largest value among arguments	<code>greatest(5, 4, 3, 2)</code>	5
<code>hash(a [, seed])</code>	integer	alias for <code>hash_murmur2()</code>	<code>hash(10, 5432)</code>	-5817877081768721676
<code>hash_fnv1a(a [, seed])</code>	integer	FNV-1a hash ¹	<code>hash_fnv1a(10, 5432)</code>	-7793829335365542153
<code>hash_murmur2(a [, seed])</code>	integer	MurmurHash2 hash ²	<code>hash_murmur2(10, 5432)</code>	-5817877081768721676
<code>int(x)</code>	integer	cast to int	<code>int(5.4 + 93.8)</code>	93

¹ https://en.wikipedia.org/wiki/Fowler%E2%80%93Noll%E2%80%93Vo_hash_function

² <https://en.wikipedia.org/wiki/MurmurHash>

Function	Return Type	Description	Example	Result
<code>least(a [, ...])</code>	double if any <i>a</i> is double, else integer	smallest value among arguments	<code>least(5, 4, 3, 2.1)</code>	2.1
<code>ln(x)</code>	double	natural logarithm	<code>ln(2.718281828459045)</code>	
<code>mod(i, j)</code>	integer	modulo	<code>mod(54, 32)</code>	22
<code>pi()</code>	double	value of the constant PI	<code>pi()</code>	3.14159265358979323846
<code>pow(x, y), power(x, y)</code>	double	exponentiation	<code>pow(2.0, 10), power(2.0, 10)</code>	1024.0
<code>random(lb, ub)</code>	integer	uniformly-distributed random integer in [lb, ub]	<code>random(1, 10)</code>	an integer between 1 and 10
<code>random_exponential(lb, ub, parameter)</code>	integer	exponentially-distributed random integer in [lb, ub], see below	<code>random_exponential(1, 10, 3.0)</code>	an integer between 1 and 10
<code>random_gaussian(lb, ub, parameter)</code>	integer	Gaussian-distributed random integer in [lb, ub], see below	<code>random_gaussian(1, 10, 2.5)</code>	an integer between 1 and 10
<code>random_zipfian(lb, ub, parameter)</code>	integer	Zipfian-distributed random integer in [lb, ub], see below	<code>random_zipfian(1, 10, 1.5)</code>	an integer between 1 and 10
<code>sqrt(x)</code>	double	square root	<code>sqrt(2.0)</code>	1.414213562

The `random` function generates values using a uniform distribution, that is all the values are drawn within the specified range with equal probability. The `random_exponential`, `random_gaussian` and `random_zipfian` functions require an additional double parameter which determines the precise shape of the distribution.

- For an exponential distribution, *parameter* controls the distribution by truncating a quickly-decreasing exponential distribution at *parameter*, and then projecting onto integers between the bounds. To be precise, with

$$f(x) = \exp(-\text{parameter} * (x - \text{min}) / (\text{max} - \text{min} + 1)) / (1 - \exp(-\text{parameter}))$$

Then value *i* between *min* and *max* inclusive is drawn with probability: $f(i) - f(i + 1)$.

Intuitively, the larger the *parameter*, the more frequently values close to *min* are accessed, and the less frequently values close to *max* are accessed. The closer to 0 *parameter* is, the flatter (more uniform) the access distribution. A crude approximation of the distribution is that the most frequent 1% values in the range, close to *min*, are drawn *parameter*% of the time. The *parameter* value must be strictly positive.

- For a Gaussian distribution, the interval is mapped onto a standard normal distribution (the classical bell-shaped Gaussian curve) truncated at `-parameter` on the left and `+parameter` on the right. Values in the middle of the interval are more likely to be drawn. To be precise, if $\text{PHI}(x)$ is the cumulative distribution function of the standard normal distribution, with mean μ defined as $(\text{max} + \text{min}) / 2.0$, with

$$f(x) = \frac{\text{PHI}(2.0 * \text{parameter} * (x - \mu) / (\text{max} - \text{min} + 1))}{(2.0 * \text{PHI}(\text{parameter}) - 1)}$$

then value i between min and max inclusive is drawn with probability: $f(i + 0.5) - f(i - 0.5)$. Intuitively, the larger the *parameter*, the more frequently values close to the middle of the interval are drawn, and the less frequently values close to the *min* and *max* bounds. About 67% of values are drawn from the middle $1.0 / \text{parameter}$, that is a relative $0.5 / \text{parameter}$ around the mean, and 95% in the middle $2.0 / \text{parameter}$, that is a relative $1.0 / \text{parameter}$ around the mean; for instance, if *parameter* is 4.0, 67% of values are drawn from the middle quarter ($1.0 / 4.0$) of the interval (i.e. from $3.0 / 8.0$ to $5.0 / 8.0$) and 95% from the middle half ($2.0 / 4.0$) of the interval (second and third quartiles). The minimum allowed *parameter* value is 2.0.

- `random_zipfian` generates a bounded Zipfian distribution. *parameter* defines how skewed the distribution is. The larger the *parameter*, the more frequently values closer to the beginning of the interval are drawn. The distribution is such that, assuming the range starts from 1, the ratio of the probability of drawing k versus drawing $k+1$ is $((k+1)/k)**\text{parameter}$. For example, `random_zipfian(1, ..., 2.5)` produces the value 1 about $(2/1)**2.5 = 5.66$ times more frequently than 2, which itself is produced $(3/2)**2.5 = 2.76$ times more frequently than 3, and so on.

pgbench's implementation is based on "Non-Uniform Random Variate Generation", Luc Devroye, p. 550-551, Springer 1986. Due to limitations of that algorithm, the *parameter* value is restricted to the range [1.001, 1000].

Hash functions `hash`, `hash_murmur2` and `hash_fnv1a` accept an input value and an optional seed parameter. In case the seed isn't provided the value of `:default_seed` is used, which is initialized randomly unless set by the command-line `-D` option. Hash functions can be used to scatter the distribution of random functions such as `random_zipfian` or `random_exponential`. For instance, the following pgbench script simulates possible real world workload typical for social media and blogging platforms where few accounts generate excessive load:

```
\set r random_zipfian(0, 100000000, 1.07)
\set k abs(hash(:r)) % 1000000
```

In some cases several distinct distributions are needed which don't correlate with each other and this is when implicit seed parameter comes in handy:

```
\set k1 abs(hash(:r, :default_seed + 123)) % 1000000
\set k2 abs(hash(:r, :default_seed + 321)) % 1000000
```

As an example, the full definition of the built-in TPC-B-like transaction is:

```
\set aid random(1, 100000 * :scale)
\set bid random(1, 1 * :scale)
\set tid random(1, 10 * :scale)
\set delta random(-5000, 5000)
BEGIN;
UPDATE pgbench_accounts SET abalance = abalance + :delta WHERE aid
= :aid;
SELECT abalance FROM pgbench_accounts WHERE aid = :aid;
UPDATE pgbench_tellers SET tbalance = tbalance + :delta WHERE tid
= :tid;
UPDATE pgbench_branches SET bbalance = bbalance + :delta WHERE bid
= :bid;
INSERT INTO pgbench_history (tid, bid, aid, delta, mtime) VALUES
(:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);
```

END ;

This script allows each iteration of the transaction to reference different, randomly-chosen rows. (This example also shows why it's important for each client session to have its own variables — otherwise they'd not be independently touching different rows.)

Per-Transaction Logging

With the `-l` option (but without the `--aggregate-interval` option), `pgbench` writes information about each transaction to a log file. The log file will be named `prefix.nnn`, where `prefix` defaults to `pgbench_log`, and `nnn` is the PID of the `pgbench` process. The prefix can be changed by using the `--log-prefix` option. If the `-j` option is 2 or higher, so that there are multiple worker threads, each will have its own log file. The first worker will use the same name for its log file as in the standard single worker case. The additional log files for the other workers will be named `prefix.nnn.mmm`, where `mmm` is a sequential number for each worker starting with 1.

The format of the log is:

```
client_id transaction_no time script_no time_epoch time_us
[ schedule_lag ]
```

where `client_id` indicates which client session ran the transaction, `transaction_no` counts how many transactions have been run by that session, `time` is the total elapsed transaction time in microseconds, `script_no` identifies which script file was used (useful when multiple scripts were specified with `-f` or `-b`), and `time_epoch/time_us` are a Unix-epoch time stamp and an offset in microseconds (suitable for creating an ISO 8601 time stamp with fractional seconds) showing when the transaction completed. The `schedule_lag` field is the difference between the transaction's scheduled start time, and the time it actually started, in microseconds. It is only present when the `--rate` option is used. When both `--rate` and `--latency-limit` are used, the `time` for a skipped transaction will be reported as `skipped`.

Here is a snippet of a log file generated in a single-client run:

```
0 199 2241 0 1175850568 995598
0 200 2465 0 1175850568 998079
0 201 2513 0 1175850569 608
0 202 2038 0 1175850569 2663
```

Another example with `--rate=100` and `--latency-limit=5` (note the additional `schedule_lag` column):

```
0 81 4621 0 1412881037 912698 3005
0 82 6173 0 1412881037 914578 4304
0 83 skipped 0 1412881037 914578 5217
0 83 skipped 0 1412881037 914578 5099
0 83 4722 0 1412881037 916203 3108
0 84 4142 0 1412881037 918023 2333
0 85 2465 0 1412881037 919759 740
```

In this example, transaction 82 was late, because its latency (6.173 ms) was over the 5 ms limit. The next two transactions were skipped, because they were already late before they were even started.

When running a long test on hardware that can handle a lot of transactions, the log files can become very large. The `--sampling-rate` option can be used to log only a random sample of transactions.

Aggregated Logging

With the `--aggregate-interval` option, a different format is used for the log files:

```
interval_start num_transactions sum_latency sum_latency_2 min_latency max_latency
[ sum_lag sum_lag_2 min_lag max_lag [ skipped ] ]
```

where *interval_start* is the start of the interval (as a Unix epoch time stamp), *num_transactions* is the number of transactions within the interval, *sum_latency* is the sum of the transaction latencies within the interval, *sum_latency_2* is the sum of squares of the transaction latencies within the interval, *min_latency* is the minimum latency within the interval, and *max_latency* is the maximum latency within the interval. The next fields, *sum_lag*, *sum_lag_2*, *min_lag*, and *max_lag*, are only present if the `--rate` option is used. They provide statistics about the time each transaction had to wait for the previous one to finish, i.e. the difference between each transaction's scheduled start time and the time it actually started. The very last field, *skipped*, is only present if the `--latency-limit` option is used, too. It counts the number of transactions skipped because they would have started too late. Each transaction is counted in the interval when it was committed.

Here is some example output:

```
1345828501 5601 1542744 483552416 61 2573
1345828503 7884 1979812 565806736 60 1479
1345828505 7208 1979422 567277552 59 1391
1345828507 7685 1980268 569784714 60 1398
1345828509 7073 1979779 573489941 236 1411
```

Notice that while the plain (unaggregated) log file shows which script was used for each transaction, the aggregated log does not. Therefore if you need per-script data, you need to aggregate the data on your own.

Per-Statement Latencies

With the `-r` option, pgbench collects the elapsed transaction time of each statement executed by every client. It then reports an average of those values, referred to as the latency for each statement, after the benchmark has finished.

For the default script, the output will look similar to this:

```
starting vacuum...end.
transaction type: <builtin: TPC-B (sort of)>
scaling factor: 1
query mode: simple
number of clients: 10
number of threads: 1
number of transactions per client: 1000
number of transactions actually processed: 10000/10000
latency average = 15.844 ms
latency stddev = 2.715 ms
tps = 618.764555 (including connections establishing)
tps = 622.977698 (excluding connections establishing)
statement latencies in milliseconds:
    0.002  \set aid random(1, 100000 * :scale)
    0.005  \set bid random(1, 1 * :scale)
    0.002  \set tid random(1, 10 * :scale)
    0.001  \set delta random(-5000, 5000)
    0.326  BEGIN;
    0.603  UPDATE pgbench_accounts SET abalance = abalance
+ :delta WHERE aid = :aid;
    0.454  SELECT abalance FROM pgbench_accounts WHERE aid
= :aid;
```

```
5.528 UPDATE pgbench_tellers SET tbalance = tbalance
+ :delta WHERE tid = :tid;
7.335 UPDATE pgbench_branches SET bbalance = bbalance
+ :delta WHERE bid = :bid;
0.371 INSERT INTO pgbench_history (tid, bid, aid, delta,
mtime) VALUES (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);
1.212 END;
```

If multiple script files are specified, the averages are reported separately for each script file.

Note that collecting the additional timing information needed for per-statement latency computation adds some overhead. This will slow average execution speed and lower the computed TPS. The amount of slowdown varies significantly depending on platform and hardware. Comparing average TPS values with and without latency reporting enabled is a good way to measure if the timing overhead is significant.

Good Practices

It is very easy to use pgbench to produce completely meaningless numbers. Here are some guidelines to help you get useful results.

In the first place, *never* believe any test that runs for only a few seconds. Use the `-t` or `-T` option to make the run last at least a few minutes, so as to average out noise. In some cases you could need hours to get numbers that are reproducible. It's a good idea to try the test run a few times, to find out if your numbers are reproducible or not.

For the default TPC-B-like test scenario, the initialization scale factor (`-s`) should be at least as large as the largest number of clients you intend to test (`-c`); else you'll mostly be measuring update contention. There are only `-s` rows in the `pgbench_branches` table, and every transaction wants to update one of them, so `-c` values in excess of `-s` will undoubtedly result in lots of transactions blocked waiting for other transactions.

The default test scenario is also quite sensitive to how long it's been since the tables were initialized: accumulation of dead rows and dead space in the tables changes the results. To understand the results you must keep track of the total number of updates and when vacuuming happens. If autovacuum is enabled it can result in unpredictable changes in measured performance.

A limitation of pgbench is that it can itself become the bottleneck when trying to test a large number of client sessions. This can be alleviated by running pgbench on a different machine from the database server, although low network latency will be essential. It might even be useful to run several pgbench instances concurrently, on several client machines, against the same database server.

Security

If untrusted users have access to a database that has not adopted a secure schema usage pattern, do not run pgbench in that database. pgbench uses unqualified names and does not manipulate the search path.

pg_config

pg_config — retrieve information about the installed version of PostgreSQL

Synopsis

```
pg_config [option...]
```

Description

The `pg_config` utility prints configuration parameters of the currently installed version of PostgreSQL. It is intended, for example, to be used by software packages that want to interface to PostgreSQL to facilitate finding the required header files and libraries.

Options

To use `pg_config`, supply one or more of the following options:

`--bindir`

Print the location of user executables. Use this, for example, to find the `psql` program. This is normally also the location where the `pg_config` program resides.

`--docdir`

Print the location of documentation files.

`--htmldir`

Print the location of HTML documentation files.

`--includedir`

Print the location of C header files of the client interfaces.

`--pkgincludedir`

Print the location of other C header files.

`--includedir-server`

Print the location of C header files for server programming.

`--libdir`

Print the location of object code libraries.

`--pkglibdir`

Print the location of dynamically loadable modules, or where the server would search for them. (Other architecture-dependent data files might also be installed in this directory.)

`--localedir`

Print the location of locale support files. (This will be an empty string if locale support was not configured when PostgreSQL was built.)

--mandir

Print the location of manual pages.

--sharedir

Print the location of architecture-independent support files.

--sysconfdir

Print the location of system-wide configuration files.

--pgxs

Print the location of extension makefiles.

--configure

Print the options that were given to the `configure` script when PostgreSQL was configured for building. This can be used to reproduce the identical configuration, or to find out with what options a binary package was built. (Note however that binary packages often contain vendor-specific custom patches.) See also the examples below.

--cc

Print the value of the `CC` variable that was used for building PostgreSQL. This shows the C compiler used.

--cppflags

Print the value of the `CPPFLAGS` variable that was used for building PostgreSQL. This shows C compiler switches needed at preprocessing time (typically, `-I` switches).

--cflags

Print the value of the `CFLAGS` variable that was used for building PostgreSQL. This shows C compiler switches.

--cflags_sl

Print the value of the `CFLAGS_SL` variable that was used for building PostgreSQL. This shows extra C compiler switches used for building shared libraries.

--ldflags

Print the value of the `LDFLAGS` variable that was used for building PostgreSQL. This shows linker switches.

--ldflags_ex

Print the value of the `LDFLAGS_EX` variable that was used for building PostgreSQL. This shows linker switches used for building executables only.

--ldflags_sl

Print the value of the `LDFLAGS_SL` variable that was used for building PostgreSQL. This shows linker switches used for building shared libraries only.

--libs

Print the value of the `LIBS` variable that was used for building PostgreSQL. This normally contains `-l` switches for external libraries linked into PostgreSQL.

`--version`

Print the version of PostgreSQL.

`-?`

`--help`

Show help about `pg_config` command line arguments, and exit.

If more than one option is given, the information is printed in that order, one item per line. If no options are given, all available information is printed, with labels.

Notes

The options `--docdir`, `--pkgincludedir`, `--localedir`, `--mandir`, `--sharedir`, `--sysconfdir`, `--cc`, `--cppflags`, `--cflags`, `--cflags_sl`, `--ldflags`, `--ldflags_sl`, and `--libs` were added in PostgreSQL 8.1. The option `--htmldir` was added in PostgreSQL 8.4. The option `--ldflags_ex` was added in PostgreSQL 9.0.

Example

To reproduce the build configuration of the current PostgreSQL installation, run the following command:

```
eval `./configure `pg_config --configure`
```

The output of `pg_config --configure` contains shell quotation marks so arguments with spaces are represented correctly. Therefore, using `eval` is required for proper results.

pg_dump

`pg_dump` — extract a PostgreSQL database into a script file or other archive file

Synopsis

```
pg_dump [connection-option...] [option...] [dbname]
```

Description

`pg_dump` is a utility for backing up a PostgreSQL database. It makes consistent backups even if the database is being used concurrently. `pg_dump` does not block other users accessing the database (readers or writers).

`pg_dump` only dumps a single database. To back up an entire cluster, or to back up global objects that are common to all databases in a cluster (such as roles and tablespaces), use `pg_dumpall`.

Dumps can be output in script or archive file formats. Script dumps are plain-text files containing the SQL commands required to reconstruct the database to the state it was in at the time it was saved. To restore from such a script, feed it to `psql`. Script files can be used to reconstruct the database even on other machines and other architectures; with some modifications, even on other SQL database products.

The alternative archive file formats must be used with `pg_restore` to rebuild the database. They allow `pg_restore` to be selective about what is restored, or even to reorder the items prior to being restored. The archive file formats are designed to be portable across architectures.

When used with one of the archive file formats and combined with `pg_restore`, `pg_dump` provides a flexible archival and transfer mechanism. `pg_dump` can be used to backup an entire database, then `pg_restore` can be used to examine the archive and/or select which parts of the database are to be restored. The most flexible output file formats are the “custom” format (`-Fc`) and the “directory” format (`-Fd`). They allow for selection and reordering of all archived items, support parallel restoration, and are compressed by default. The “directory” format is the only format that supports parallel dumps.

While running `pg_dump`, one should examine the output for any warnings (printed on standard error), especially in light of the limitations listed below.

Options

The following command-line options control the content and format of the output.

dbname

Specifies the name of the database to be dumped. If this is not specified, the environment variable `PGDATABASE` is used. If that is not set, the user name specified for the connection is used.

`-a`
`--data-only`

Dump only the data, not the schema (data definitions). Table data, large objects, and sequence values are dumped.

This option is similar to, but for historical reasons not identical to, specifying `--section=data`.

`-b`
`--blobs`

Include large objects in the dump. This is the default behavior except when `--schema`, `--table`, or `--schema-only` is specified. The `-b` switch is therefore only useful to add large objects to dumps where a specific schema or table has been requested. Note that blobs are considered data and therefore will be included when `--data-only` is used, but not when `--schema-only` is.

`-B`
`--no-blobs`

Exclude large objects in the dump.

When both `-b` and `-B` are given, the behavior is to output large objects, when data is being dumped, see the `-b` documentation.

`-c`
`--clean`

Output commands to clean (drop) database objects prior to outputting the commands for creating them. (Unless `--if-exists` is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`-C`
`--create`

Begin the output with a command to create the database itself and reconnect to the created database. (With a script of this form, it doesn't matter which database in the destination installation you connect to before running the script.) If `--clean` is also specified, the script drops and recreates the target database before reconnecting to it.

With `--create`, the output also includes the database's comment if any, and any configuration variable settings that are specific to this database, that is, any `ALTER DATABASE ... SET ...` and `ALTER ROLE ... IN DATABASE ... SET ...` commands that mention this database. Access privileges for the database itself are also dumped, unless `--no-acl` is specified.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`-E encoding`
`--encoding=encoding`

Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `PGCLIENTENCODING` environment variable to the desired dump encoding.)

`-f file`
`--file=file`

Send output to the specified file. This parameter can be omitted for file based output formats, in which case the standard output is used. It must be given for the directory output format however, where it specifies the target directory instead of a file. In this case the directory is created by `pg_dump` and must not exist before.

`-F format`
`--format=format`

Selects the format of the output. *format* can be one of the following:

p
plain

Output a plain-text SQL script file (the default).

c
custom

Output a custom-format archive suitable for input into `pg_restore`. Together with the directory output format, this is the most flexible output format in that it allows manual selection and reordering of archived items during restore. This format is also compressed by default.

d
directory

Output a directory-format archive suitable for input into `pg_restore`. This will create a directory with one file for each table and blob being dumped, plus a so-called Table of Contents file describing the dumped objects in a machine-readable format that `pg_restore` can read. A directory format archive can be manipulated with standard Unix tools; for example, files in an uncompressed archive can be compressed with the `gzip` tool. This format is compressed by default and also supports parallel dumps.

t
tar

Output a `tar`-format archive suitable for input into `pg_restore`. The `tar` format is compatible with the directory format: extracting a `tar`-format archive produces a valid directory-format archive. However, the `tar` format does not support compression. Also, when using `tar` format the relative order of table data items cannot be changed during restore.

-j *njobs*
--jobs=*njobs*

Run the dump in parallel by dumping *njobs* tables simultaneously. This option reduces the time of the dump but it also increases the load on the database server. You can only use this option with the directory output format because this is the only output format where multiple processes can write their data at the same time.

`pg_dump` will open *njobs* + 1 connections to the database, so make sure your `max_connections` setting is high enough to accommodate all connections.

Requesting exclusive locks on database objects while running a parallel dump could cause the dump to fail. The reason is that the `pg_dump` master process requests shared locks on the objects that the worker processes are going to dump later in order to make sure that nobody deletes them and makes them go away while the dump is running. If another client then requests an exclusive lock on a table, that lock will not be granted but will be queued waiting for the shared lock of the master process to be released. Consequently any other access to the table will not be granted either and will queue after the exclusive lock request. This includes the worker process trying to dump the table. Without any precautions this would be a classic deadlock situation. To detect this conflict, the `pg_dump` worker process requests another shared lock using the `NOWAIT` option. If the worker process is not granted this shared lock, somebody else must have requested an exclusive lock in the meantime and there is no way to continue with the dump, so `pg_dump` has no choice but to abort the dump.

For a consistent backup, the database server needs to support synchronized snapshots, a feature that was introduced in PostgreSQL 9.2 for primary servers and 10 for standbys. With this feature, database clients can ensure they see the same data set even though they use different connections. `pg_dump -j` uses multiple database connections; it connects to the database once with the master process and once again for each worker job. Without the synchronized snapshot feature, the different worker jobs wouldn't be guaranteed to see the same data in each connection, which could lead to an inconsistent backup.

If you want to run a parallel dump of a pre-9.2 server, you need to make sure that the database content doesn't change from between the time the master connects to the database until the last worker job has connected to the database. The easiest way to do this is to halt any data modifying processes (DDL and DML) accessing the database before starting the backup. You also need to specify the `--no-synchronized-snapshots` parameter when running `pg_dump -j` against a pre-9.2 PostgreSQL server.

`-n pattern`
`--schema=pattern`

Dump only schemas matching *pattern*; this selects both the schema itself, and all its contained objects. When this option is not specified, all non-system schemas in the target database will be dumped. Multiple schemas can be selected by writing multiple `-n` switches. The *pattern* parameter is interpreted as a pattern according to the same rules used by `psql's \d` commands (see Patterns), so multiple schemas can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards; see Examples.

Note

When `-n` is specified, `pg_dump` makes no attempt to dump any other database objects that the selected schema(s) might depend upon. Therefore, there is no guarantee that the results of a specific-schema dump can be successfully restored by themselves into a clean database.

Note

Non-schema objects such as blobs are not dumped when `-n` is specified. You can add blobs back to the dump with the `--blobs` switch.

`-N pattern`
`--exclude-schema=pattern`

Do not dump any schemas matching *pattern*. The pattern is interpreted according to the same rules as for `-n`. `-N` can be given more than once to exclude schemas matching any of several patterns.

When both `-n` and `-N` are given, the behavior is to dump just the schemas that match at least one `-n` switch but no `-N` switches. If `-N` appears without `-n`, then schemas matching `-N` are excluded from what is otherwise a normal dump.

`-O`
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, `pg_dump` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`-R`
`--no-reconnect`

This option is obsolete but still accepted for backwards compatibility.

`-s`
`--schema-only`

Dump only the object definitions (schema), not data.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data --section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word “schema” in a different meaning.)

To exclude table data for only a subset of tables in the database, see `--exclude-table-data`.

`-S username`
`--superuser=username`

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

`-t pattern`
`--table=pattern`

Dump only tables with names matching *pattern*. For this purpose, “table” includes views, materialized views, sequences, and foreign tables. Multiple tables can be selected by writing multiple `-t` switches. The *pattern* parameter is interpreted as a pattern according to the same rules used by `psql`'s `\d` commands (see Patterns), so multiple tables can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards; see Examples.

The `-n` and `-N` switches have no effect when `-t` is used, because tables selected by `-t` will be dumped regardless of those switches, and non-table objects will not be dumped.

Note

When `-t` is specified, `pg_dump` makes no attempt to dump any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that the results of a specific-table dump can be successfully restored by themselves into a clean database.

Note

The behavior of the `-t` switch is not entirely upward compatible with pre-8.2 PostgreSQL versions. Formerly, writing `-t tab` would dump all tables named `tab`, but now it just dumps whichever one is visible in your default search path. To get the old behavior you can write `-t '* . tab'`. Also, you must write something like `-t sch . tab` to select a table in a particular schema, rather than the old locution of `-n sch -t tab`.

`-T pattern`
`--exclude-table=pattern`

Do not dump any tables matching *pattern*. The pattern is interpreted according to the same rules as for `-t`. `-T` can be given more than once to exclude tables matching any of several patterns.

When both `-t` and `-T` are given, the behavior is to dump just the tables that match at least one `-t` switch but no `-T` switches. If `-T` appears without `-t`, then tables matching `-T` are excluded from what is otherwise a normal dump.

`-v`
`--verbose`

Specifies verbose mode. This will cause `pg_dump` to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

`-V`
`--version`

Print the `pg_dump` version and exit.

`-x`
`--no-privileges`
`--no-acl`

Prevent dumping of access privileges (grant/revoke commands).

`-Z 0..9`
`--compress=0..9`

Specify the compression level to use. Zero means no compression. For the custom archive format, this specifies compression of individual table-data segments, and the default is to compress at a moderate level. For plain text output, setting a nonzero compression level causes the entire output file to be compressed, as though it had been fed through `gzip`; but the default is not to compress. The tar archive format currently does not support compression at all.

`--binary-upgrade`

This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

`--column-inserts`
`--attribute-inserts`

Dump data as `INSERT` commands with explicit column names (`INSERT INTO table (column, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases. Any error during reloading will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

`--disable-dollar-quoting`

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

`--disable-triggers`

This option is relevant only when creating a data-only dump. It instructs `pg_dump` to include commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data reload.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

--enable-row-security

This option is relevant only when dumping the contents of a table which has row security. By default, `pg_dump` will set `row_security` to off, to ensure that all data is dumped from the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `pg_dump` to set `row_security` to on instead, allowing the user to dump the parts of the contents of the table that they have access to.

Note that if you use this option currently, you probably also want the dump be in `INSERT` format, as the `COPY FROM` during restore does not support row security.

--exclude-table-data=*pattern*

Do not dump data for any tables matching *pattern*. The pattern is interpreted according to the same rules as for `-t`. `--exclude-table-data` can be given more than once to exclude tables matching any of several patterns. This option is useful when you need the definition of a particular table even though you do not need the data in it.

To exclude data for all tables in the database, see `--schema-only`.

--extra-float-digits=*ndigits*

Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

--if-exists

Use conditional commands (i.e. add an `IF EXISTS` clause) when cleaning database objects. This option is not valid unless `--clean` is also specified.

--inserts

Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases. Any error during reloading will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safe against column order changes, though even slower.

--load-via-partition-root

When dumping data for a table partition, make the `COPY` or `INSERT` statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when reloading data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type text and the two systems have different definitions of the collation used to sort the partitioning column.

It is best not to use parallelism when restoring from an archive made with this option, because `pg_restore` will not know exactly which partition(s) a given archive data item will load data into. This could result in inefficiency due to lock conflicts between parallel jobs, or perhaps even reload failures due to foreign key constraints being set up before all the relevant data is loaded.

--lock-wait-timeout=*timeout*

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead fail if unable to lock a table within the specified *timeout*. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. (Allowed formats vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions.)

`--no-comments`

Do not dump comments.

`--no-publications`

Do not dump publications.

`--no-security-labels`

Do not dump security labels.

`--no-subscriptions`

Do not dump subscriptions.

`--no-sync`

By default, `pg_dump` will wait for all files to be written safely to disk. This option causes `pg_dump` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the dump corrupt. Generally, this option is useful for testing but should not be used when dumping data from production installation.

`--no-synchronized-snapshots`

This option allows running `pg_dump -j` against a pre-9.2 server, see the documentation of the `-j` parameter for more details.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`--no-unlogged-table-data`

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data. Data in unlogged tables is always excluded when dumping from a standby server.

`--on-conflict-do-nothing`

Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts`, `--column-inserts` or `--rows-per-insert` is also specified.

`--quote-all-identifiers`

Force quoting of all identifiers. This option is recommended when dumping a database from a server whose PostgreSQL major version is different from `pg_dump`'s, or when the output is intended to be loaded into a server of a different major version. By default, `pg_dump` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

`--rows-per-insert=nrows`

Dump data as `INSERT` commands (rather than `COPY`). Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during reloading will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

`--section=sectionname`

Only dump the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to dump all sections.

The data section contains actual table data, large-object contents, and sequence values. Post-data items include definitions of indexes, triggers, rules, and constraints other than validated check constraints. Pre-data items include all other data definition items.

`--serializable-deferrable`

Use a `serializable` transaction for the dump, to ensure that the snapshot used is consistent with later database states; but do this by waiting for a point in the transaction stream at which no anomalies can be present, so that there isn't a risk of the dump failing or causing other transactions to roll back with a `serialization_failure`. See Chapter 13 for more information about transaction isolation and concurrency control.

This option is not beneficial for a dump which is intended only for disaster recovery. It could be useful for a dump used to load a copy of the database for reporting or other read-only load sharing while the original database continues to be updated. Without it the dump may reflect a state which is not consistent with any serial execution of the transactions eventually committed. For example, if batch processing techniques are used, a batch may show as closed in the dump without all of the items which are in the batch appearing.

This option will make no difference if there are no read-write transactions active when `pg_dump` is started. If read-write transactions are active, the start of the dump may be delayed for an indeterminate length of time. Once running, performance with or without the switch is the same.

`--snapshot=snapshotname`

Use the specified synchronized snapshot when making a dump of the database (see Table 9.87 for more details).

This option is useful when needing to synchronize the dump with a logical replication slot (see Chapter 48) or with a concurrent session.

In the case of a parallel dump, the snapshot name defined by this option is used rather than taking a new snapshot.

`--strict-names`

Require that each schema (`-n/--schema`) and table (`-t/--table`) qualifier match at least one schema/table in the database to be dumped. Note that if none of the schema/table qualifiers find matches, `pg_dump` will generate an error even without `--strict-names`.

This option has no effect on `-N/--exclude-schema`, `-T/--exclude-table`, or `--exclude-table-data`. An exclude pattern failing to match any objects is not considered an error.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly. Also, a dump using `SET SESSION AUTHORIZATION` will certainly require superuser privileges to restore correctly, whereas `ALTER OWNER` requires lesser privileges.

`-?`

`--help`

Show help about `pg_dump` command line arguments, and exit.

The following command-line options control the database connection parameters.

`-d dbname`
`--dbname=dbname`

Specifies the name of the database to connect to. This is equivalent to specifying *dbname* as the first non-option argument on the command line.

If this parameter contains an = sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a *conninfo* string. See Section 33.1 for more information.

`-h host`
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force `pg_dump` to prompt for a password before connecting to a database.

This option is never essential, since `pg_dump` will automatically prompt for a password if the server demands password authentication. However, `pg_dump` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--role=rolename`

Specifies a role name to be used to create the dump. This option causes `pg_dump` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `pg_dump`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

Environment

`PGDATABASE`
`PGHOST`
`PGOPTIONS`
`PGPORT`
`PGUSER`

Default connection parameters.

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Diagnostics

`pg_dump` internally executes `SELECT` statements. If you have problems running `pg_dump`, make sure you are able to select information from the database using, for example, `psql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

The database activity of `pg_dump` is normally collected by the statistics collector. If this is undesirable, you can set parameter `track_counts` to `false` via `PGOPTIONS` or the `ALTER USER` command.

Notes

If your database cluster has any local additions to the `template1` database, be careful to restore the output of `pg_dump` into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

When a data-only dump is chosen and the option `--disable-triggers` is used, `pg_dump` emits commands to disable triggers on user tables before inserting the data, and then commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.

The dump file produced by `pg_dump` does not contain the statistics used by the optimizer to make query planning decisions. Therefore, it is wise to run `ANALYZE` after restoring from a dump file to ensure optimal performance; see Section 24.1.3 and Section 24.1.6 for more information.

Because `pg_dump` is used to transfer data to newer versions of PostgreSQL, the output of `pg_dump` can be expected to load into PostgreSQL server versions newer than `pg_dump`'s version. `pg_dump` can also dump from PostgreSQL servers older than its own version. (Currently, servers back to version 8.0 are supported.) However, `pg_dump` cannot dump from PostgreSQL servers newer than its own major version; it will refuse to even try, rather than risk making an invalid dump. Also, it is not guaranteed that `pg_dump`'s output can be loaded into a server of an older major version — not even if the dump was taken from a server of that version. Loading a dump file into an older server may require manual editing of the dump file to remove syntax not understood by the older server. Use of the `--quote-all-identifiers` option is recommended in cross-version cases, as it can prevent problems arising from varying reserved-word lists in different PostgreSQL versions.

When dumping logical replication subscriptions, `pg_dump` will generate `CREATE SUBSCRIPTION` commands that use the `connect = false` option, so that restoring the subscription does not make remote connections for creating a replication slot or for initial table copy. That way, the dump can be restored without requiring network access to the remote servers. It is then up to the user to reactivate the subscriptions in a suitable way. If the involved hosts have changed, the connection information might have to be changed. It might also be appropriate to truncate the target tables before initiating a new full table copy.

Examples

To dump a database called `mydb` into a SQL-script file:

```
$ pg_dump mydb > db.sql
```

To reload such a script into a (freshly created) database named newdb:

```
$ psql -d newdb -f db.sql
```

To dump a database into a custom-format archive file:

```
$ pg_dump -Fc mydb > db.dump
```

To dump a database into a directory-format archive:

```
$ pg_dump -Fd mydb -f dumpdir
```

To dump a database into a directory-format archive in parallel with 5 worker jobs:

```
$ pg_dump -Fd mydb -j 5 -f dumpdir
```

To reload an archive file into a (freshly created) database named newdb:

```
$ pg_restore -d newdb db.dump
```

To reload an archive file into the same database it was dumped from, discarding the current contents of that database:

```
$ pg_restore -d postgres --clean --create db.dump
```

To dump a single table named mytab:

```
$ pg_dump -t mytab mydb > db.sql
```

To dump all tables whose names start with emp in the detroit schema, except for the table named employee_log:

```
$ pg_dump -t 'detroit.emp*' -T detroit.employee_log mydb > db.sql
```

To dump all schemas whose names start with east or west and end in gsm, excluding any schemas whose names contain the word test:

```
$ pg_dump -n 'east*gsm' -n 'west*gsm' -N '*test*' mydb > db.sql
```

The same, using regular expression notation to consolidate the switches:

```
$ pg_dump -n '(east|west)*gsm' -N '*test*' mydb > db.sql
```

To dump all database objects except for tables whose names begin with ts_:

```
$ pg_dump -T 'ts_*' mydb > db.sql
```

To specify an upper-case or mixed-case name in -t and related switches, you need to double-quote the name; else it will be folded to lower case (see Patterns). But double quotes are special to the

shell, so in turn they must be quoted. Thus, to dump a single table with a mixed-case name, you need something like

```
$ pg_dump -t "\"MixedCaseName\"" mydb > mytab.sql
```

See Also

[pg_dumpall](#), [pg_restore](#), [psql](#)

pg_dumpall

pg_dumpall — extract a PostgreSQL database cluster into a script file

Synopsis

```
pg_dumpall [connection-option...] [option...]
```

Description

pg_dumpall is a utility for writing out (“dumping”) all PostgreSQL databases of a cluster into one script file. The script file contains SQL commands that can be used as input to psql to restore the databases. It does this by calling pg_dump for each database in the cluster. pg_dumpall also dumps global objects that are common to all databases, that is, database roles and tablespaces. (pg_dump does not save these objects.)

Since pg_dumpall reads tables from all databases you will most likely have to connect as a database superuser in order to produce a complete dump. Also you will need superuser privileges to execute the saved script in order to be allowed to add roles and create databases.

The SQL script will be written to the standard output. Use the `-f/--file` option or shell operators to redirect it into a file.

pg_dumpall needs to connect several times to the PostgreSQL server (once per database). If you use password authentication it will ask for a password each time. It is convenient to have a `~/ .pgpass` file in such cases. See Section 33.15 for more information.

Options

The following command-line options control the content and format of the output.

`-a`
`--data-only`

Dump only the data, not the schema (data definitions).

`-c`
`--clean`

Include SQL commands to clean (drop) databases before recreating them. DROP commands for roles and tablespaces are added as well.

`-E encoding`
`--encoding=encoding`

Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the PGCLIENTENCODING environment variable to the desired dump encoding.)

`-f filename`
`--file=filename`

Send output to the specified file. If this is omitted, the standard output is used.

`-g`
`--globals-only`

Dump only global objects (roles and tablespaces), no databases.

-O

--no-owner

Do not output commands to set ownership of objects to match the original database. By default, `pg_dumpall` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

-r

--roles-only

Dump only roles, no databases or tablespaces.

-s

--schema-only

Dump only the object definitions (schema), not data.

-S *username*

--superuser=*username*

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

-t

--tablespaces-only

Dump only tablespaces, no databases or roles.

-v

--verbose

Specifies verbose mode. This will cause `pg_dumpall` to output start/stop times to the dump file, and progress messages to standard error. It will also enable verbose output in `pg_dump`.

-V

--version

Print the `pg_dumpall` version and exit.

-x

--no-privileges

--no-acl

Prevent dumping of access privileges (grant/revoke commands).

--binary-upgrade

This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

--column-inserts

--attribute-inserts

Dump data as `INSERT` commands with explicit column names (`INSERT INTO table (column, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases.

--disable-dollar-quoting

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

--disable-triggers

This option is relevant only when creating a data-only dump. It instructs `pg_dumpall` to include commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data reload.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

--extra-float-digits=*ndigits*

Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

--exclude-database=*pattern*

Do not dump databases whose name matches *pattern*. Multiple patterns can be excluded by writing multiple `--exclude-database` switches. The *pattern* parameter is interpreted as a pattern according to the same rules used by `psql`'s `\d` commands (see Patterns), so multiple databases can also be excluded by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent shell wildcard expansion.

--if-exists

Use conditional commands (i.e. add an `IF EXISTS` clause) to drop databases and other objects. This option is not valid unless `--clean` is also specified.

--inserts

Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safer, though even slower.

--load-via-partition-root

When dumping data for a table partition, make the `COPY` or `INSERT` statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when reloading data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type text and the two systems have different definitions of the collation used to sort the partitioning column.

--lock-wait-timeout=*timeout*

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead, fail if unable to lock a table within the specified *timeout*. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. Allowed values vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions since 7.3. This option is ignored when dumping from a pre-7.3 server.

--no-comments

Do not dump comments.

--no-publications

Do not dump publications.

--no-role-passwords

Do not dump passwords for roles. When restored, roles will have a null password, and password authentication will always fail until the password is set. Since password values aren't needed when this option is specified, the role information is read from the catalog view `pg_roles` instead of `pg_authid`. Therefore, this option also helps if access to `pg_authid` is restricted by some security policy.

--no-security-labels

Do not dump security labels.

--no-subscriptions

Do not dump subscriptions.

--no-sync

By default, `pg_dumpall` will wait for all files to be written safely to disk. This option causes `pg_dumpall` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the dump corrupt. Generally, this option is useful for testing but should not be used when dumping data from production installation.

--no-tablespaces

Do not output commands to create tablespaces nor select tablespaces for objects. With this option, all objects will be created in whichever tablespace is the default during restore.

--no-unlogged-table-data

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data.

--on-conflict-do-nothing

Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts` or `--column-inserts` is also specified.

--quote-all-identifiers

Force quoting of all identifiers. This option is recommended when dumping a database from a server whose PostgreSQL major version is different from `pg_dumpall`'s, or when the output is intended to be loaded into a server of a different major version. By default, `pg_dumpall` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

--rows-per-insert=*nrows*

Dump data as `INSERT` commands (rather than `COPY`). Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during reloading will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

--use-set-session-authorization

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards compatible, but depending on the history of the objects in the dump, might not restore properly.

-?
--help

Show help about pg_dumpall command line arguments, and exit.

The following command-line options control the database connection parameters.

-d *connstr*
--dbname=*connstr*

Specifies parameters used to connect to the server, as a connection string. See Section 33.1.1 for more information.

The option is called --dbname for consistency with other client applications, but because pg_dumpall needs to connect to many databases, the database name in the connection string will be ignored. Use the -l option to specify the name of the database used for the initial connection, which will dump global objects and discover what other databases should be dumped.

-h *host*
--host=*host*

Specifies the host name of the machine on which the database server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the PGHOST environment variable, if set, else a Unix domain socket connection is attempted.

-l *dbname*
--database=*dbname*

Specifies the name of the database to connect to for dumping global objects and discovering what other databases should be dumped. If not specified, the postgres database will be used, and if that does not exist, template1 will be used.

-p *port*
--port=*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the PGPORT environment variable, if set, or a compiled-in default.

-U *username*
--username=*username*

User name to connect as.

-w
--no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W
--password

Force pg_dumpall to prompt for a password before connecting to a database.

This option is never essential, since pg_dumpall will automatically prompt for a password if the server demands password authentication. However, pg_dumpall will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing -W to avoid the extra connection attempt.

Note that the password prompt will occur again for each database to be dumped. Usually, it's better to set up a ~/.pgpass file than to rely on manual password entry.

`--role=rolename`

Specifies a role name to be used to create the dump. This option causes `pg_dumpall` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `pg_dumpall`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

Environment

PGHOST
PGOPTIONS
PGPORT
PGUSER

Default connection parameters

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Notes

Since `pg_dumpall` calls `pg_dump` internally, some diagnostic messages will refer to `pg_dump`.

The `--clean` option can be useful even when your intention is to restore the dump script into a fresh cluster. Use of `--clean` authorizes the script to drop and re-create the built-in `postgres` and `template1` databases, ensuring that those databases will retain the same properties (for instance, locale and encoding) that they had in the source cluster. Without the option, those databases will retain their existing database-level properties, as well as any pre-existing contents.

Once restored, it is wise to run `ANALYZE` on each database so the optimizer has useful statistics. You can also run `vacuumdb -a -z` to analyze all databases.

The dump script should not be expected to run completely without errors. In particular, because the script will issue `CREATE ROLE` for every role existing in the source cluster, it is certain to get a “role already exists” error for the bootstrap superuser, unless the destination cluster was initialized with a different bootstrap superuser name. This error is harmless and should be ignored. Use of the `--clean` option is likely to produce additional harmless error messages about non-existent objects, although you can minimize those by adding `--if-exists`.

`pg_dumpall` requires all needed tablespace directories to exist before the restore; otherwise, database creation will fail for databases in non-default locations.

Examples

To dump all databases:

```
$ pg_dumpall > db.out
```

To reload database(s) from this file, you can use:

```
$ psql -f db.out postgres
```

It is not important to which database you connect here since the script file created by `pg_dumpall` will contain the appropriate commands to create and connect to the saved databases. An exception is that if you specified `--clean`, you must connect to the `postgres` database initially; the script will attempt to drop other databases immediately, and that will fail for the database you are connected to.

See Also

Check `pg_dump` for details on possible error conditions.

pg_isready

pg_isready — check the connection status of a PostgreSQL server

Synopsis

```
pg_isready [connection-option...] [option...]
```

Description

pg_isready is a utility for checking the connection status of a PostgreSQL database server. The exit status specifies the result of the connection check.

Options

```
-d dbname  
--dbname=dbname
```

Specifies the name of the database to connect to.

If this parameter contains an = sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a *conninfo* string. See Section 33.1.1 for more information.

```
-h hostname  
--host=hostname
```

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix-domain socket.

```
-p port  
--port=port
```

Specifies the TCP port or the local Unix-domain socket file extension on which the server is listening for connections. Defaults to the value of the `PGPORT` environment variable or, if not set, to the port specified at compile time, usually 5432.

```
-q  
--quiet
```

Do not display status message. This is useful when scripting.

```
-t seconds  
--timeout=seconds
```

The maximum number of seconds to wait when attempting connection before returning that the server is not responding. Setting to 0 disables. The default is 3 seconds.

```
-U username  
--username=username
```

Connect to the database as the user *username* instead of the default.

```
-V  
--version
```

Print the pg_isready version and exit.

-?
--help

Show help about pg_isready command line arguments, and exit.

Exit Status

pg_isready returns 0 to the shell if the server is accepting connections normally, 1 if the server is rejecting connections (for example during startup), 2 if there was no response to the connection attempt, and 3 if no attempt was made (for example due to invalid parameters).

Environment

pg_isready, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 33.14).

The environment variable PG_COLOR specifies whether to use color in diagnostics messages. Possible values are always, auto, never.

Notes

It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

Examples

Standard Usage:

```
$ pg_isready
/tmp:5432 - accepting connections
$ echo $?
0
```

Running with connection parameters to a PostgreSQL cluster in startup:

```
$ pg_isready -h localhost -p 5433
localhost:5433 - rejecting connections
$ echo $?
1
```

Running with connection parameters to a non-responsive PostgreSQL cluster:

```
$ pg_isready -h someremotehost
someremotehost:5432 - no response
$ echo $?
2
```

pg_receivewal

pg_receivewal — stream write-ahead logs from a PostgreSQL server

Synopsis

```
pg_receivewal [option...]
```

Description

pg_receivewal is used to stream the write-ahead log from a running PostgreSQL cluster. The write-ahead log is streamed using the streaming replication protocol, and is written to a local directory of files. This directory can be used as the archive location for doing a restore using point-in-time recovery (see Section 25.3).

pg_receivewal streams the write-ahead log in real time as it's being generated on the server, and does not wait for segments to complete like `archive_command` does. For this reason, it is not necessary to set `archive_timeout` when using `pg_receivewal`.

Unlike the WAL receiver of a PostgreSQL standby server, `pg_receivewal` by default flushes WAL data only when a WAL file is closed. The option `--synchronous` must be specified to flush WAL data in real time. Since `pg_receivewal` does not apply WAL, you should not allow it to become a synchronous standby when `synchronous_commit` equals `remote_apply`. If it does, it will appear to be a standby that never catches up, and will cause transaction commits to block. To avoid this, you should either configure an appropriate value for `synchronous_standby_names`, or specify `application_name` for `pg_receivewal` that does not match it, or change the value of `synchronous_commit` to something other than `remote_apply`.

The write-ahead log is streamed over a regular PostgreSQL connection and uses the replication protocol. The connection must be made with a superuser or a user having `REPLICATION` permissions (see Section 21.2), and `pg_hba.conf` must permit the replication connection. The server must also be configured with `max_wal_senders` set high enough to leave at least one session available for the stream.

If the connection is lost, or if it cannot be initially established, with a non-fatal error, `pg_receivewal` will retry the connection indefinitely, and reestablish streaming as soon as possible. To avoid this behavior, use the `-n` parameter.

In the absence of fatal errors, `pg_receivewal` will run until terminated by the SIGINT signal (**Control+C**).

Options

```
-D directory  
--directory=directory
```

Directory to write the output to.

This parameter is required.

```
-E lsn  
--endpos=lsn
```

Automatically stop replication and exit with normal exit status 0 when receiving reaches the specified LSN.

If there is a record with LSN exactly equal to *lsn*, the record will be processed.

`--if-not-exists`

Do not error out when `--create-slot` is specified and a slot with the specified name already exists.

`-n`

`--no-loop`

Don't loop on connection errors. Instead, exit right away with an error.

`--no-sync`

This option causes `pg_receivewal` to not force WAL data to be flushed to disk. This is faster, but means that a subsequent operating system crash can leave the WAL segments corrupt. Generally, this option is useful for testing but should not be used when doing WAL archiving on a production deployment.

This option is incompatible with `--synchronous`.

`-s interval`

`--status-interval=interval`

Specifies the number of seconds between status packets sent back to the server. This allows for easier monitoring of the progress from server. A value of zero disables the periodic status updates completely, although an update will still be sent when requested by the server, to avoid timeout disconnect. The default value is 10 seconds.

`-S slotname`

`--slot=slotname`

Require `pg_receivewal` to use an existing replication slot (see Section 26.2.6). When this option is used, `pg_receivewal` will report a flush position to the server, indicating when each segment has been synchronized to disk so that the server can remove that segment if it is not otherwise needed.

When the replication client of `pg_receivewal` is configured on the server as a synchronous standby, then using a replication slot will report the flush position to the server, but only when a WAL file is closed. Therefore, that configuration will cause transactions on the primary to wait for a long time and effectively not work satisfactorily. The option `--synchronous` (see below) must be specified in addition to make this work correctly.

`--synchronous`

Flush the WAL data to disk immediately after it has been received. Also send a status packet back to the server immediately after flushing, regardless of `--status-interval`.

This option should be specified if the replication client of `pg_receivewal` is configured on the server as a synchronous standby, to ensure that timely feedback is sent to the server.

`-v`

`--verbose`

Enables verbose mode.

`-Z level`

`--compress=level`

Enables `gzip` compression of write-ahead logs, and specifies the compression level (0 through 9, 0 being no compression and 9 being best compression). The suffix `.gz` will automatically be added to all filenames.

The following command-line options control the database connection parameters.

`-d connstr`
`--dbname=connstr`

Specifies parameters used to connect to the server, as a connection string. See Section 33.1.1 for more information.

The option is called `--dbname` for consistency with other client applications, but because `pg_receivewal` doesn't connect to any particular database in the cluster, database name in the connection string will be ignored.

`-h host`
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force `pg_receivewal` to prompt for a password before connecting to a database.

This option is never essential, since `pg_receivewal` will automatically prompt for a password if the server demands password authentication. However, `pg_receivewal` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`pg_receivewal` can perform one of the two following actions in order to control physical replication slots:

`--create-slot`

Create a new physical replication slot with the name specified in `--slot`, then exit.

`--drop-slot`

Drop the replication slot with the name specified in `--slot`, then exit.

Other options are also available:

`-v`
`--version`

Print the `pg_receivewal` version and exit.

-?
--help

Show help about `pg_receivewal` command line arguments, and exit.

Exit Status

`pg_receivewal` will exit with status 0 when terminated by the SIGINT signal. (That is the normal way to end it. Hence it is not an error.) For fatal errors or other signals, the exit status will be nonzero.

Environment

This utility, like most other PostgreSQL utilities, uses the environment variables supported by libpq (see Section 33.14).

The environment variable `PG_COLOR` specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

When using `pg_receivewal` instead of `archive_command` as the main WAL backup method, it is strongly recommended to use replication slots. Otherwise, the server is free to recycle or remove write-ahead log files before they are backed up, because it does not have any information, either from `archive_command` or the replication slots, about how far the WAL stream has been archived. Note, however, that a replication slot will fill up the server's disk space if the receiver does not keep up with fetching the WAL data.

`pg_receivewal` will preserve group permissions on the received WAL files if group permissions are enabled on the source cluster.

Examples

To stream the write-ahead log from the server at `mydbserver` and store it in the local directory `/usr/local/pgsql/archive`:

```
$ pg_receivewal -h mydbserver -D /usr/local/pgsql/archive
```

See Also

`pg_basebackup`

pg_recvlogical

pg_recvlogical — control PostgreSQL logical decoding streams

Synopsis

```
pg_recvlogical [option...]
```

Description

`pg_recvlogical` controls logical decoding replication slots and streams data from such replication slots.

It creates a replication-mode connection, so it is subject to the same constraints as `pg_receivewal`, plus those for logical replication (see Chapter 48).

`pg_recvlogical` has no equivalent to the logical decoding SQL interface's peek and get modes. It sends replay confirmations for data lazily as it receives it and on clean exit. To examine pending data on a slot without consuming it, use `pg_logical_slot_peek_changes`.

Options

At least one of the following options must be specified to select an action:

`--create-slot`

Create a new logical replication slot with the name specified by `--slot`, using the output plugin specified by `--plugin`, for the database specified by `--dbname`.

`--drop-slot`

Drop the replication slot with the name specified by `--slot`, then exit.

`--start`

Begin streaming changes from the logical replication slot specified by `--slot`, continuing until terminated by a signal. If the server side change stream ends with a server shutdown or disconnect, retry in a loop unless `--no-loop` is specified.

The stream format is determined by the output plugin specified when the slot was created.

The connection must be to the same database used to create the slot.

`--create-slot` and `--start` can be specified together. `--drop-slot` cannot be combined with another action.

The following command-line options control the location and format of the output and other replication behavior:

`-E lsn`

`--endpos=lsn`

In `--start` mode, automatically stop replication and exit with normal exit status 0 when receiving reaches the specified LSN. If specified when not in `--start` mode, an error is raised.

If there's a record with LSN exactly equal to `lsn`, the record will be output.

The `--endpos` option is not aware of transaction boundaries and may truncate output partway through a transaction. Any partially output transaction will not be consumed and will be replayed again when the slot is next read from. Individual messages are never truncated.

`-f filename`
`--file=filename`

Write received and decoded transaction data into this file. Use `-` for stdout.

`-F interval_seconds`
`--fsync-interval=interval_seconds`

Specifies how often `pg_recvlogical` should issue `fsync()` calls to ensure the output file is safely flushed to disk.

The server will occasionally request the client to perform a flush and report the flush position to the server. This setting is in addition to that, to perform flushes more frequently.

Specifying an interval of 0 disables issuing `fsync()` calls altogether, while still reporting progress to the server. In this case, data could be lost in the event of a crash.

`-I lsn`
`--startpos=lsn`

In `--start` mode, start replication from the given LSN. For details on the effect of this, see the documentation in Chapter 48 and Section 52.4. Ignored in other modes.

`--if-not-exists`

Do not error out when `--create-slot` is specified and a slot with the specified name already exists.

`-n`
`--no-loop`

When the connection to the server is lost, do not retry in a loop, just exit.

`-o name [=value]`
`--option=name [=value]`

Pass the option `name` to the output plugin with, if specified, the option value `value`. Which options exist and their effects depends on the used output plugin.

`-P plugin`
`--plugin=plugin`

When creating a slot, use the specified logical decoding output plugin. See Chapter 48. This option has no effect if the slot already exists.

`-s interval_seconds`
`--status-interval=interval_seconds`

This option has the same effect as the option of the same name in `pg_receivewal`. See the description there.

`-S slot_name`
`--slot=slot_name`

In `--start` mode, use the existing logical replication slot named `slot_name`. In `--create-slot` mode, create the slot with this name. In `--drop-slot` mode, delete the slot with this name.

`-v`
`--verbose`

Enables verbose mode.

The following command-line options control the database connection parameters.

`-d database`
`--dbname=database`

The database to connect to. See the description of the actions for what this means in detail. This can be a libpq connection string; see Section 33.1.1 for more information. Defaults to user name.

`-h hostname-or-ip`
`--host=hostname-or-ip`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U user`
`--username=user`

User name to connect as. Defaults to current operating system user name.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force `pg_recvlogical` to prompt for a password before connecting to a database.

This option is never essential, since `pg_recvlogical` will automatically prompt for a password if the server demands password authentication. However, `pg_recvlogical` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

The following additional options are available:

`-V`
`--version`

Print the `pg_recvlogical` version and exit.

`-?`
`--help`

Show help about `pg_recvlogical` command line arguments, and exit.

Environment

This utility, like most other PostgreSQL utilities, uses the environment variables supported by libpq (see Section 33.14).

The environment variable `PG_COLOR` specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

pg_recvlogical will preserve group permissions on the received WAL files if group permissions are enabled on the source cluster.

Examples

See Section 48.1 for an example.

See Also

pg_receivewal

pg_restore

pg_restore — restore a PostgreSQL database from an archive file created by pg_dump

Synopsis

```
pg_restore [connection-option...] [option...] [filename]
```

Description

pg_restore is a utility for restoring a PostgreSQL database from an archive created by pg_dump in one of the non-plain-text formats. It will issue the commands necessary to reconstruct the database to the state it was in at the time it was saved. The archive files also allow pg_restore to be selective about what is restored, or even to reorder the items prior to being restored. The archive files are designed to be portable across architectures.

pg_restore can operate in two modes. If a database name is specified, pg_restore connects to that database and restores archive contents directly into the database. Otherwise, a script containing the SQL commands necessary to rebuild the database is created and written to a file or standard output. This script output is equivalent to the plain text output format of pg_dump. Some of the options controlling the output are therefore analogous to pg_dump options.

Obviously, pg_restore cannot restore information that is not present in the archive file. For instance, if the archive was made using the “dump data as INSERT commands” option, pg_restore will not be able to load the data using COPY statements.

Options

pg_restore accepts the following command line arguments.

filename

Specifies the location of the archive file (or directory, for a directory-format archive) to be restored. If not specified, the standard input is used.

-a
--data-only

Restore only the data, not the schema (data definitions). Table data, large objects, and sequence values are restored, if present in the archive.

This option is similar to, but for historical reasons not identical to, specifying --section=data.

-c
--clean

Clean (drop) database objects before recreating them. (Unless --if-exists is used, this might generate some harmless error messages, if any objects were not present in the destination database.)

-C
--create

Create the database before restoring into it. If --clean is also specified, drop and recreate the target database before connecting to it.

With `--create`, `pg_restore` also restores the database's comment if any, and any configuration variable settings that are specific to this database, that is, any `ALTER DATABASE ... SET ...` and `ALTER ROLE ... IN DATABASE ... SET ...` commands that mention this database. Access privileges for the database itself are also restored, unless `--no-acl` is specified.

When this option is used, the database named with `-d` is used only to issue the initial `DROP DATABASE` and `CREATE DATABASE` commands. All data is restored into the database name that appears in the archive.

`-d dbname`
`--dbname=dbname`

Connect to database *dbname* and restore directly into the database.

`-e`
`--exit-on-error`

Exit if an error is encountered while sending SQL commands to the database. The default is to continue and to display a count of errors at the end of the restoration.

`-f filename`
`--file=filename`

Specify output file for generated script, or for the listing when used with `-l`. Use `-` for stdout.

`-F format`
`--format=format`

Specify format of the archive. It is not necessary to specify the format, since `pg_restore` will determine the format automatically. If specified, it can be one of the following:

`c`
custom

The archive is in the custom format of `pg_dump`.

`d`
directory

The archive is a directory archive.

`t`
tar

The archive is a tar archive.

`-I index`
`--index=index`

Restore definition of named index only. Multiple indexes may be specified with multiple `-I` switches.

`-j number-of-jobs`
`--jobs=number-of-jobs`

Run the most time-consuming parts of `pg_restore` — those which load data, create indexes, or create constraints — using multiple concurrent jobs. This option can dramatically reduce the time to restore a large database to a server running on a multiprocessor machine.

Each job is one process or one thread, depending on the operating system, and uses a separate connection to the server.

The optimal value for this option depends on the hardware setup of the server, of the client, and of the network. Factors include the number of CPU cores and the disk setup. A good place to start is the number of CPU cores on the server, but values larger than that can also lead to faster restore times in many cases. Of course, values that are too high will lead to decreased performance because of thrashing.

Only the custom and directory archive formats are supported with this option. The input must be a regular file or directory (not, for example, a pipe). This option is ignored when emitting a script rather than connecting directly to a database server. Also, multiple jobs cannot be used together with the option `--single-transaction`.

`-l`
`--list`

List the table of contents of the archive. The output of this operation can be used as input to the `-L` option. Note that if filtering switches such as `-n` or `-t` are used with `-l`, they will restrict the items listed.

`-L list-file`
`--use-list=list-file`

Restore only those archive elements that are listed in *list-file*, and restore them in the order they appear in the file. Note that if filtering switches such as `-n` or `-t` are used with `-L`, they will further restrict the items restored.

list-file is normally created by editing the output of a previous `-l` operation. Lines can be moved or removed, and can also be commented out by placing a semicolon (`;`) at the start of the line. See below for examples.

`-n schema`
`--schema=schema`

Restore only objects that are in the named schema. Multiple schemas may be specified with multiple `-n` switches. This can be combined with the `-t` option to restore just a specific table.

`-N schema`
`--exclude-schema=schema`

Do not restore objects that are in the named schema. Multiple schemas to be excluded may be specified with multiple `-N` switches.

When both `-n` and `-N` are given for the same schema name, the `-N` switch wins and the schema is excluded.

`-O`
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, `pg_restore` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail unless the initial connection to the database is made by a superuser (or the same user that owns all of the objects in the script). With `-O`, any user name can be used for the initial connection, and this user will own all the created objects.

`-P function-name(argtype [, ...])`
`--function=function-name(argtype [, ...])`

Restore the named function only. Be careful to spell the function name and arguments exactly as they appear in the dump file's table of contents. Multiple functions may be specified with multiple `-P` switches.

`-R`
`--no-reconnect`

This option is obsolete but still accepted for backwards compatibility.

`-s`
`--schema-only`

Restore only the schema (data definitions), not data, to the extent that schema entries are present in the archive.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data` `--section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word “schema” in a different meaning.)

`-S username`
`--superuser=username`

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used.

`-t table`
`--table=table`

Restore definition and/or data of only the named table. For this purpose, “table” includes views, materialized views, sequences, and foreign tables. Multiple tables can be selected by writing multiple `-t` switches. This option can be combined with the `-n` option to specify table(s) in a particular schema.

Note

When `-t` is specified, `pg_restore` makes no attempt to restore any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that a specific-table restore into a clean database will succeed.

Note

This flag does not behave identically to the `-t` flag of `pg_dump`. There is not currently any provision for wild-card matching in `pg_restore`, nor can you include a schema name within its `-t`. And, while `pg_dump`'s `-t` flag will also dump subsidiary objects (such as indexes) of the selected table(s), `pg_restore`'s `-t` flag does not include such subsidiary objects.

Note

In versions prior to PostgreSQL 9.6, this flag matched only tables, not any other type of relation.

`-T trigger`
`--trigger=trigger`

Restore named trigger only. Multiple triggers may be specified with multiple `-T` switches.

`-v`
`--verbose`

Specifies verbose mode.

`-V`
`--version`

Print the `pg_restore` version and exit.

`-x`
`--no-privileges`
`--no-acl`

Prevent restoration of access privileges (grant/revoke commands).

`-1`
`--single-transaction`

Execute the restore as a single transaction (that is, wrap the emitted commands in `BEGIN/COMMIT`). This ensures that either all the commands complete successfully, or no changes are applied. This option implies `--exit-on-error`.

`--disable-triggers`

This option is relevant only when performing a data-only restore. It instructs `pg_restore` to execute commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data reload.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So you should also specify a superuser name with `-S` or, preferably, run `pg_restore` as a PostgreSQL superuser.

`--enable-row-security`

This option is relevant only when restoring the contents of a table which has row security. By default, `pg_restore` will set `row_security` to off, to ensure that all data is restored in to the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `pg_restore` to set `row_security` to on instead, allowing the user to attempt to restore the contents of the table with row security enabled. This might still fail if the user does not have the right to insert the rows from the dump into the table.

Note that this option currently also requires the dump be in `INSERT` format, as `COPY FROM` does not support row security.

`--if-exists`

Use conditional commands (i.e. add an `IF EXISTS` clause) to drop database objects. This option is not valid unless `--clean` is also specified.

`--no-comments`

Do not output commands to restore comments, even if the archive contains them.

`--no-data-for-failed-tables`

By default, table data is restored even if the creation command for the table failed (e.g., because it already exists). With this option, data for such a table is skipped. This behavior is useful if the target database already contains the desired table contents. For example, auxiliary tables for

PostgreSQL extensions such as PostGIS might already be loaded in the target database; specifying this option prevents duplicate or obsolete data from being loaded into them.

This option is effective only when restoring directly into a database, not when producing SQL script output.

`--no-publications`

Do not output commands to restore publications, even if the archive contains them.

`--no-security-labels`

Do not output commands to restore security labels, even if the archive contains them.

`--no-subscriptions`

Do not output commands to restore subscriptions, even if the archive contains them.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

`--section=sectionname`

Only restore the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to restore all sections.

The data section contains actual table data as well as large-object definitions. Post-data items consist of definitions of indexes, triggers, rules and constraints other than validated check constraints. Pre-data items consist of all other data definition items.

`--strict-names`

Require that each schema (`-n/--schema`) and table (`-t/--table`) qualifier match at least one schema/table in the backup file.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly.

`-?`

`--help`

Show help about `pg_restore` command line arguments, and exit.

`pg_restore` also accepts the following command line arguments for connection parameters:

`-h host`

`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p port`

`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force `pg_restore` to prompt for a password before connecting to a database.

This option is never essential, since `pg_restore` will automatically prompt for a password if the server demands password authentication. However, `pg_restore` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--role=rolename`

Specifies a role name to be used to perform the restore. This option causes `pg_restore` to issue a `SET ROLE rolename` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `pg_restore`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows restores to be performed without violating the policy.

Environment

`PGHOST`
`PGOPTIONS`
`PGPORT`
`PGUSER`

Default connection parameters

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14). However, it does not read `PGDATABASE` when a database name is not supplied.

Diagnostics

When a direct database connection is specified using the `-d` option, `pg_restore` internally executes SQL statements. If you have problems running `pg_restore`, make sure you are able to select information from the database using, for example, `psql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Notes

If your installation has any local additions to the `template1` database, be careful to load the output of `pg_restore` into a truly empty database; otherwise you are likely to get errors due to duplicate

definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

The limitations of `pg_restore` are detailed below.

- When restoring data to a pre-existing table and the option `--disable-triggers` is used, `pg_restore` emits commands to disable triggers on user tables before inserting the data, then emits commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.
- `pg_restore` cannot restore large objects selectively; for instance, only those for a specific table. If an archive contains large objects, then all large objects will be restored, or none of them if they are excluded via `-L`, `-t`, or other options.

See also the `pg_dump` documentation for details on limitations of `pg_dump`.

Once restored, it is wise to run `ANALYZE` on each restored table so the optimizer has useful statistics; see Section 24.1.3 and Section 24.1.6 for more information.

Examples

Assume we have dumped a database called `mydb` into a custom-format dump file:

```
$ pg_dump -Fc mydb > db.dump
```

To drop the database and recreate it from the dump:

```
$ dropdb mydb
$ pg_restore -C -d postgres db.dump
```

The database named in the `-d` switch can be any database existing in the cluster; `pg_restore` only uses it to issue the `CREATE DATABASE` command for `mydb`. With `-C`, data is always restored into the database name that appears in the dump file.

To reload the dump into a new database called `newdb`:

```
$ createdb -T template0 newdb
$ pg_restore -d newdb db.dump
```

Notice we don't use `-C`, and instead connect directly to the database to be restored into. Also note that we clone the new database from `template0` not `template1`, to ensure it is initially empty.

To reorder database items, it is first necessary to dump the table of contents of the archive:

```
$ pg_restore -l db.dump > db.list
```

The listing file consists of a header and one line for each item, e.g.:

```
;
; Archive created at Mon Sep 14 13:55:39 2009
;   dbname: DBDEMOS
;   TOC Entries: 81
;   Compression: 9
```

```
; Dump Version: 1.10-0
; Format: CUSTOM
; Integer: 4 bytes
; Offset: 8 bytes
; Dumped from database version: 8.3.5
; Dumped by pg_dump version: 8.3.8
;
;
; Selected TOC Entries:
;
3; 2615 2200 SCHEMA - public pasha
1861; 0 0 COMMENT - SCHEMA public pasha
1862; 0 0 ACL - public pasha
317; 1247 17715 TYPE public composite pasha
319; 1247 25899 DOMAIN public domain0 pasha
```

Semicolons start a comment, and the numbers at the start of lines refer to the internal archive ID assigned to each item.

Lines in the file can be commented out, deleted, and reordered. For example:

```
10; 145433 TABLE map_resolutions postgres
;2; 145344 TABLE species postgres
;4; 145359 TABLE nt_header postgres
6; 145402 TABLE species_records postgres
;8; 145416 TABLE ss_old postgres
```

could be used as input to `pg_restore` and would only restore items 10 and 6, in that order:

```
$ pg_restore -L db.list db.dump
```

See Also

`pg_dump`, `pg_dumpall`, `psql`

psql

psql — PostgreSQL interactive terminal

Synopsis

```
psql [option...] [dbname [username]]
```

Description

psql is a terminal-based front-end to PostgreSQL. It enables you to type in queries interactively, issue them to PostgreSQL, and see the query results. Alternatively, input can be from a file or from command line arguments. In addition, psql provides a number of meta-commands and various shell-like features to facilitate writing scripts and automating a wide variety of tasks.

Options

```
-a  
--echo-all
```

Print all nonempty input lines to standard output as they are read. (This does not apply to lines read interactively.) This is equivalent to setting the variable `ECHO` to `all`.

```
-A  
--no-align
```

Switches to unaligned output mode. (The default output mode is aligned.) This is equivalent to `\pset format unaligned`.

```
-b  
--echo-errors
```

Print failed SQL commands to standard error output. This is equivalent to setting the variable `ECHO` to `errors`.

```
-c command  
--command=command
```

Specifies that psql is to execute the given command string, *command*. This option can be repeated and combined in any order with the `-f` option. When either `-c` or `-f` is specified, psql does not read commands from standard input; instead it terminates after processing all the `-c` and `-f` options in sequence.

command must be either a command string that is completely parsable by the server (i.e., it contains no psql-specific features), or a single backslash command. Thus you cannot mix SQL and psql meta-commands within a `-c` option. To achieve that, you could use repeated `-c` options or pipe the string into psql, for example:

```
psql -c '\x' -c 'SELECT * FROM foo;'
```

or

```
echo '\x \ SELECT * FROM foo;' | psql
```

(`\` is the separator meta-command.)

Each SQL command string passed to `-c` is sent to the server as a single request. Because of this, the server executes it as a single transaction even if the string contains multiple SQL commands, unless there are explicit `BEGIN/COMMIT` commands included in the string to divide it into multiple transactions. (See Section 52.2.2.1 for more details about how the server handles multi-query strings.) Also, `psql` only prints the result of the last SQL command in the string. This is different from the behavior when the same string is read from a file or fed to `psql`'s standard input, because then `psql` sends each SQL command separately.

Because of this behavior, putting more than one SQL command in a single `-c` string often has unexpected results. It's better to use repeated `-c` commands or feed multiple commands to `psql`'s standard input, either using `echo` as illustrated above, or via a shell here-document, for example:

```
psql <<EOF
\x
SELECT * FROM foo;
EOF
```

`--csv`

Switches to CSV (Comma-Separated Values) output mode. This is equivalent to `\pset format csv`.

`-d dbname`

`--dbname=dbname`

Specifies the name of the database to connect to. This is equivalent to specifying `dbname` as the first non-option argument on the command line.

If this parameter contains an `=` sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a `conninfo` string. See Section 33.1.1 for more information.

`-e`

`--echo-queries`

Copy all SQL commands sent to the server to standard output as well. This is equivalent to setting the variable `ECHO` to `queries`.

`-E`

`--echo-hidden`

Echo the actual queries generated by `\d` and other backslash commands. You can use this to study `psql`'s internal operations. This is equivalent to setting the variable `ECHO_HIDDEN` to `on`.

`-f filename`

`--file=filename`

Read commands from the file `filename`, rather than standard input. This option can be repeated and combined in any order with the `-c` option. When either `-c` or `-f` is specified, `psql` does not read commands from standard input; instead it terminates after processing all the `-c` and `-f` options in sequence. Except for that, this option is largely equivalent to the meta-command `\i`.

If `filename` is `-` (hyphen), then standard input is read until an EOF indication or `\q` meta-command. This can be used to intersperse interactive input with input from files. Note however that `Readline` is not used in this case (much as if `-n` had been specified).

Using this option is subtly different from writing `psql < filename`. In general, both will do what you expect, but using `-f` enables some nice features such as error messages with line

numbers. There is also a slight chance that using this option will reduce the start-up overhead. On the other hand, the variant using the shell's input redirection is (in theory) guaranteed to yield exactly the same output you would have received had you entered everything by hand.

`-F separator`
`--field-separator=separator`

Use *separator* as the field separator for unaligned output. This is equivalent to `\pset fieldsep` or `\f`.

`-h hostname`
`--host=hostname`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix-domain socket.

`-H`
`--html`

Switches to HTML output mode. This is equivalent to `\pset format html` or the `\H` command.

`-l`
`--list`

List all available databases, then exit. Other non-connection options are ignored. This is similar to the meta-command `\list`.

When this option is used, `psql` will connect to the database `postgres`, unless a different database is named on the command line (option `-d` or non-option argument, possibly via a service entry, but not via an environment variable).

`-L filename`
`--log-file=filename`

Write all query output into file *filename*, in addition to the normal output destination.

`-n`
`--no-readline`

Do not use Readline for line editing and do not use the command history. This can be useful to turn off tab expansion when cutting and pasting.

`-o filename`
`--output=filename`

Put all query output into file *filename*. This is equivalent to the command `\o`.

`-p port`
`--port=port`

Specifies the TCP port or the local Unix-domain socket file extension on which the server is listening for connections. Defaults to the value of the `PGPORT` environment variable or, if not set, to the port specified at compile time, usually 5432.

`-P assignment`
`--pset=assignment`

Specifies printing options, in the style of `\pset`. Note that here you have to separate name and value with an equal sign instead of a space. For example, to set the output format to LaTeX, you could write `-P format=latex`.

-q
--quiet

Specifies that psql should do its work quietly. By default, it prints welcome messages and various informational output. If this option is used, none of this happens. This is useful with the `-c` option. This is equivalent to setting the variable `QUIET` to on.

-R *separator*
--record-separator=*separator*

Use *separator* as the record separator for unaligned output. This is equivalent to `\pset recordsep`.

-s
--single-step

Run in single-step mode. That means the user is prompted before each command is sent to the server, with the option to cancel execution as well. Use this to debug scripts.

-S
--single-line

Runs in single-line mode where a newline terminates an SQL command, as a semicolon does.

Note

This mode is provided for those who insist on it, but you are not necessarily encouraged to use it. In particular, if you mix SQL and meta-commands on a line the order of execution might not always be clear to the inexperienced user.

-t
--tuples-only

Turn off printing of column names and result row count footers, etc. This is equivalent to `\t` or `\pset tuples_only`.

-T *table_options*
--table-attr=*table_options*

Specifies options to be placed within the HTML table tag. See `\pset tableattr` for details.

-U *username*
--username=*username*

Connect to the database as the user *username* instead of the default. (You must have permission to do so, of course.)

-v *assignment*
--set=*assignment*
--variable=*assignment*

Perform a variable assignment, like the `\set` meta-command. Note that you must separate name and value, if any, by an equal sign on the command line. To unset a variable, leave off the equal sign. To set a variable with an empty value, use the equal sign but leave off the value. These assignments are done during command line processing, so variables that reflect connection state will get overwritten later.

-V
--version

Print the psql version and exit.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

Note that this option will remain set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

`-W`
`--password`

Force psql to prompt for a password before connecting to a database.

This option is never essential, since psql will automatically prompt for a password if the server demands password authentication. However, psql will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Note that this option will remain set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

`-x`
`--expanded`

Turn on the expanded table formatting mode. This is equivalent to `\x` or `\pset expanded`.

`-X,`
`--no-psqlrc`

Do not read the start-up file (neither the system-wide `psqlrc` file nor the user's `~/ .psqlrc` file).

`-z`
`--field-separator-zero`

Set the field separator for unaligned output to a zero byte. This is equivalent to `\pset fieldsep_zero`.

`-0`
`--record-separator-zero`

Set the record separator for unaligned output to a zero byte. This is useful for interfacing, for example, with `xargs -0`. This is equivalent to `\pset recordsep_zero`.

`-1`
`--single-transaction`

This option can only be used in combination with one or more `-c` and/or `-f` options. It causes psql to issue a `BEGIN` command before the first such option and a `COMMIT` command after the last one, thereby wrapping all the commands into a single transaction. This ensures that either all the commands complete successfully, or no changes are applied.

If the commands themselves contain `BEGIN`, `COMMIT`, or `ROLLBACK`, this option will not have the desired effects. Also, if an individual command cannot be executed inside a transaction block, specifying this option will cause the whole transaction to fail.

`-?`
`--help[=topic]`

Show help about psql and exit. The optional *topic* parameter (defaulting to `options`) selects which part of psql is explained: `commands` describes psql's backslash commands; `options`

describes the command-line options that can be passed to `psql`; and `variables` shows help about `psql` configuration variables.

Exit Status

`psql` returns 0 to the shell if it finished normally, 1 if a fatal error of its own occurs (e.g. out of memory, file not found), 2 if the connection to the server went bad and the session was not interactive, and 3 if an error occurred in a script and the variable `ON_ERROR_STOP` was set.

Usage

Connecting to a Database

`psql` is a regular PostgreSQL client application. In order to connect to a database you need to know the name of your target database, the host name and port number of the server, and what user name you want to connect as. `psql` can be told about those parameters via command line options, namely `-d`, `-h`, `-p`, and `-U` respectively. If an argument is found that does not belong to any option it will be interpreted as the database name (or the user name, if the database name is already given). Not all of these options are required; there are useful defaults. If you omit the host name, `psql` will connect via a Unix-domain socket to a server on the local host, or via TCP/IP to `localhost` on machines that don't have Unix-domain sockets. The default port number is determined at compile time. Since the database server uses the same default, you will not have to specify the port in most cases. The default user name is your operating-system user name, as is the default database name. Note that you cannot just connect to any database under any user name. Your database administrator should have informed you about your access rights.

When the defaults aren't quite right, you can save yourself some typing by setting the environment variables `PGDATABASE`, `PGHOST`, `PGPORT` and/or `PGUSER` to appropriate values. (For additional environment variables, see Section 33.14.) It is also convenient to have a `~/ .pgpass` file to avoid regularly having to type in passwords. See Section 33.15 for more information.

An alternative way to specify connection parameters is in a `conninfo` string or a URI, which is used instead of a database name. This mechanism give you very wide control over the connection. For example:

```
$ psql "service=myervice sslmode=require"
$ psql postgresql://dbmaster:5433/mydb?sslmode=require
```

This way you can also use LDAP for connection parameter lookup as described in Section 33.17. See Section 33.1.2 for more information on all the available connection options.

If the connection could not be made for any reason (e.g., insufficient privileges, server is not running on the targeted host, etc.), `psql` will return an error and terminate.

If both standard input and standard output are a terminal, then `psql` sets the client encoding to “auto”, which will detect the appropriate client encoding from the locale settings (`LC_CTYPE` environment variable on Unix systems). If this doesn't work out as expected, the client encoding can be overridden using the environment variable `PGCLIENTENCODING`.

Entering SQL Commands

In normal operation, `psql` provides a prompt with the name of the database to which `psql` is currently connected, followed by the string `=>`. For example:

```
$ psql testdb
psql (12.1)
```

Type "help" for help.

testdb=>

At the prompt, the user can type in SQL commands. Ordinarily, input lines are sent to the server when a command-terminating semicolon is reached. An end of line does not terminate a command. Thus commands can be spread over several lines for clarity. If the command was sent and executed without error, the results of the command are displayed on the screen.

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin your session by removing publicly-writable schemas from `search_path`. One can add `options=-csearch_path=` to the connection string or issue `SELECT pg_catalog.set_config('search_path', '', false)` before other SQL commands. This consideration is not specific to psql; it applies to every interface for executing arbitrary SQL commands.

Whenever a command is executed, psql also polls for asynchronous notification events generated by LISTEN and NOTIFY.

While C-style block comments are passed to the server for processing and removal, SQL-standard comments are removed by psql.

Meta-Commands

Anything you enter in psql that begins with an unquoted backslash is a psql meta-command that is processed by psql itself. These commands make psql more useful for administration or scripting. Meta-commands are often called slash or backslash commands.

The format of a psql command is the backslash, followed immediately by a command verb, then any arguments. The arguments are separated from the command verb and each other by any number of whitespace characters.

To include whitespace in an argument you can quote it with single quotes. To include a single quote in an argument, write two single quotes within single-quoted text. Anything contained in single quotes is furthermore subject to C-like substitutions for `\n` (new line), `\t` (tab), `\b` (backspace), `\r` (carriage return), `\f` (form feed), `\digits` (octal), and `\xdigits` (hexadecimal). A backslash preceding any other character within single-quoted text quotes that single character, whatever it is.

If an unquoted colon (`:`) followed by a psql variable name appears within an argument, it is replaced by the variable's value, as described in SQL Interpolation. The forms `: 'variable_name'` and `:"variable_name"` described there work as well. The `: {?variable_name}` syntax allows testing whether a variable is defined. It is substituted by TRUE or FALSE. Escaping the colon with a backslash protects it from substitution.

Within an argument, text that is enclosed in backquotes (```) is taken as a command line that is passed to the shell. The output of the command (with any trailing newline removed) replaces the backquoted text. Within the text enclosed in backquotes, no special quoting or other processing occurs, except that appearances of `:variable_name` where `variable_name` is a psql variable name are replaced by the variable's value. Also, appearances of `: 'variable_name'` are replaced by the variable's value suitably quoted to become a single shell command argument. (The latter form is almost always preferable, unless you are very sure of what is in the variable.) Because carriage return and line feed characters cannot be safely quoted on all platforms, the `: 'variable_name'` form prints an error message and does not substitute the variable value when such characters appear in the value.

Some commands take an SQL identifier (such as a table name) as argument. These arguments follow the syntax rules of SQL: Unquoted letters are forced to lowercase, while double quotes (`"`) protect letters from case conversion and allow incorporation of whitespace into the identifier. Within double quotes, paired double quotes reduce to a single double quote in the resulting name. For example, `FOO"BAR"BAZ` is interpreted as `fooBARbaz`, and `"A weird" " name"` becomes `A weird" name`.

Parsing for arguments stops at the end of the line, or when another unquoted backslash is found. An unquoted backslash is taken as the beginning of a new meta-command. The special sequence `\\` (two backslashes) marks the end of arguments and continues parsing SQL commands, if any. That way SQL and psql commands can be freely mixed on a line. But in any case, the arguments of a meta-command cannot continue beyond the end of the line.

Many of the meta-commands act on the *current query buffer*. This is simply a buffer holding whatever SQL command text has been typed but not yet sent to the server for execution. This will include previous input lines as well as any text appearing before the meta-command on the same line.

The following meta-commands are defined:

`\a`

If the current table output format is unaligned, it is switched to aligned. If it is not unaligned, it is set to unaligned. This command is kept for backwards compatibility. See `\pset` for a more general solution.

`\c` or `\connect` [`-reuse-previous=on/off`] [*dbname* [*username*] [*host*] [*port*] | *conninfo*]

Establishes a new connection to a PostgreSQL server. The connection parameters to use can be specified either using a positional syntax, or using *conninfo* connection strings as detailed in Section 33.1.1.

Where the command omits database name, user, host, or port, the new connection can reuse values from the previous connection. By default, values from the previous connection are reused except when processing a *conninfo* string. Passing a first argument of `-reuse-previous=on` or `-reuse-previous=off` overrides that default. When the command neither specifies nor reuses a particular parameter, the libpq default is used. Specifying any of *dbname*, *username*, *host* or *port* as `-` is equivalent to omitting that parameter. If *hostaddr* was specified in the original connection's *conninfo*, that address is reused for the new connection (disregarding any other host specification).

If the new connection is successfully made, the previous connection is closed. If the connection attempt failed (wrong user name, access denied, etc.), the previous connection will only be kept if psql is in interactive mode. When executing a non-interactive script, processing will immediately stop with an error. This distinction was chosen as a user convenience against typos on the one hand, and a safety mechanism that scripts are not accidentally acting on the wrong database on the other hand.

Examples:

```
=> \c mydb myuser host.dom 6432
=> \c service=foo
=> \c "host=localhost port=5432 dbname=mydb connect_timeout=10
    sslmode=disable"
=> \c postgresql://tom@localhost/mydb?application_name=myapp
```

`\C` [*title*]

Sets the title of any tables being printed as the result of a query or unset any such title. This command is equivalent to `\pset title title`. (The name of this command derives from “caption”, as it was previously only used to set the caption in an HTML table.)

`\cd` [*directory*]

Changes the current working directory to *directory*. Without argument, changes to the current user's home directory.

Tip

To print your current working directory, use `\! pwd`.

`\conninfo`

Outputs information about the current database connection.

```
\copy { table [ ( column_list ) ] | ( query ) } { from | to } {
'filename' | program 'command' | stdin | stdout | pstdin | pstdout }
[ [ with ] ( option [, ...] ) ]
```

Performs a frontend (client) copy. This is an operation that runs an SQL COPY command, but instead of the server reading or writing the specified file, psql reads or writes the file and routes the data between the server and the local file system. This means that file accessibility and privileges are those of the local user, not the server, and no SQL superuser privileges are required.

When `program` is specified, `command` is executed by psql and the data passed from or to `command` is routed between the server and the client. Again, the execution privileges are those of the local user, not the server, and no SQL superuser privileges are required.

For `\copy ... from stdin`, data rows are read from the same source that issued the command, continuing until `\.` is read or the stream reaches EOF. This option is useful for populating tables in-line within a SQL script file. For `\copy ... to stdout`, output is sent to the same place as psql command output, and the COPY *count* command status is not printed (since it might be confused with a data row). To read/write psql's standard input or output regardless of the current command source or `\o` option, write from `pstdin` or to `pstdout`.

The syntax of this command is similar to that of the SQL COPY command. All options other than the data source/destination are as specified for COPY. Because of this, special parsing rules apply to the `\copy` meta-command. Unlike most other meta-commands, the entire remainder of the line is always taken to be the arguments of `\copy`, and neither variable interpolation nor backquote expansion are performed in the arguments.

Tip

Another way to obtain the same result as `\copy ... to` is to use the SQL COPY ... TO STDOUT command and terminate it with `\g filename` or `\g |program`. Unlike `\copy`, this method allows the command to span multiple lines; also, variable interpolation and backquote expansion can be used.

Tip

These operations are not as efficient as the SQL COPY command with a file or program data source or destination, because all data must pass through the client/server connection. For large amounts of data the SQL command might be preferable.

`\copyright`

Shows the copyright and distribution terms of PostgreSQL.

```
\crosstabview [ colV [ colH [ colD [ sortcolH ] ] ] ]
```

Executes the current query buffer (like `\g`) and shows the results in a crosstab grid. The query must return at least three columns. The output column identified by `colV` becomes a vertical

header and the output column identified by *colH* becomes a horizontal header. *colD* identifies the output column to display within the grid. *sortcolH* identifies an optional sort column for the horizontal header.

Each column specification can be a column number (starting at 1) or a column name. The usual SQL case folding and quoting rules apply to column names. If omitted, *colV* is taken as column 1 and *colH* as column 2. *colH* must differ from *colV*. If *colD* is not specified, then there must be exactly three columns in the query result, and the column that is neither *colV* nor *colH* is taken to be *colD*.

The vertical header, displayed as the leftmost column, contains the values found in column *colV*, in the same order as in the query results, but with duplicates removed.

The horizontal header, displayed as the first row, contains the values found in column *colH*, with duplicates removed. By default, these appear in the same order as in the query results. But if the optional *sortcolH* argument is given, it identifies a column whose values must be integer numbers, and the values from *colH* will appear in the horizontal header sorted according to the corresponding *sortcolH* values.

Inside the crosstab grid, for each distinct value *x* of *colH* and each distinct value *y* of *colV*, the cell located at the intersection (*x*, *y*) contains the value of the *colD* column in the query result row for which the value of *colH* is *x* and the value of *colV* is *y*. If there is no such row, the cell is empty. If there are multiple such rows, an error is reported.

`\d[S+] [pattern]`

For each relation (table, view, materialized view, index, sequence, or foreign table) or composite type matching the *pattern*, show all columns, their types, the tablespace (if not the default) and any special attributes such as NOT NULL or defaults. Associated indexes, constraints, rules, and triggers are also shown. For foreign tables, the associated foreign server is shown as well. (“Matching the pattern” is defined in Patterns below.)

For some types of relation, `\d` shows additional information for each column: column values for sequences, indexed expressions for indexes, and foreign data wrapper options for foreign tables.

The command form `\d+` is identical, except that more information is displayed: any comments associated with the columns of the table are shown, as is the presence of OIDs in the table, the view definition if the relation is a view, a non-default replica identity setting.

By default, only user-created objects are shown; supply a *pattern* or the *S* modifier to include system objects.

Note

If `\d` is used without a *pattern* argument, it is equivalent to `\dtvmsE` which will show a list of all visible tables, views, materialized views, sequences and foreign tables. This is purely a convenience measure.

`\da[S] [pattern]`

Lists aggregate functions, together with their return type and the data types they operate on. If *pattern* is specified, only aggregates whose names match the *pattern* are shown. By default, only user-created objects are shown; supply a *pattern* or the *S* modifier to include system objects.

`\dA[+] [pattern]`

Lists access methods. If *pattern* is specified, only access methods whose names match the *pattern* are shown. If *+* is appended to the command name, each access method is listed with its associated handler function and description.

```
\db[+] [ pattern ]
```

Lists tablespaces. If *pattern* is specified, only tablespaces whose names match the pattern are shown. If + is appended to the command name, each tablespace is listed with its associated options, on-disk size, permissions and description.

```
\dc[S+] [ pattern ]
```

Lists conversions between character-set encodings. If *pattern* is specified, only conversions whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If + is appended to the command name, each object is listed with its associated description.

```
\dC[+] [ pattern ]
```

Lists type casts. If *pattern* is specified, only casts whose source or target types match the pattern are listed. If + is appended to the command name, each object is listed with its associated description.

```
\dd[S] [ pattern ]
```

Shows the descriptions of objects of type `constraint`, `operator class`, `operator family`, `rule`, and `trigger`. All other comments may be viewed by the respective backslash commands for those object types.

`\dd` displays descriptions for objects matching the *pattern*, or of visible objects of the appropriate type if no argument is given. But in either case, only objects that have a description are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects.

Descriptions for objects can be created with the `COMMENT SQL` command.

```
\dD[S+] [ pattern ]
```

Lists domains. If *pattern* is specified, only domains whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If + is appended to the command name, each object is listed with its associated permissions and description.

```
\ddp [ pattern ]
```

Lists default access privilege settings. An entry is shown for each role (and schema, if applicable) for which the default privilege settings have been changed from the built-in defaults. If *pattern* is specified, only entries whose role name or schema name matches the pattern are listed.

The `ALTER DEFAULT PRIVILEGES` command is used to set default access privileges. The meaning of the privilege display is explained in Section 5.7.

```
\dE[S+] [ pattern ]
```

```
\di[S+] [ pattern ]
```

```
\dm[S+] [ pattern ]
```

```
\ds[S+] [ pattern ]
```

```
\dt[S+] [ pattern ]
```

```
\dv[S+] [ pattern ]
```

In this group of commands, the letters *E*, *i*, *m*, *s*, *t*, and *v* stand for foreign table, index, materialized view, sequence, table, and view, respectively. You can specify any or all of these letters, in any order, to obtain a listing of objects of these types. For example, `\dit` lists indexes and tables. If + is appended to the command name, each object is listed with its physical size on disk and its associated description, if any. If *pattern* is specified, only objects whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects.

`\des[+] [pattern]`

Lists foreign servers (mnemonic: “external servers”). If *pattern* is specified, only those servers whose name matches the pattern are listed. If the form `\des+` is used, a full description of each server is shown, including the server’s access privileges, type, version, options, and description.

`\det[+] [pattern]`

Lists foreign tables (mnemonic: “external tables”). If *pattern* is specified, only entries whose table name or schema name matches the pattern are listed. If the form `\det+` is used, generic options and the foreign table description are also displayed.

`\deu[+] [pattern]`

Lists user mappings (mnemonic: “external users”). If *pattern* is specified, only those mappings whose user names match the pattern are listed. If the form `\deu+` is used, additional information about each mapping is shown.

Caution

`\deu+` might also display the user name and password of the remote user, so care should be taken not to disclose them.

`\dew[+] [pattern]`

Lists foreign-data wrappers (mnemonic: “external wrappers”). If *pattern* is specified, only those foreign-data wrappers whose name matches the pattern are listed. If the form `\dew+` is used, the access privileges, options, and description of the foreign-data wrapper are also shown.

`\df[anptwS+] [pattern]`

Lists functions, together with their result data types, argument data types, and function types, which are classified as “agg” (aggregate), “normal”, “procedure”, “trigger”, or “window”. To display only functions of specific type(s), add the corresponding letters a, n, p, t, or w to the command. If *pattern* is specified, only functions whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If the form `\df+` is used, additional information about each function is shown, including volatility, parallel safety, owner, security classification, access privileges, language, source code and description.

Tip

To look up functions taking arguments or returning values of a specific data type, use your pager’s search capability to scroll through the `\df` output.

`\dF[+] [pattern]`

Lists text search configurations. If *pattern* is specified, only configurations whose names match the pattern are shown. If the form `\dF+` is used, a full description of each configuration is shown, including the underlying text search parser and the dictionary list for each parser token type.

`\dFd[+] [pattern]`

Lists text search dictionaries. If *pattern* is specified, only dictionaries whose names match the pattern are shown. If the form `\dFd+` is used, additional information is shown about each selected dictionary, including the underlying text search template and the option values.

```
\dFp[+] [ pattern ]
```

Lists text search parsers. If *pattern* is specified, only parsers whose names match the pattern are shown. If the form `\dFp+` is used, a full description of each parser is shown, including the underlying functions and the list of recognized token types.

```
\dFt[+] [ pattern ]
```

Lists text search templates. If *pattern* is specified, only templates whose names match the pattern are shown. If the form `\dFt+` is used, additional information is shown about each template, including the underlying function names.

```
\dg[S+] [ pattern ]
```

Lists database roles. (Since the concepts of “users” and “groups” have been unified into “roles”, this command is now equivalent to `\du`.) By default, only user-created roles are shown; supply the *S* modifier to include system roles. If *pattern* is specified, only those roles whose names match the pattern are listed. If the form `\dg+` is used, additional information is shown about each role; currently this adds the comment for each role.

```
\dl
```

This is an alias for `\lo_list`, which shows a list of large objects.

```
\dL[S+] [ pattern ]
```

Lists procedural languages. If *pattern* is specified, only languages whose names match the pattern are listed. By default, only user-created languages are shown; supply the *S* modifier to include system objects. If `+` is appended to the command name, each language is listed with its call handler, validator, access privileges, and whether it is a system object.

```
\dn[S+] [ pattern ]
```

Lists schemas (namespaces). If *pattern* is specified, only schemas whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If `+` is appended to the command name, each object is listed with its associated permissions and description, if any.

```
\do[S+] [ pattern ]
```

Lists operators with their operand and result types. If *pattern* is specified, only operators whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If `+` is appended to the command name, additional information about each operator is shown, currently just the name of the underlying function.

```
\dO[S+] [ pattern ]
```

Lists collations. If *pattern* is specified, only collations whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects. If `+` is appended to the command name, each collation is listed with its associated description, if any. Note that only collations usable with the current database's encoding are shown, so the results may vary in different databases of the same installation.

```
\dp [ pattern ]
```

Lists tables, views and sequences with their associated access privileges. If *pattern* is specified, only tables, views and sequences whose names match the pattern are listed.

The `GRANT` and `REVOKE` commands are used to set access privileges. The meaning of the privilege display is explained in Section 5.7.

```
\dP[itn+] [ pattern ]
```

Lists partitioned relations. If *pattern* is specified, only entries whose name matches the pattern are listed. The modifiers *t* (tables) and *i* (indexes) can be appended to the command, filtering the kind of relations to list. By default, partitioned tables and indexes are listed.

If the modifier *n* (“nested”) is used, or a pattern is specified, then non-root partitioned relations are included, and a column is shown displaying the parent of each partitioned relation.

If *+* is appended to the command name, the sum of the sizes of each relation's partitions is also displayed, along with the relation's description. If *n* is combined with *+*, two sizes are shown: one including the total size of directly-attached leaf partitions, and another showing the total size of all partitions, including indirectly attached sub-partitions.

```
\drds [ role-pattern [ database-pattern ] ]
```

Lists defined configuration settings. These settings can be role-specific, database-specific, or both. *role-pattern* and *database-pattern* are used to select specific roles and databases to list, respectively. If omitted, or if *** is specified, all settings are listed, including those not role-specific or database-specific, respectively.

The ALTER ROLE and ALTER DATABASE commands are used to define per-role and per-database configuration settings.

```
\dRp[+] [ pattern ]
```

Lists replication publications. If *pattern* is specified, only those publications whose names match the pattern are listed. If *+* is appended to the command name, the tables associated with each publication are shown as well.

```
\dRs[+] [ pattern ]
```

Lists replication subscriptions. If *pattern* is specified, only those subscriptions whose names match the pattern are listed. If *+* is appended to the command name, additional properties of the subscriptions are shown.

```
\dT[S+] [ pattern ]
```

Lists data types. If *pattern* is specified, only types whose names match the pattern are listed. If *+* is appended to the command name, each type is listed with its internal name and size, its allowed values if it is an enum type, and its associated permissions. By default, only user-created objects are shown; supply a pattern or the *S* modifier to include system objects.

```
\du[S+] [ pattern ]
```

Lists database roles. (Since the concepts of “users” and “groups” have been unified into “roles”, this command is now equivalent to `\dgr`.) By default, only user-created roles are shown; supply the *S* modifier to include system roles. If *pattern* is specified, only those roles whose names match the pattern are listed. If the form `\du+` is used, additional information is shown about each role; currently this adds the comment for each role.

```
\dx[+] [ pattern ]
```

Lists installed extensions. If *pattern* is specified, only those extensions whose names match the pattern are listed. If the form `\dx+` is used, all the objects belonging to each matching extension are listed.

```
\dy[+] [ pattern ]
```

Lists event triggers. If *pattern* is specified, only those event triggers whose names match the pattern are listed. If *+* is appended to the command name, each object is listed with its associated description.

```
\e or \edit [ filename ] [ line_number ]
```

If *filename* is specified, the file is edited; after the editor exits, the file's content is copied into the current query buffer. If no *filename* is given, the current query buffer is copied to a temporary file which is then edited in the same fashion. Or, if the current query buffer is empty, the most recently executed query is copied to a temporary file and edited in the same fashion.

The new contents of the query buffer are then re-parsed according to the normal rules of psql, treating the whole buffer as a single line. Any complete queries are immediately executed; that is, if the query buffer contains or ends with a semicolon, everything up to that point is executed. Whatever remains will wait in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel it by clearing the query buffer. Treating the buffer as a single line primarily affects meta-commands: whatever is in the buffer after a meta-command will be taken as argument(s) to the meta-command, even if it spans multiple lines. (Thus you cannot make meta-command-using scripts this way. Use `\i` for that.)

If a line number is specified, psql will position the cursor on the specified line of the file or query buffer. Note that if a single all-digits argument is given, psql assumes it is a line number, not a file name.

Tip

See under Environment for how to configure and customize your editor.

```
\echo text [ ... ]
```

Prints the arguments to the standard output, separated by one space and followed by a newline. This can be useful to intersperse information in the output of scripts. For example:

```
=> \echo `date`
Tue Oct 26 21:40:57 CEST 1999
```

If the first argument is an unquoted `-n` the trailing newline is not written.

Tip

If you use the `\o` command to redirect your query output you might wish to use `\qecho` instead of this command.

```
\ef [ function_description [ line_number ] ]
```

This command fetches and edits the definition of the named function or procedure, in the form of a `CREATE OR REPLACE FUNCTION` or `CREATE OR REPLACE PROCEDURE` command. Editing is done in the same way as for `\edit`. After the editor exits, the updated command waits in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If no function is specified, a blank `CREATE FUNCTION` template is presented for editing.

If a line number is specified, psql will position the cursor on the specified line of the function body. (Note that the function body typically does not begin on the first line of the file.)

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\ef`, and neither variable interpolation nor backquote expansion are performed in the arguments.

Tip

See under Environment for how to configure and customize your editor.

`\encoding [encoding]`

Sets the client character set encoding. Without an argument, this command shows the current encoding.

`\errverbose`

Repeats the most recent server error message at maximum verbosity, as though `VERBOSITY` were set to `verbose` and `SHOW_CONTEXT` were set to `always`.

`\ev [view_name [line_number]]`

This command fetches and edits the definition of the named view, in the form of a `CREATE OR REPLACE VIEW` command. Editing is done in the same way as for `\edit`. After the editor exits, the updated command waits in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel.

If no view is specified, a blank `CREATE VIEW` template is presented for editing.

If a line number is specified, psql will position the cursor on the specified line of the view definition.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\ev`, and neither variable interpolation nor backquote expansion are performed in the arguments.

`\f [string]`

Sets the field separator for unaligned query output. The default is the vertical bar (`|`). It is equivalent to `\pset fieldsep`.

`\g [filename]`

`\g [|command]`

Sends the current query buffer to the server for execution. If an argument is given, the query's output is written to the named file or piped to the given shell command, instead of displaying it as usual. The file or command is written to only if the query successfully returns zero or more tuples, not if the query fails or is a non-data-returning SQL command.

If the current query buffer is empty, the most recently sent query is re-executed instead. Except for that behavior, `\g` without an argument is essentially equivalent to a semicolon. A `\g` with argument is a “one-shot” alternative to the `\o` command.

If the argument begins with `|`, then the entire remainder of the line is taken to be the *command* to execute, and neither variable interpolation nor backquote expansion are performed in it. The rest of the line is simply passed literally to the shell.

`\gdesc`

Shows the description (that is, the column names and data types) of the result of the current query buffer. The query is not actually executed; however, if it contains some type of syntax error, that error will be reported in the normal way.

If the current query buffer is empty, the most recently sent query is described instead.

`\gexec`

Sends the current query buffer to the server, then treats each column of each row of the query's output (if any) as a SQL statement to be executed. For example, to create an index on each column of `my_table`:

```
=> SELECT format('create index on my_table(%I)', attname)
-> FROM pg_attribute
-> WHERE attrelid = 'my_table'::regclass AND attnum > 0
-> ORDER BY attnum
-> \gexec
CREATE INDEX
CREATE INDEX
CREATE INDEX
CREATE INDEX
```

The generated queries are executed in the order in which the rows are returned, and left-to-right within each row if there is more than one column. NULL fields are ignored. The generated queries are sent literally to the server for processing, so they cannot be psql meta-commands nor contain psql variable references. If any individual query fails, execution of the remaining queries continues unless `ON_ERROR_STOP` is set. Execution of each query is subject to ECHO processing. (Setting ECHO to `all` or `queries` is often advisable when using `\gexec`.) Query logging, single-step mode, timing, and other query execution features apply to each generated query as well.

If the current query buffer is empty, the most recently sent query is re-executed instead.

`\gset [prefix]`

Sends the current query buffer to the server and stores the query's output into psql variables (see Variables). The query to be executed must return exactly one row. Each column of the row is stored into a separate variable, named the same as the column. For example:

```
=> SELECT 'hello' AS var1, 10 AS var2
-> \gset
=> \echo :var1 :var2
hello 10
```

If you specify a *prefix*, that string is prepended to the query's column names to create the variable names to use:

```
=> SELECT 'hello' AS var1, 10 AS var2
-> \gset result_
=> \echo :result_var1 :result_var2
hello 10
```

If a column result is NULL, the corresponding variable is unset rather than being set.

If the query fails or does not return one row, no variables are changed.

If the current query buffer is empty, the most recently sent query is re-executed instead.

`\gx [filename]`
`\gx [|command]`

`\gx` is equivalent to `\g`, but forces expanded output mode for this query. See `\x`.

`\h` or `\help [command]`

Gives syntax help on the specified SQL command. If *command* is not specified, then psql will list all the commands for which syntax help is available. If *command* is an asterisk (*), then syntax help on all SQL commands is shown.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\help`, and neither variable interpolation nor backquote expansion are performed in the arguments.

Note

To simplify typing, commands that consists of several words do not have to be quoted. Thus it is fine to type `\help alter table`.

`\H` or `\html`

Turns on HTML query output format. If the HTML format is already on, it is switched back to the default aligned text format. This command is for compatibility and convenience, but see `\pset` about setting other output options.

`\i` or `\include filename`

Reads input from the file *filename* and executes it as though it had been typed on the keyboard.

If *filename* is - (hyphen), then standard input is read until an EOF indication or `\q` meta-command. This can be used to intersperse interactive input with input from files. Note that Readline behavior will be used only if it is active at the outermost level.

Note

If you want to see the lines on the screen as they are read you must set the variable ECHO to all.

```
\if expression
\elif expression
\else
\endif
```

This group of commands implements nestable conditional blocks. A conditional block must begin with an `\if` and end with an `\endif`. In between there may be any number of `\elif` clauses, which may optionally be followed by a single `\else` clause. Ordinary queries and other types of backslash commands may (and usually do) appear between the commands forming a conditional block.

The `\if` and `\elif` commands read their argument(s) and evaluate them as a boolean expression. If the expression yields true then processing continues normally; otherwise, lines are skipped until a matching `\elif`, `\else`, or `\endif` is reached. Once an `\if` or `\elif` test has succeeded, the arguments of later `\elif` commands in the same block are not evaluated but are treated as false. Lines following an `\else` are processed only if no earlier matching `\if` or `\elif` succeeded.

The *expression* argument of an `\if` or `\elif` command is subject to variable interpolation and backquote expansion, just like any other backslash command argument. After that it is evaluated like the value of an on/off option variable. So a valid value is any unambiguous case-insen-

sitive match for one of: true, false, 1, 0, on, off, yes, no. For example, t, T, and tR will all be considered to be true.

Expressions that do not properly evaluate to true or false will generate a warning and be treated as false.

Lines being skipped are parsed normally to identify queries and backslash commands, but queries are not sent to the server, and backslash commands other than conditionals (`\if`, `\elif`, `\else`, `\endif`) are ignored. Conditional commands are checked only for valid nesting. Variable references in skipped lines are not expanded, and backquote expansion is not performed either.

All the backslash commands of a given conditional block must appear in the same source file. If EOF is reached on the main input file or an `\include`-ed file before all local `\if`-blocks have been closed, then psql will raise an error.

Here is an example:

```
-- check for the existence of two separate records in the
-- database and store
-- the results in separate psql variables
SELECT
    EXISTS(SELECT 1 FROM customer WHERE customer_id = 123) as
    is_customer,
    EXISTS(SELECT 1 FROM employee WHERE employee_id = 456) as
    is_employee
\gset
\if :is_customer
    SELECT * FROM customer WHERE customer_id = 123;
\elif :is_employee
    \echo 'is not a customer but is an employee'
    SELECT * FROM employee WHERE employee_id = 456;
\else
    \if yes
        \echo 'not a customer or employee'
    \else
        \echo 'this will never print'
    \endif
\endif
```

`\ir` or `\include_relative filename`

The `\ir` command is similar to `\i`, but resolves relative file names differently. When executing in interactive mode, the two commands behave identically. However, when invoked from a script, `\ir` interprets file names relative to the directory in which the script is located, rather than the current working directory.

`\l[+]` or `\list[+] [pattern]`

List the databases in the server and show their names, owners, character set encodings, and access privileges. If *pattern* is specified, only databases whose names match the pattern are listed. If + is appended to the command name, database sizes, default tablespaces, and descriptions are also displayed. (Size information is only available for databases that the current user can connect to.)

`\lo_export oid filename`

Reads the large object with OID *loid* from the database and writes it to *filename*. Note that this is subtly different from the server function `lo_export`, which acts with the permissions of the user that the database server runs as and on the server's file system.

Tip

Use `\lo_list` to find out the large object's OID.

```
\lo_import filename [ comment ]
```

Stores the file into a PostgreSQL large object. Optionally, it associates the given comment with the object. Example:

```
foo=> \lo_import '/home/peter/pictures/photo.xcf' 'a picture of  
me'  
lo_import 152801
```

The response indicates that the large object received object ID 152801, which can be used to access the newly-created large object in the future. For the sake of readability, it is recommended to always associate a human-readable comment with every object. Both OIDs and comments can be viewed with the `\lo_list` command.

Note that this command is subtly different from the server-side `lo_import` because it acts as the local user on the local file system, rather than the server's user and file system.

```
\lo_list
```

Shows a list of all PostgreSQL large objects currently stored in the database, along with any comments provided for them.

```
\lo_unlink oid
```

Deletes the large object with OID *oid* from the database.

Tip

Use `\lo_list` to find out the large object's OID.

```
\o or \out [ filename ]
```

```
\o or \out [ |command ]
```

Arranges to save future query results to the file *filename* or pipe future results to the shell command *command*. If no argument is specified, the query output is reset to the standard output.

If the argument begins with `|`, then the entire remainder of the line is taken to be the *command* to execute, and neither variable interpolation nor backquote expansion are performed in it. The rest of the line is simply passed literally to the shell.

“Query results” includes all tables, command responses, and notices obtained from the database server, as well as output of various backslash commands that query the database (such as `\d`); but not error messages.

Tip

To intersperse text output in between query results, use `\qecho`.

`\p` or `\print`

Print the current query buffer to the standard output. If the current query buffer is empty, the most recently executed query is printed instead.

`\password [username]`

Changes the password of the specified user (by default, the current user). This command prompts for the new password, encrypts it, and sends it to the server as an `ALTER ROLE` command. This makes sure that the new password does not appear in cleartext in the command history, the server log, or elsewhere.

`\prompt [text] name`

Prompts the user to supply text, which is assigned to the variable *name*. An optional prompt string, *text*, can be specified. (For multiword prompts, surround the text with single quotes.)

By default, `\prompt` uses the terminal for input and output. However, if the `-f` command line switch was used, `\prompt` uses standard input and standard output.

`\pset [option [value]]`

This command sets options affecting the output of query result tables. *option* indicates which option is to be set. The semantics of *value* vary depending on the selected option. For some options, omitting *value* causes the option to be toggled or unset, as described under the particular option. If no such behavior is mentioned, then omitting *value* just results in the current setting being displayed.

`\pset` without any arguments displays the current status of all printing options.

Adjustable printing options are:

`border`

The *value* must be a number. In general, the higher the number the more borders and lines the tables will have, but details depend on the particular format. In `HTML` format, this will translate directly into the `border=...` attribute. In most other formats only values 0 (no border), 1 (internal dividing lines), and 2 (table frame) make sense, and values above 2 will be treated the same as `border = 2`. The `latex` and `latex-longtable` formats additionally allow a value of 3 to add dividing lines between data rows.

`columns`

Sets the target width for the `wrapped` format, and also the width limit for determining whether output is wide enough to require the pager or switch to the vertical display in expanded auto mode. Zero (the default) causes the target width to be controlled by the environment variable `COLUMNS`, or the detected screen width if `COLUMNS` is not set. In addition, if `columns` is zero then the `wrapped` format only affects screen output. If `columns` is nonzero then file and pipe output is wrapped to that width as well.

`csv_fieldsep`

Specifies the field separator to be used in CSV output format. If the separator character appears in a field's value, that field is output within double quotes, following standard CSV rules. The default is a comma.

`expanded (or x)`

If *value* is specified it must be either `on` or `off`, which will enable or disable expanded mode, or `auto`. If *value* is omitted the command toggles between the on and off settings.

When expanded mode is enabled, query results are displayed in two columns, with the column name on the left and the data on the right. This mode is useful if the data wouldn't fit on the screen in the normal “horizontal” mode. In the auto setting, the expanded mode is used whenever the query output has more than one column and is wider than the screen; otherwise, the regular mode is used. The auto setting is only effective in the aligned and wrapped formats. In other formats, it always behaves as if the expanded mode is off.

fieldsep

Specifies the field separator to be used in unaligned output format. That way one can create, for example, tab-separated output, which other programs might prefer. To set a tab as field separator, type `\pset fieldsep '\t'`. The default field separator is `'|'` (a vertical bar).

fieldsep_zero

Sets the field separator to use in unaligned output format to a zero byte.

footer

If *value* is specified it must be either `on` or `off` which will enable or disable display of the table footer (the `(n rows)` count). If *value* is omitted the command toggles footer display on or off.

format

Sets the output format to one of `aligned`, `asciidoc`, `csv`, `html`, `latex`, `latex-longtable`, `troff-ms`, `unaligned`, or `wrapped`. Unique abbreviations are allowed.

`aligned` format is the standard, human-readable, nicely formatted text output; this is the default.

`unaligned` format writes all columns of a row on one line, separated by the currently active field separator. This is useful for creating output that might be intended to be read in by other programs, for example, tab-separated or comma-separated format. However, the field separator character is not treated specially if it appears in a column's value; so CSV format may be better suited for such purposes.

`csv` format writes column values separated by commas, applying the quoting rules described in RFC 4180¹. This output is compatible with the CSV format of the server's `COPY` command. A header line with column names is generated unless the `tuples_only` parameter is on. Titles and footers are not printed. Each row is terminated by the system-dependent end-of-line character, which is typically a single newline (`\n`) for Unix-like systems or a carriage return and newline sequence (`\r\n`) for Microsoft Windows. Field separator characters other than comma can be selected with `\pset csv_fieldsep`.

`wrapped` format is like `aligned` but wraps wide data values across lines to make the output fit in the target column width. The target width is determined as described under the `columns` option. Note that `psql` will not attempt to wrap column header titles; therefore, `wrapped` format behaves the same as `aligned` if the total width needed for column headers exceeds the target.

The `asciidoc`, `html`, `latex`, `latex-longtable`, and `troff-ms` formats put out tables that are intended to be included in documents using the respective mark-up language. They are not complete documents! This might not be necessary in HTML, but in LaTeX you must have a complete document wrapper. The `latex` format uses LaTeX's `tabular` environment. The `latex-longtable` format requires the LaTeX `longtable` and `booktabs` packages.

¹ <https://tools.ietf.org/html/rfc4180>

linestyle

Sets the border line drawing style to one of `ascii`, `old-ascii`, or `unicode`. Unique abbreviations are allowed. (That would mean one letter is enough.) The default setting is `ascii`. This option only affects the aligned and wrapped output formats.

`ascii` style uses plain ASCII characters. Newlines in data are shown using a `+` symbol in the right-hand margin. When the wrapped format wraps data from one line to the next without a newline character, a dot (`.`) is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

`old-ascii` style uses plain ASCII characters, using the formatting style used in PostgreSQL 8.4 and earlier. Newlines in data are shown using a `:` symbol in place of the left-hand column separator. When the data is wrapped from one line to the next without a newline character, a `;` symbol is used in place of the left-hand column separator.

`unicode` style uses Unicode box-drawing characters. Newlines in data are shown using a carriage return symbol in the right-hand margin. When the data is wrapped from one line to the next without a newline character, an ellipsis symbol is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

When the `border` setting is greater than zero, the `linestyle` option also determines the characters with which the border lines are drawn. Plain ASCII characters work everywhere, but Unicode characters look nicer on displays that recognize them.

null

Sets the string to be printed in place of a null value. The default is to print nothing, which can easily be mistaken for an empty string. For example, one might prefer `\pset null '(null)'`.

numericlocale

If *value* is specified it must be either `on` or `off` which will enable or disable display of a locale-specific character to separate groups of digits to the left of the decimal marker. If *value* is omitted the command toggles between regular and locale-specific numeric output.

pager

Controls use of a pager program for query and psql help output. If the environment variable `PSQL_PAGER` or `PAGER` is set, the output is piped to the specified program. Otherwise a platform-dependent default program (such as `more`) is used.

When the `pager` option is `off`, the pager program is not used. When the `pager` option is `on`, the pager is used when appropriate, i.e., when the output is to a terminal and will not fit on the screen. The `pager` option can also be set to `always`, which causes the pager to be used for all terminal output regardless of whether it fits on the screen. `\pset pager` without a *value* toggles pager use on and off.

pager_min_lines

If `pager_min_lines` is set to a number greater than the page height, the pager program will not be called unless there are at least this many lines of output to show. The default setting is 0.

recordsep

Specifies the record (line) separator to use in unaligned output format. The default is a newline character.

`recordsep_zero`

Sets the record separator to use in unaligned output format to a zero byte.

`tableattr` (or `T`)

In HTML format, this specifies attributes to be placed inside the `table` tag. This could for example be `cellpadding` or `bgcolor`. Note that you probably don't want to specify `border` here, as that is already taken care of by `\pset border`. If no *value* is given, the table attributes are unset.

In `latex-longtable` format, this controls the proportional width of each column containing a left-aligned data type. It is specified as a whitespace-separated list of values, e.g. `'0.2 0.2 0.6'`. Unspecified output columns use the last specified value.

`title` (or `C`)

Sets the table title for any subsequently printed tables. This can be used to give your output descriptive tags. If no *value* is given, the title is unset.

`tuples_only` (or `t`)

If *value* is specified it must be either `on` or `off` which will enable or disable tuples-only mode. If *value* is omitted the command toggles between regular and tuples-only output. Regular output includes extra information such as column headers, titles, and various footers. In tuples-only mode, only actual table data is shown.

`unicode_border_linestyle`

Sets the border drawing style for the unicode line style to one of `single` or `double`.

`unicode_column_linestyle`

Sets the column drawing style for the unicode line style to one of `single` or `double`.

`unicode_header_linestyle`

Sets the header drawing style for the unicode line style to one of `single` or `double`.

Illustrations of how these different formats look can be seen in the Examples section.

Tip

There are various shortcut commands for `\pset`. See `\a`, `\C`, `\f`, `\H`, `\t`, `\T`, and `\x`.

`\q` or `\quit`

Quits the psql program. In a script file, only execution of that script is terminated.

`\qecho text [...]`

This command is identical to `\echo` except that the output will be written to the query output channel, as set by `\o`.

`\r` or `\reset`

Resets (clears) the query buffer.

`\s [filename]`

Print psql's command line history to *filename*. If *filename* is omitted, the history is written to the standard output (using the pager if appropriate). This command is not available if psql was built without Readline support.

`\set [name [value [...]]]`

Sets the psql variable *name* to *value*, or if more than one value is given, to the concatenation of all of them. If only one argument is given, the variable is set to an empty-string value. To unset a variable, use the `\unset` command.

`\set` without any arguments displays the names and values of all currently-set psql variables.

Valid variable names can contain letters, digits, and underscores. See the section Variables below for details. Variable names are case-sensitive.

Certain variables are special, in that they control psql's behavior or are automatically set to reflect connection state. These variables are documented in Variables, below.

Note

This command is unrelated to the SQL command SET.

`\setenv name [value]`

Sets the environment variable *name* to *value*, or if the *value* is not supplied, unsets the environment variable. Example:

```
testdb=> \setenv PAGER less
testdb=> \setenv LESS -imx4F
```

`\sf[+] function_description`

This command fetches and shows the definition of the named function or procedure, in the form of a CREATE OR REPLACE FUNCTION or CREATE OR REPLACE PROCEDURE command. The definition is printed to the current query output channel, as set by `\o`.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If `+` is appended to the command name, then the output lines are numbered, with the first line of the function body being line 1.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\sf`, and neither variable interpolation nor backquote expansion are performed in the arguments.

`\sv[+] view_name`

This command fetches and shows the definition of the named view, in the form of a CREATE OR REPLACE VIEW command. The definition is printed to the current query output channel, as set by `\o`.

If `+` is appended to the command name, then the output lines are numbered from 1.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\sv`, and neither variable interpolation nor backquote expansion are performed in the arguments.

`\t`

Toggles the display of output column name headings and row count footer. This command is equivalent to `\pset tuples_only` and is provided for convenience.

`\T table_options`

Specifies attributes to be placed within the `table` tag in HTML output format. This command is equivalent to `\pset tableattr table_options`.

`\timing [on | off]`

With a parameter, turns displaying of how long each SQL statement takes on or off. Without a parameter, toggles the display between on and off. The display is in milliseconds; intervals longer than 1 second are also shown in minutes:seconds format, with hours and days fields added if needed.

`\unset name`

Unsets (deletes) the psql variable *name*.

Most variables that control psql's behavior cannot be unset; instead, an `\unset` command is interpreted as setting them to their default values. See Variables, below.

`\w` or `\write filename`

`\w` or `\write |command`

Writes the current query buffer to the file *filename* or pipes it to the shell command *command*. If the current query buffer is empty, the most recently executed query is written instead.

If the argument begins with `|`, then the entire remainder of the line is taken to be the *command* to execute, and neither variable interpolation nor backquote expansion are performed in it. The rest of the line is simply passed literally to the shell.

`\watch [seconds]`

Repeatedly execute the current query buffer (as `\g` does) until interrupted or the query fails. Wait the specified number of seconds (default 2) between executions. Each query result is displayed with a header that includes the `\pset title` string (if any), the time as of query start, and the delay interval.

If the current query buffer is empty, the most recently sent query is re-executed instead.

`\x [on | off | auto]`

Sets or toggles expanded table formatting mode. As such it is equivalent to `\pset expanded`.

`\z [pattern]`

Lists tables, views and sequences with their associated access privileges. If a *pattern* is specified, only tables, views and sequences whose names match the pattern are listed.

This is an alias for `\dp` (“display privileges”).

`\! [command]`

With no argument, escapes to a sub-shell; psql resumes when the sub-shell exits. With an argument, executes the shell command *command*.

Unlike most other meta-commands, the entire remainder of the line is always taken to be the argument(s) of `\!`, and neither variable interpolation nor backquote expansion are performed in the arguments. The rest of the line is simply passed literally to the shell.

`\? [topic]`

Shows help information. The optional *topic* parameter (defaulting to `commands`) selects which part of psql is explained: `commands` describes psql's backslash commands; `options` describes the command-line options that can be passed to psql; and `variables` shows help about psql configuration variables.

`\;`

Backslash-semicolon is not a meta-command in the same way as the preceding commands; rather, it simply causes a semicolon to be added to the query buffer without any further processing.

Normally, psql will dispatch a SQL command to the server as soon as it reaches the command-ending semicolon, even if more input remains on the current line. Thus for example entering

```
select 1; select 2; select 3;
```

will result in the three SQL commands being individually sent to the server, with each one's results being displayed before continuing to the next command. However, a semicolon entered as `\;` will not trigger command processing, so that the command before it and the one after are effectively combined and sent to the server in one request. So for example

```
select 1\; select 2\; select 3;
```

results in sending the three SQL commands to the server in a single request, when the non-backslashed semicolon is reached. The server executes such a request as a single transaction, unless there are explicit `BEGIN/COMMIT` commands included in the string to divide it into multiple transactions. (See Section 52.2.2.1 for more details about how the server handles multi-query strings.) psql prints only the last query result it receives for each request; in this example, although all three `SELECT`s are indeed executed, psql only prints the 3.

Patterns

The various `\d` commands accept a *pattern* parameter to specify the object name(s) to be displayed. In the simplest case, a pattern is just the exact name of the object. The characters within a pattern are normally folded to lower case, just as in SQL names; for example, `\dt FOO` will display the table named `foo`. As in SQL names, placing double quotes around a pattern stops folding to lower case. Should you need to include an actual double quote character in a pattern, write it as a pair of double quotes within a double-quote sequence; again this is in accord with the rules for SQL quoted identifiers. For example, `\dt "FOO" "BAR"` will display the table named `FOO"BAR` (not `foo"bar`). Unlike the normal rules for SQL names, you can put double quotes around just part of a pattern, for instance `\dt FOO"FOO"BAR` will display the table named `fooFOObar`.

Whenever the *pattern* parameter is omitted completely, the `\d` commands display all objects that are visible in the current schema search path — this is equivalent to using `*` as the pattern. (An object is said to be *visible* if its containing schema is in the search path and no object of the same kind and name appears earlier in the search path. This is equivalent to the statement that the object can be referenced by name without explicit schema qualification.) To see all objects in the database regardless of visibility, use `*.*` as the pattern.

Within a pattern, `*` matches any sequence of characters (including no characters) and `?` matches any single character. (This notation is comparable to Unix shell file name patterns.) For example, `\dt int*` displays tables whose names begin with `int`. But within double quotes, `*` and `?` lose these special meanings and are just matched literally.

A pattern that contains a dot (.) is interpreted as a schema name pattern followed by an object name pattern. For example, `\dt foo*. *bar*` displays all tables whose table name includes `bar` that are in schemas whose schema name starts with `foo`. When no dot appears, then the pattern matches only objects that are visible in the current schema search path. Again, a dot within double quotes loses its special meaning and is matched literally.

Advanced users can use regular-expression notations such as character classes, for example `[0-9]` to match any digit. All regular expression special characters work as specified in Section 9.7.3, except for `.` which is taken as a separator as mentioned above, `*` which is translated to the regular-expression notation `.`, `?` which is translated to `.`, and `$` which is matched literally. You can emulate these pattern characters at need by writing `?` for `.`, `(R+|)` for `R*`, or `(R|)` for `R?`. `$` is not needed as a regular-expression character since the pattern must match the whole name, unlike the usual interpretation of regular expressions (in other words, `$` is automatically appended to your pattern). Write `*` at the beginning and/or end if you don't wish the pattern to be anchored. Note that within double quotes, all regular expression special characters lose their special meanings and are matched literally. Also, the regular expression special characters are matched literally in operator name patterns (i.e., the argument of `\do`).

Advanced Features

Variables

psql provides variable substitution features similar to common Unix command shells. Variables are simply name/value pairs, where the value can be any string of any length. The name must consist of letters (including non-Latin letters), digits, and underscores.

To set a variable, use the psql meta-command `\set`. For example,

```
testdb=> \set foo bar
```

sets the variable `foo` to the value `bar`. To retrieve the content of the variable, precede the name with a colon, for example:

```
testdb=> \echo :foo
bar
```

This works in both regular SQL commands and meta-commands; there is more detail in SQL Interpolation, below.

If you call `\set` without a second argument, the variable is set to an empty-string value. To unset (i.e., delete) a variable, use the command `\unset`. To show the values of all variables, call `\set` without any argument.

Note

The arguments of `\set` are subject to the same substitution rules as with other commands. Thus you can construct interesting references such as `\set :foo 'something'` and get “soft links” or “variable variables” of Perl or PHP fame, respectively. Unfortunately (or fortunately?), there is no way to do anything useful with these constructs. On the other hand, `\set bar :foo` is a perfectly valid way to copy a variable.

A number of these variables are treated specially by psql. They represent certain option settings that can be changed at run time by altering the value of the variable, or in some cases represent changeable

state of psql. By convention, all specially treated variables' names consist of all upper-case ASCII letters (and possibly digits and underscores). To ensure maximum compatibility in the future, avoid using such variable names for your own purposes.

Variables that control psql's behavior generally cannot be unset or set to invalid values. An `\unset` command is allowed but is interpreted as setting the variable to its default value. A `\set` command without a second argument is interpreted as setting the variable to `on`, for control variables that accept that value, and is rejected for others. Also, control variables that accept the values `on` and `off` will also accept other common spellings of Boolean values, such as `true` and `false`.

The specially treated variables are:

AUTOCOMMIT

When `on` (the default), each SQL command is automatically committed upon successful completion. To postpone commit in this mode, you must enter a `BEGIN` or `START TRANSACTION` SQL command. When `off` or `unset`, SQL commands are not committed until you explicitly issue `COMMIT` or `END`. The autocommit-off mode works by issuing an implicit `BEGIN` for you, just before any command that is not already in a transaction block and is not itself a `BEGIN` or other transaction-control command, nor a command that cannot be executed inside a transaction block (such as `VACUUM`).

Note

In autocommit-off mode, you must explicitly abandon any failed transaction by entering `ABORT` or `ROLLBACK`. Also keep in mind that if you exit the session without committing, your work will be lost.

Note

The autocommit-on mode is PostgreSQL's traditional behavior, but autocommit-off is closer to the SQL spec. If you prefer autocommit-off, you might wish to set it in the system-wide `psqlrc` file or your `~/.psqlrc` file.

COMP_KEYWORD_CASE

Determines which letter case to use when completing an SQL key word. If set to `lower` or `upper`, the completed word will be in lower or upper case, respectively. If set to `preserve-lower` or `preserve-upper` (the default), the completed word will be in the case of the word already entered, but words being completed without anything entered will be in lower or upper case, respectively.

DBNAME

The name of the database you are currently connected to. This is set every time you connect to a database (including program start-up), but can be changed or unset.

ECHO

If set to `all`, all nonempty input lines are printed to standard output as they are read. (This does not apply to lines read interactively.) To select this behavior on program start-up, use the switch `-a`. If set to `queries`, psql prints each query to standard output as it is sent to the server. The switch to select this behavior is `-e`. If set to `errors`, then only failed queries are displayed on standard error output. The switch for this behavior is `-b`. If set to `none` (the default), then no queries are displayed.

ECHO_HIDDEN

When this variable is set to `on` and a backslash command queries the database, the query is first shown. This feature helps you to study PostgreSQL internals and provide similar functionality in your own programs. (To select this behavior on program start-up, use the switch `-E`.) If you set this variable to the value `noexec`, the queries are just shown but are not actually sent to the server and executed. The default value is `off`.

ENCODING

The current client character set encoding. This is set every time you connect to a database (including program start-up), and when you change the encoding with `\encoding`, but it can be changed or unset.

ERROR

`true` if the last SQL query failed, `false` if it succeeded. See also `SQLSTATE`.

FETCH_COUNT

If this variable is set to an integer value greater than zero, the results of `SELECT` queries are fetched and displayed in groups of that many rows, rather than the default behavior of collecting the entire result set before display. Therefore only a limited amount of memory is used, regardless of the size of the result set. Settings of 100 to 1000 are commonly used when enabling this feature. Keep in mind that when using this feature, a query might fail after having already displayed some rows.

Tip

Although you can use any output format with this feature, the default `aligned` format tends to look bad because each group of `FETCH_COUNT` rows will be formatted separately, leading to varying column widths across the row groups. The other output formats work better.

HIDE_TABLEAM

If this variable is set to `true`, a table's access method details are not displayed. This is mainly useful for regression tests.

HISTCONTROL

If this variable is set to `ignoreSpace`, lines which begin with a space are not entered into the history list. If set to a value of `ignoreDups`, lines matching the previous history line are not entered. A value of `ignoreBoth` combines the two options. If set to `none` (the default), all lines read in interactive mode are saved on the history list.

Note

This feature was shamelessly plagiarized from Bash.

HISTFILE

The file name that will be used to store the history list. If unset, the file name is taken from the `PSQL_HISTORY` environment variable. If that is not set either, the default is `~/.psql_history`, or `%APPDATA%\postgresql\psql_history` on Windows. For example, putting:

```
\set HISTFILE ~/.psql_history- :DBNAME
```

in `~/.psqlrc` will cause `psql` to maintain a separate history for each database.

Note

This feature was shamelessly plagiarized from Bash.

HISTSIZE

The maximum number of commands to store in the command history (default 500). If set to a negative value, no limit is applied.

Note

This feature was shamelessly plagiarized from Bash.

HOST

The database server host you are currently connected to. This is set every time you connect to a database (including program start-up), but can be changed or unset.

IGNOREEOF

If set to 1 or less, sending an EOF character (usually **Control+D**) to an interactive session of `psql` will terminate the application. If set to a larger numeric value, that many consecutive EOF characters must be typed to make an interactive session terminate. If the variable is set to a non-numeric value, it is interpreted as 10. The default is 0.

Note

This feature was shamelessly plagiarized from Bash.

LASTOID

The value of the last affected OID, as returned from an `INSERT` or `\lo_import` command. This variable is only guaranteed to be valid until after the result of the next SQL command has been displayed. PostgreSQL servers since version 12 do not support OID system columns anymore, thus `LASTOID` will always be 0 following `INSERT` when targeting such servers.

LAST_ERROR_MESSAGE

LAST_ERROR_SQLSTATE

The primary error message and associated `SQLSTATE` code for the most recent failed query in the current `psql` session, or an empty string and `00000` if no error has occurred in the current session.

ON_ERROR_ROLLBACK

When set to `on`, if a statement in a transaction block generates an error, the error is ignored and the transaction continues. When set to `interactive`, such errors are only ignored in interactive sessions, and not when reading script files. When set to `off` (the default), a statement in a transaction block that generates an error aborts the entire transaction. The error rollback mode works

by issuing an implicit `SAVEPOINT` for you, just before each command that is in a transaction block, and then rolling back to the savepoint if the command fails.

ON_ERROR_STOP

By default, command processing continues after an error. When this variable is set to `on`, processing will instead stop immediately. In interactive mode, `psql` will return to the command prompt; otherwise, `psql` will exit, returning error code 3 to distinguish this case from fatal error conditions, which are reported using error code 1. In either case, any currently running scripts (the top-level script, if any, and any other scripts which it may have invoked) will be terminated immediately. If the top-level command string contained multiple SQL commands, processing will stop with the current command.

PORT

The database server port to which you are currently connected. This is set every time you connect to a database (including program start-up), but can be changed or unset.

PROMPT1

PROMPT2

PROMPT3

These specify what the prompts `psql` issues should look like. See Prompting below.

QUIET

Setting this variable to `on` is equivalent to the command line option `-q`. It is probably not too useful in interactive mode.

ROW_COUNT

The number of rows returned or affected by the last SQL query, or 0 if the query failed or did not report a row count.

SERVER_VERSION_NAME

SERVER_VERSION_NUM

The server's version number as a string, for example `9.6.2`, `10.1` or `11beta1`, and in numeric form, for example `90602` or `100001`. These are set every time you connect to a database (including program start-up), but can be changed or unset.

SHOW_CONTEXT

This variable can be set to the values `never`, `errors`, or `always` to control whether `CONTEXT` fields are displayed in messages from the server. The default is `errors` (meaning that context will be shown in error messages, but not in notice or warning messages). This setting has no effect when `VERBOSITY` is set to `terse` or `sqlstate`. (See also `\errverbose`, for use when you want a verbose version of the error you just got.)

SINGLELINE

Setting this variable to `on` is equivalent to the command line option `-S`.

SINGLESTEP

Setting this variable to `on` is equivalent to the command line option `-s`.

SQLSTATE

The error code (see Appendix A) associated with the last SQL query's failure, or `00000` if it succeeded.

USER

The database user you are currently connected as. This is set every time you connect to a database (including program start-up), but can be changed or unset.

VERBOSITY

This variable can be set to the values `default`, `verbose`, `terse`, or `sqlstate` to control the verbosity of error reports. (See also `\errverbose`, for use when you want a verbose version of the error you just got.)

VERSION**VERSION_NAME****VERSION_NUM**

These variables are set at program start-up to reflect psql's version, respectively as a verbose string, a short string (e.g., `9.6.2`, `10.1`, or `11beta1`), and a number (e.g., `90602` or `100001`). They can be changed or unset.

SQL Interpolation

A key feature of psql variables is that you can substitute (“interpolate”) them into regular SQL statements, as well as the arguments of meta-commands. Furthermore, psql provides facilities for ensuring that variable values used as SQL literals and identifiers are properly quoted. The syntax for interpolating a value without any quoting is to prepend the variable name with a colon (:). For example,

```
testdb=> \set foo 'my_table'
testdb=> SELECT * FROM :foo;
```

would query the table `my_table`. Note that this may be unsafe: the value of the variable is copied literally, so it can contain unbalanced quotes, or even backslash commands. You must make sure that it makes sense where you put it.

When a value is to be used as an SQL literal or identifier, it is safest to arrange for it to be quoted. To quote the value of a variable as an SQL literal, write a colon followed by the variable name in single quotes. To quote the value as an SQL identifier, write a colon followed by the variable name in double quotes. These constructs deal correctly with quotes and other special characters embedded within the variable value. The previous example would be more safely written this way:

```
testdb=> \set foo 'my_table'
testdb=> SELECT * FROM :"foo";
```

Variable interpolation will not be performed within quoted SQL literals and identifiers. Therefore, a construction such as `:foo` doesn't work to produce a quoted literal from a variable's value (and it would be unsafe if it did work, since it wouldn't correctly handle quotes embedded in the value).

One example use of this mechanism is to copy the contents of a file into a table column. First load the file into a variable and then interpolate the variable's value as a quoted string:

```
testdb=> \set content `cat my_file.txt`
testdb=> INSERT INTO my_table VALUES (:content');
```

(Note that this still won't work if `my_file.txt` contains NUL bytes. psql does not support embedded NUL bytes in variable values.)

Since colons can legally appear in SQL commands, an apparent attempt at interpolation (that is, `:name`, `:'name'`, or `:"name"`) is not replaced unless the named variable is currently set. In any case, you can escape a colon with a backslash to protect it from substitution.

The `: { ?name }` special syntax returns TRUE or FALSE depending on whether the variable exists or not, and is thus always substituted, unless the colon is backslash-escaped.

The colon syntax for variables is standard SQL for embedded query languages, such as ECPG. The colon syntaxes for array slices and type casts are PostgreSQL extensions, which can sometimes conflict with the standard usage. The colon-quote syntax for escaping a variable's value as an SQL literal or identifier is a psql extension.

Prompting

The prompts psql issues can be customized to your preference. The three variables `PROMPT1`, `PROMPT2`, and `PROMPT3` contain strings and special escape sequences that describe the appearance of the prompt. Prompt 1 is the normal prompt that is issued when psql requests a new command. Prompt 2 is issued when more input is expected during command entry, for example because the command was not terminated with a semicolon or a quote was not closed. Prompt 3 is issued when you are running an SQL `COPY FROM STDIN` command and you need to type in a row value on the terminal.

The value of the selected prompt variable is printed literally, except where a percent sign (%) is encountered. Depending on the next character, certain other text is substituted instead. Defined substitutions are:

`%M`

The full host name (with domain name) of the database server, or `[local]` if the connection is over a Unix domain socket, or `[local:/dir/name]`, if the Unix domain socket is not at the compiled in default location.

`%m`

The host name of the database server, truncated at the first dot, or `[local]` if the connection is over a Unix domain socket.

`%>`

The port number at which the database server is listening.

`%n`

The database session user name. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

`%/`

The name of the current database.

`%~`

Like `%/`, but the output is `~` (tilde) if the database is your default database.

`%#`

If the session user is a database superuser, then a `#`, otherwise a `>`. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

`%p`

The process ID of the backend currently connected to.

`%R`

In prompt 1 normally `=`, but `@` if the session is in an inactive branch of a conditional block, or `^` if in single-line mode, or `!` if the session is disconnected from the database (which can happen if

\connect fails). In prompt 2 %R is replaced by a character that depends on why psql expects more input: - if the command simply wasn't terminated yet, but * if there is an unfinished / * . . . */ comment, a single quote if there is an unfinished quoted string, a double quote if there is an unfinished quoted identifier, a dollar sign if there is an unfinished dollar-quoted string, or (if there is an unmatched left parenthesis. In prompt 3 %R doesn't produce anything.

%x

Transaction status: an empty string when not in a transaction block, or * when in a transaction block, or ! when in a failed transaction block, or ? when the transaction state is indeterminate (for example, because there is no connection).

%l

The line number inside the current statement, starting from 1.

%digits

The character with the indicated octal code is substituted.

%:name:

The value of the psql variable *name*. See the section Variables for details.

%`command`

The output of *command*, similar to ordinary “back-tick” substitution.

%[... %]

Prompts can contain terminal control characters which, for example, change the color, background, or style of the prompt text, or change the title of the terminal window. In order for the line editing features of Readline to work properly, these non-printing control characters must be designated as invisible by surrounding them with %[and %]. Multiple pairs of these can occur within the prompt. For example:

```
testdb=> \set PROMPT1 '%[%033[1;33;40m%]%n@%/%R%[%033[0m%]## '
```

results in a boldfaced (1;) yellow-on-black (33;40) prompt on VT100-compatible, color-capable terminals.

To insert a percent sign into your prompt, write %%. The default prompts are '%/%R## ' for prompts 1 and 2, and '>> ' for prompt 3.

Note

This feature was shamelessly plagiarized from tcsh.

Command-Line Editing

psql supports the Readline library for convenient line editing and retrieval. The command history is automatically saved when psql exits and is reloaded when psql starts up. Tab-completion is also supported, although the completion logic makes no claim to be an SQL parser. The queries generated by tab-completion can also interfere with other SQL commands, e.g. SET TRANSACTION ISOLATION LEVEL. If for some reason you do not like the tab completion, you can turn it off by putting this in a file named `.inputrc` in your home directory:

```
$if psql
set disable-completion on
$endif
```

(This is not a psql but a Readline feature. Read its documentation for further details.)

Environment

COLUMNS

If `\pset columns` is zero, controls the width for the wrapped format and width for determining if wide output requires the pager or should be switched to the vertical format in expanded auto mode.

PGDATABASE
PGHOST
PGPORT
PGUSER

Default connection parameters (see Section 33.14).

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

PSQL_EDITOR
EDITOR
VISUAL

Editor used by the `\e`, `\ef`, and `\ev` commands. These variables are examined in the order listed; the first that is set is used. If none of them is set, the default is to use `vi` on Unix systems or `notepad.exe` on Windows systems.

PSQL_EDITOR_LINENUMBER_ARG

When `\e`, `\ef`, or `\ev` is used with a line number argument, this variable specifies the command-line argument used to pass the starting line number to the user's editor. For editors such as Emacs or `vi`, this is a plus sign. Include a trailing space in the value of the variable if there needs to be space between the option name and the line number. Examples:

```
PSQL_EDITOR_LINENUMBER_ARG='+'
PSQL_EDITOR_LINENUMBER_ARG='--line '
```

The default is `+` on Unix systems (corresponding to the default editor `vi`, and useful for many other common editors); but there is no default on Windows systems.

PSQL_HISTORY

Alternative location for the command history file. Tilde (`~`) expansion is performed.

PSQL_PAGER
PAGER

If a query's results do not fit on the screen, they are piped through this command. Typical values are `more` or `less`. Use of the pager can be disabled by setting `PSQL_PAGER` or `PAGER` to an empty string, or by adjusting the pager-related options of the `\pset` command. These variables are examined in the order listed; the first that is set is used. If none of them is set, the default is to use `more` on most platforms, but `less` on Cygwin.

PSQLRC

Alternative location of the user's `.psqlrc` file. Tilde (`~`) expansion is performed.

SHELL

Command executed by the `\!` command.

TMPDIR

Directory for storing temporary files. The default is `/tmp`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Files

psqlrc and `~/.psqlrc`

Unless it is passed an `-X` option, `psql` attempts to read and execute commands from the system-wide startup file (`psqlrc`) and then the user's personal startup file (`~/.psqlrc`), after connecting to the database but before accepting normal commands. These files can be used to set up the client and/or the server to taste, typically with `\set` and `SET` commands.

The system-wide startup file is named `psqlrc` and is sought in the installation's "system configuration" directory, which is most reliably identified by running `pg_config --sysconfdir`. By default this directory will be `../etc/` relative to the directory containing the PostgreSQL executables. The name of this directory can be set explicitly via the `PGSYSCONFDIR` environment variable.

The user's personal startup file is named `.psqlrc` and is sought in the invoking user's home directory. On Windows, which lacks such a concept, the personal startup file is named `%APPDATA%\postgresql\psqlrc.conf`. The location of the user's startup file can be set explicitly via the `PSQLRC` environment variable.

Both the system-wide startup file and the user's personal startup file can be made `psql`-version-specific by appending a dash and the PostgreSQL major or minor release number to the file name, for example `~/.psqlrc-9.2` or `~/.psqlrc-9.2.5`. The most specific version-matching file will be read in preference to a non-version-specific file.

.psql_history

The command-line history is stored in the file `~/.psql_history`, or `%APPDATA%\postgresql\psql_history` on Windows.

The location of the history file can be set explicitly via the `HISTFILE` `psql` variable or the `PSQL_HISTORY` environment variable.

Notes

- `psql` works best with servers of the same or an older major version. Backslash commands are particularly likely to fail if the server is of a newer version than `psql` itself. However, backslash commands of the `\d` family should work with servers of versions back to 7.4, though not necessarily with servers newer than `psql` itself. The general functionality of running SQL commands and displaying query results should also work with servers of a newer major version, but this cannot be guaranteed in all cases.

If you want to use `psql` to connect to several servers of different major versions, it is recommended that you use the newest version of `psql`. Alternatively, you can keep around a copy of `psql` from

each major version and be sure to use the version that matches the respective server. But in practice, this additional complication should not be necessary.

- Before PostgreSQL 9.6, the `-c` option implied `-X (--no-psqlrc)`; this is no longer the case.
- Before PostgreSQL 8.4, psql allowed the first argument of a single-letter backslash command to start directly after the command, without intervening whitespace. Now, some whitespace is required.

Notes for Windows Users

psql is built as a “console application”. Since the Windows console windows use a different encoding than the rest of the system, you must take special care when using 8-bit characters within psql. If psql detects a problematic console code page, it will warn you at startup. To change the console code page, two things are necessary:

- Set the code page by entering `cmd.exe /c chcp 1252`. (1252 is a code page that is appropriate for German; replace it with your value.) If you are using Cygwin, you can put this command in `/etc/profile`.
- Set the console font to `Lucida Console`, because the raster font does not work with the ANSI code page.

Examples

The first example shows how to spread a command over several lines of input. Notice the changing prompt:

```
testdb=> CREATE TABLE my_table (
testdb(> first integer not null default 0,
testdb(> second text)
testdb-> ;
CREATE TABLE
```

Now look at the table definition again:

```
testdb=> \d my_table
          Table "public.my_table"
  Column | Type      | Collation | Nullable | Default
-----+-----+-----+-----+-----
 first   | integer   |           | not null | 0
 second  | text      |           |          |
```

Now we change the prompt to something more interesting:

```
testdb=> \set PROMPT1 '%n@m %~%R%# '
peter@localhost testdb=>
```

Let's assume you have filled the table with data and want to take a look at it:

```
peter@localhost testdb=> SELECT * FROM my_table;
 first | second
-----+-----
 1     | one
 2     | two
 3     | three
```

```

    4 | four
(4 rows)

```

You can display tables in different ways by using the `\pset` command:

```

peter@localhost testdb=> \pset border 2
Border style is 2.
peter@localhost testdb=> SELECT * FROM my_table;
+-----+-----+
| first | second |
+-----+-----+
|      1 | one    |
|      2 | two    |
|      3 | three  |
|      4 | four   |
+-----+-----+
(4 rows)

```

```

peter@localhost testdb=> \pset border 0
Border style is 0.
peter@localhost testdb=> SELECT * FROM my_table;
first second
-----
    1 one
    2 two
    3 three
    4 four
(4 rows)

```

```

peter@localhost testdb=> \pset border 1
Border style is 1.
peter@localhost testdb=> \pset format csv
Output format is csv.
peter@localhost testdb=> \pset tuples_only
Tuples only is on.
peter@localhost testdb=> SELECT second, first FROM my_table;
one,1
two,2
three,3
four,4
peter@localhost testdb=> \pset format unaligned
Output format is unaligned.
peter@localhost testdb=> \pset fieldsep '\t'
Field separator is "    ".
peter@localhost testdb=> SELECT second, first FROM my_table;
one      1
two      2
three    3
four     4

```

Alternatively, use the short commands:

```

peter@localhost testdb=> \a \t \x
Output format is aligned.
Tuples only is off.
Expanded display is on.

```

```

peter@localhost testdb=> SELECT * FROM my_table;
-[ RECORD 1 ]-
first  | 1
second | one
-[ RECORD 2 ]-
first  | 2
second | two
-[ RECORD 3 ]-
first  | 3
second | three
-[ RECORD 4 ]-
first  | 4
second | four

```

When suitable, query results can be shown in a crosstab representation with the `\crosstabview` command:

```

testdb=> SELECT first, second, first > 2 AS gt2 FROM my_table;
 first | second | gt2
-----+-----+----
      1 | one    | f
      2 | two    | f
      3 | three  | t
      4 | four   | t
(4 rows)

```

```

testdb=> \crosstabview first second
 first | one | two | three | four
-----+----+----+-----+----
      1 | f   |    |      |
      2 |    | f   |      |
      3 |    |    | t    |
      4 |    |    |      | t
(4 rows)

```

This second example shows a multiplication table with rows sorted in reverse numerical order and columns with an independent, ascending numerical order.

```

testdb=> SELECT t1.first as "A", t2.first+100 AS "B",
      t1.first*(t2.first+100) as "AxB",
testdb(> row_number() over(order by t2.first) AS ord
testdb(> FROM my_table t1 CROSS JOIN my_table t2 ORDER BY 1 DESC
testdb(> \crosstabview "A" "B" "AxB" ord
 A | 101 | 102 | 103 | 104
---+---+---+---+---
 4 | 404 | 408 | 412 | 416
 3 | 303 | 306 | 309 | 312
 2 | 202 | 204 | 206 | 208
 1 | 101 | 102 | 103 | 104
(4 rows)

```

reindexdb

reindexdb — reindex a PostgreSQL database

Synopsis

```
reindexdb [connection-option...] [option...] [ --schema | -S schema ] ... [ --table  
| -t table ] ... [ --index | -i index ] ... [dbname]
```

```
reindexdb [connection-option...] [option...] --all | -a
```

```
reindexdb [connection-option...] [option...] --system | -s [dbname]
```

Description

reindexdb is a utility for rebuilding indexes in a PostgreSQL database.

reindexdb is a wrapper around the SQL command REINDEX. There is no effective difference between reindexing databases via this utility and via other methods for accessing the server.

Options

reindexdb accepts the following command-line arguments:

-a
--all

Reindex all databases.

--concurrently

Use the CONCURRENTLY option. See REINDEX for further information.

[-d] *dbname*
[--dbname=] *dbname*

Specifies the name of the database to be reindexed. If this is not specified and -a (or --all) is not used, the database name is read from the environment variable PGDATABASE. If that is not set, the user name specified for the connection is used.

-e
--echo

Echo the commands that reindexdb generates and sends to the server.

-i *index*
--index=*index*

Recreate *index* only. Multiple indexes can be recreated by writing multiple -i switches.

-q
--quiet

Do not display progress messages.

-s
--system

Reindex database's system catalogs.

`-S schema`
`--schema=schema`

Reindex *schema* only. Multiple schemas can be reindexed by writing multiple `-S` switches.

`-t table`
`--table=table`

Reindex *table* only. Multiple tables can be reindexed by writing multiple `-t` switches.

`-v`
`--verbose`

Print detailed information during processing.

`-V`
`--version`

Print the reindexdb version and exit.

`-?`
`--help`

Show help about reindexdb command line arguments, and exit.

reindexdb also accepts the following command-line arguments for connection parameters:

`-h host`
`--host=host`

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p port`
`--port=port`

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force reindexdb to prompt for a password before connecting to a database.

This option is never essential, since reindexdb will automatically prompt for a password if the server demands password authentication. However, reindexdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to discover what other databases should be reindexed. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

Environment

PGDATABASE
PGHOST
PGPORT
PGUSER

Default connection parameters

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Diagnostics

In case of difficulty, see `REINDEX` and `psql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Notes

`reindexdb` might need to connect several times to the PostgreSQL server, asking for a password each time. It is convenient to have a `~/ .pgpass` file in such cases. See Section 33.15 for more information.

Examples

To reindex the database `test`:

```
$ reindexdb test
```

To reindex the table `foo` and the index `bar` in a database named `abcd`:

```
$ reindexdb --table=foo --index=bar abcd
```

See Also

`REINDEX`

vacuumdb

vacuumdb — garbage-collect and analyze a PostgreSQL database

Synopsis

```
vacuumdb [connection-option...] [option...] [ --table | -t table [(column [,...])] ] ...  
[dbname]
```

```
vacuumdb [connection-option...] [option...] --all | -a
```

Description

vacuumdb is a utility for cleaning a PostgreSQL database. vacuumdb will also generate internal statistics used by the PostgreSQL query optimizer.

vacuumdb is a wrapper around the SQL command VACUUM. There is no effective difference between vacuuming and analyzing databases via this utility and via other methods for accessing the server.

Options

vacuumdb accepts the following command-line arguments:

-a
--all

Vacuum all databases.

[*-d*] *dbname*
[*--dbname=*] *dbname*

Specifies the name of the database to be cleaned or analyzed. If this is not specified and *-a* (or *--all*) is not used, the database name is read from the environment variable PGDATABASE. If that is not set, the user name specified for the connection is used.

--disable-page-skipping

Disable skipping pages based on the contents of the visibility map.

<p style="text-align: center;">Note</p> <p style="text-align: center;">This option is only available for servers running PostgreSQL 9.6 and later.</p>

-e
--echo

Echo the commands that vacuumdb generates and sends to the server.

-f
--full

Perform “full” vacuuming.

-F
--freeze

Aggressively “freeze” tuples.

`-j njobs`
`--jobs=njobs`

Execute the vacuum or analyze commands in parallel by running *njobs* commands simultaneously. This option reduces the time of the processing but it also increases the load on the database server.

`vacuumdb` will open *njobs* connections to the database, so make sure your `max_connections` setting is high enough to accommodate all connections.

Note that using this mode together with the `-f` (FULL) option might cause deadlock failures if certain system catalogs are processed in parallel.

`--min-mxid-age mxid_age`

Only execute the vacuum or analyze commands on tables with a multixact ID age of at least *mxid_age*. This setting is useful for prioritizing tables to process to prevent multixact ID wrap-around (see Section 24.1.5.1).

For the purposes of this option, the multixact ID age of a relation is the greatest of the ages of the main relation and its associated TOAST table, if one exists. Since the commands issued by `vacuumdb` will also process the TOAST table for the relation if necessary, it does not need to be considered separately.

Note

This option is only available for servers running PostgreSQL 9.6 and later.

`--min-xid-age xid_age`

Only execute the vacuum or analyze commands on tables with a transaction ID age of at least *xid_age*. This setting is useful for prioritizing tables to process to prevent transaction ID wrap-around (see Section 24.1.5).

For the purposes of this option, the transaction ID age of a relation is the greatest of the ages of the main relation and its associated TOAST table, if one exists. Since the commands issued by `vacuumdb` will also process the TOAST table for the relation if necessary, it does not need to be considered separately.

Note

This option is only available for servers running PostgreSQL 9.6 and later.

`-q`
`--quiet`

Do not display progress messages.

`--skip-locked`

Skip relations that cannot be immediately locked for processing.

Note

This option is only available for servers running PostgreSQL 12 and later.

```
-t table [ (column [,...]) ]
--table=table [ (column [,...]) ]
```

Clean or analyze *table* only. Column names can be specified only in conjunction with the `--analyze` or `--analyze-only` options. Multiple tables can be vacuumed by writing multiple `-t` switches.

Tip

If you specify columns, you probably have to escape the parentheses from the shell. (See examples below.)

```
-v
--verbose
```

Print detailed information during processing.

```
-V
--version
```

Print the vacuumdb version and exit.

```
-z
--analyze
```

Also calculate statistics for use by the optimizer.

```
-Z
--analyze-only
```

Only calculate statistics for use by the optimizer (no vacuum).

```
--analyze-in-stages
```

Only calculate statistics for use by the optimizer (no vacuum), like `--analyze-only`. Run several (currently three) stages of analyze with different configuration settings, to produce usable statistics faster.

This option is useful to analyze a database that was newly populated from a restored dump or by `pg_upgrade`. This option will try to create some statistics as fast as possible, to make the database usable, and then produce full statistics in the subsequent stages.

```
-?
--help
```

Show help about vacuumdb command line arguments, and exit.

vacuumdb also accepts the following command-line arguments for connection parameters:

```
-h host
--host=host
```

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

```
-p port
--port=port
```

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force vacuumdb to prompt for a password before connecting to a database.

This option is never essential, since vacuumdb will automatically prompt for a password if the server demands password authentication. However, vacuumdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=dbname`

Specifies the name of the database to connect to discover what other databases should be vacuumed. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

Environment

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 33.14).

Diagnostics

In case of difficulty, see `VACUUM` and `psql` for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Notes

vacuumdb might need to connect several times to the PostgreSQL server, asking for a password each time. It is convenient to have a `~/ .pgpass` file in such cases. See Section 33.15 for more information.

Examples

To clean the database `test`:

```
$ vacuumdb test
```

To clean and analyze for the optimizer a database named bigdb:

```
$ vacuumdb --analyze bigdb
```

To clean a single table `foo` in a database named `xyzzzy`, and analyze a single column `bar` of the table for the optimizer:

```
$ vacuumdb --analyze --verbose --table='foo(bar)' xyzzzy
```

See Also

VACUUM

PostgreSQL Server Applications

This part contains reference information for PostgreSQL server applications and support utilities. These commands can only be run usefully on the host where the database server resides. Other utility programs are listed in PostgreSQL Client Applications.

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initdb

initdb — create a new PostgreSQL database cluster

Synopsis

```
initdb [option...][ --pgdata | -D ] directory
```

Description

`initdb` creates a new PostgreSQL database cluster. A database cluster is a collection of databases that are managed by a single server instance.

Creating a database cluster consists of creating the directories in which the database data will live, generating the shared catalog tables (tables that belong to the whole cluster rather than to any particular database), and creating the `template1` and `postgres` databases. When you later create a new database, everything in the `template1` database is copied. (Therefore, anything installed in `template1` is automatically copied into each database created later.) The `postgres` database is a default database meant for use by users, utilities and third party applications.

Although `initdb` will attempt to create the specified data directory, it might not have permission if the parent directory of the desired data directory is root-owned. To initialize in such a setup, create an empty data directory as root, then use `chown` to assign ownership of that directory to the database user account, then `su` to become the database user to run `initdb`.

`initdb` must be run as the user that will own the server process, because the server needs to have access to the files and directories that `initdb` creates. Since the server cannot be run as root, you must not run `initdb` as root either. (It will in fact refuse to do so.)

For security reasons the new cluster created by `initdb` will only be accessible by the cluster owner by default. The `--allow-group-access` option allows any user in the same group as the cluster owner to read files in the cluster. This is useful for performing backups as a non-privileged user.

`initdb` initializes the database cluster's default locale and character set encoding. The character set encoding, collation order (`LC_COLLATE`) and character set classes (`LC_CTYPE`, e.g. `upper`, `lower`, `digit`) can be set separately for a database when it is created. `initdb` determines those settings for the `template1` database, which will serve as the default for all other databases.

To alter the default collation order or character set classes, use the `--lc-collate` and `--lc-ctype` options. Collation orders other than `C` or `POSIX` also have a performance penalty. For these reasons it is important to choose the right locale when running `initdb`.

The remaining locale categories can be changed later when the server is started. You can also use `--locale` to set the default for all locale categories, including collation order and character set classes. All server locale values (`lc_*`) can be displayed via `SHOW ALL`. More details can be found in Section 23.1.

To alter the default encoding, use the `--encoding`. More details can be found in Section 23.3.

Options

```
-A authmethod  
--auth=authmethod
```

This option specifies the default authentication method for local users used in `pg_hba.conf` (host and local lines). `initdb` will prepopulate `pg_hba.conf` entries using the specified authentication method for non-replication as well as replication connections.

Do not use `trust` unless you trust all local users on your system. `trust` is the default for ease of installation.

`--auth-host=authmethod`

This option specifies the authentication method for local users via TCP/IP connections used in `pg_hba.conf` (host lines).

`--auth-local=authmethod`

This option specifies the authentication method for local users via Unix-domain socket connections used in `pg_hba.conf` (local lines).

`-D directory`

`--pgdata=directory`

This option specifies the directory where the database cluster should be stored. This is the only information required by `initdb`, but you can avoid writing it by setting the `PGDATA` environment variable, which can be convenient since the database server (`postgres`) can find the database directory later by the same variable.

`-E encoding`

`--encoding=encoding`

Selects the encoding of the template database. This will also be the default encoding of any database you create later, unless you override it there. The default is derived from the locale, or `SQL_ASCII` if that does not work. The character sets supported by the PostgreSQL server are described in Section 23.3.1.

`-g`

`--allow-group-access`

Allows users in the same group as the cluster owner to read all cluster files created by `initdb`. This option is ignored on Windows as it does not support POSIX-style group permissions.

`-k`

`--data-checksums`

Use checksums on data pages to help detect corruption by the I/O system that would otherwise be silent. Enabling checksums may incur a noticeable performance penalty. If set, checksums are calculated for all objects, in all databases. All checksum failures will be reported in the `pg_stat_database` view.

`--locale=locale`

Sets the default locale for the database cluster. If this option is not specified, the locale is inherited from the environment that `initdb` runs in. Locale support is described in Section 23.1.

`--lc-collate=locale`

`--lc-ctype=locale`

`--lc-messages=locale`

`--lc-monetary=locale`

`--lc-numeric=locale`

`--lc-time=locale`

Like `--locale`, but only sets the locale in the specified category.

`--no-locale`

Equivalent to `--locale=C`.

-N
--no-sync

By default, `initdb` will wait for all files to be written safely to disk. This option causes `initdb` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the data directory corrupt. Generally, this option is useful for testing, but should not be used when creating a production installation.

--pwfile=*filename*

Makes `initdb` read the database superuser's password from a file. The first line of the file is taken as the password.

-S
--sync-only

Safely write all database files to disk and exit. This does not perform any of the normal `initdb` operations.

-T *config*
--text-search-config=*config*

Sets the default text search configuration. See `default_text_search_config` for further information.

-U *username*
--username=*username*

Selects the user name of the database superuser. This defaults to the name of the effective user running `initdb`. It is really not important what the superuser's name is, but one might choose to keep the customary name `postgres`, even if the operating system user's name is different.

-W
--pwprompt

Makes `initdb` prompt for a password to give the database superuser. If you don't plan on using password authentication, this is not important. Otherwise you won't be able to use password authentication until you have a password set up.

-X *directory*
--waldir=*directory*

This option specifies the directory where the write-ahead log should be stored.

--wal-segsize=*size*

Set the *WAL segment size*, in megabytes. This is the size of each individual file in the WAL log. The default size is 16 megabytes. The value must be a power of 2 between 1 and 1024 (megabytes). This option can only be set during initialization, and cannot be changed later.

It may be useful to adjust this size to control the granularity of WAL log shipping or archiving. Also, in databases with a high volume of WAL, the sheer number of WAL files per directory can become a performance and management problem. Increasing the WAL file size will reduce the number of WAL files.

Other, less commonly used, options are also available:

-d
--debug

Print debugging output from the bootstrap backend and a few other messages of lesser interest for the general public. The bootstrap backend is the program `initdb` uses to create the catalog tables. This option generates a tremendous amount of extremely boring output.

`-L directory`

Specifies where `initdb` should find its input files to initialize the database cluster. This is normally not necessary. You will be told if you need to specify their location explicitly.

`-n`

`--no-clean`

By default, when `initdb` determines that an error prevented it from completely creating the database cluster, it removes any files it might have created before discovering that it cannot finish the job. This option inhibits tidying-up and is thus useful for debugging.

Other options:

`-V`

`--version`

Print the `initdb` version and exit.

`-?`

`--help`

Show help about `initdb` command line arguments, and exit.

Environment

`PGDATA`

Specifies the directory where the database cluster is to be stored; can be overridden using the `-D` option.

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

`TZ`

Specifies the default time zone of the created database cluster. The value should be a full time zone name (see Section 8.5.3).

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Notes

`initdb` can also be invoked via `pg_ctl initdb`.

See Also

`pg_ctl`, `postgres`

pg_archivecleanup

pg_archivecleanup — clean up PostgreSQL WAL archive files

Synopsis

```
pg_archivecleanup [option...] archive_location oldestkeptwalfile
```

Description

pg_archivecleanup is designed to be used as an `archive_cleanup_command` to clean up WAL file archives when running as a standby server (see Section 26.2). pg_archivecleanup can also be used as a standalone program to clean WAL file archives.

To configure a standby server to use pg_archivecleanup, put this into its `postgresql.conf` configuration file:

```
archive_cleanup_command = 'pg_archivecleanup archive_location %r'
```

where *archive_location* is the directory from which WAL segment files should be removed.

When used within `archive_cleanup_command`, all WAL files logically preceding the value of the `%r` argument will be removed from *archive_location*. This minimizes the number of files that need to be retained, while preserving crash-restart capability. Use of this parameter is appropriate if the *archive_location* is a transient staging area for this particular standby server, but *not* when the *archive_location* is intended as a long-term WAL archive area, or when multiple standby servers are recovering from the same archive location.

When used as a standalone program all WAL files logically preceding the *oldestkeptwalfile* will be removed from *archive_location*. In this mode, if you specify a `.partial` or `.backup` file name, then only the file prefix will be used as the *oldestkeptwalfile*. This treatment of `.backup` file name allows you to remove all WAL files archived prior to a specific base backup without error. For example, the following example will remove all files older than WAL file name 000000010000003700000010:

```
pg_archivecleanup -d archive
000000010000003700000010.00000020.backup
```

```
pg_archivecleanup: keep WAL file
"archive/000000010000003700000010" and later
pg_archivecleanup: removing file
"archive/00000001000000370000000F"
pg_archivecleanup: removing file
"archive/00000001000000370000000E"
```

pg_archivecleanup assumes that *archive_location* is a directory readable and writable by the server-owning user.

Options

pg_archivecleanup accepts the following command-line arguments:

`-d`

Print lots of debug logging output on `stderr`.

-n

Print the names of the files that would have been removed on `stdout` (performs a dry run).

-V

--version

Print the `pg_archivecleanup` version and exit.

-x *extension*

Provide an extension that will be stripped from all file names before deciding if they should be deleted. This is typically useful for cleaning up archives that have been compressed during storage, and therefore have had an extension added by the compression program. For example: -x `.gz`.

-?

--help

Show help about `pg_archivecleanup` command line arguments, and exit.

Notes

`pg_archivecleanup` is designed to work with PostgreSQL 8.0 and later when used as a standalone utility, or with PostgreSQL 9.0 and later when used as an archive cleanup command.

`pg_archivecleanup` is written in C and has an easy-to-modify source code, with specifically designated sections to modify for your own needs

Examples

On Linux or Unix systems, you might use:

```
archive_cleanup_command = 'pg_archivecleanup -d /mnt/standby/  
archive %r 2>>cleanup.log'
```

where the archive directory is physically located on the standby server, so that the `archive_command` is accessing it across NFS, but the files are local to the standby. This will:

- produce debugging output in `cleanup.log`
- remove no-longer-needed files from the archive directory

See Also

`pg_standby`

pg_checksums

pg_checksums — enable, disable or check data checksums in a PostgreSQL database cluster

Synopsis

```
pg_checksums [option...] [[ -D | --pgdata ] datadir]
```

Description

pg_checksums checks, enables or disables data checksums in a PostgreSQL cluster. The server must be shut down cleanly before running pg_checksums. When verifying checksums, the exit status is zero if there are no checksum errors, and nonzero if at least one checksum failure is detected. When enabling or disabling checksums, the exit status is nonzero if the operation failed.

When verifying checksums, every file in the cluster is scanned. When enabling checksums, every file in the cluster is rewritten. Disabling checksums only updates the file `pg_control`.

Options

The following command-line options are available:

```
-D directory  
--pgdata=directory
```

Specifies the directory where the database cluster is stored.

```
-c  
--check
```

Checks checksums. This is the default mode if nothing else is specified.

```
-d  
--disable
```

Disables checksums.

```
-e  
--enable
```

Enables checksums.

```
-f filenode  
--filenode=filenode
```

Only validate checksums in the relation with filenode *filenode*.

```
-N  
--no-sync
```

By default, pg_checksums will wait for all files to be written safely to disk. This option causes pg_checksums to return without waiting, which is faster, but means that a subsequent operating system crash can leave the updated data directory corrupt. Generally, this option is useful for testing but should not be used on a production installation. This option has no effect when using `--check`.

-P

--progress

Enable progress reporting. Turning this on will deliver a progress report while checking or enabling checksums.

-v

--verbose

Enable verbose output. Lists all checked files.

-V

--version

Print the pg_checksums version and exit.

-?

--help

Show help about pg_checksums command line arguments, and exit.

Environment

PGDATA

Specifies the directory where the database cluster is stored; can be overridden using the `-D` option.

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

Enabling checksums in a large cluster can potentially take a long time. During this operation, the cluster or other programs that write to the data directory must not be started or else data loss may occur.

When using a replication setup with tools which perform direct copies of relation file blocks (for example `pg_rewind`), enabling or disabling checksums can lead to page corruptions in the shape of incorrect checksums if the operation is not done consistently across all nodes. When enabling or disabling checksums in a replication setup, it is thus recommended to stop all the clusters before switching them all consistently. Destroying all standbys, performing the operation on the primary and finally recreating the standbys from scratch is also safe.

If `pg_checksums` is aborted or killed while enabling or disabling checksums, the cluster's data checksum configuration remains unchanged, and `pg_checksums` can be re-run to perform the same operation.

pg_controldata

pg_controldata — display control information of a PostgreSQL database cluster

Synopsis

```
pg_controldata [option] [[ --pgdata | -D ] datadir]
```

Description

pg_controldata prints information initialized during `initdb`, such as the catalog version. It also shows information about write-ahead logging and checkpoint processing. This information is cluster-wide, and not specific to any one database.

This utility can only be run by the user who initialized the cluster because it requires read access to the data directory. You can specify the data directory on the command line, or use the environment variable `PGDATA`. This utility supports the options `-V` and `--version`, which print the pg_controldata version and exit. It also supports options `-?` and `--help`, which output the supported arguments.

Environment

PGDATA

Default data directory location

PG_COLOR

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

pg_ctl

pg_ctl — initialize, start, stop, or control a PostgreSQL server

Synopsis

```
pg_ctl init[db] [-D datadir] [-s] [-o initdb-options]
```

```
pg_ctl start [-D datadir] [-l filename] [-W] [-t seconds] [-s] [-o options] [-p path] [-c]
```

```
pg_ctl stop [-D datadir] [-m s[mart] | f[ast] | i[mmediate] ] [-W] [-t seconds] [-s]
```

```
pg_ctl restart [-D datadir] [-m s[mart] | f[ast] | i[mmediate] ] [-W] [-t seconds] [-s] [-o options] [-c]
```

```
pg_ctl reload [-D datadir] [-s]
```

```
pg_ctl status [-D datadir]
```

```
pg_ctl promote [-D datadir] [-W] [-t seconds] [-s]
```

```
pg_ctl logrotate [-D datadir] [-s]
```

```
pg_ctl kill signal_name process_id
```

On Microsoft Windows, also:

```
pg_ctl register [-D datadir] [-N servicename] [-U username] [-P password] [-S a[uto] | d[emand] ] [-e source] [-W] [-t seconds] [-s] [-o options]
```

```
pg_ctl unregister [-N servicename]
```

Description

pg_ctl is a utility for initializing a PostgreSQL database cluster, starting, stopping, or restarting the PostgreSQL database server (postgres), or displaying the status of a running server. Although the server can be started manually, pg_ctl encapsulates tasks such as redirecting log output and properly detaching from the terminal and process group. It also provides convenient options for controlled shutdown.

The `init` or `initdb` mode creates a new PostgreSQL database cluster, that is, a collection of databases that will be managed by a single server instance. This mode invokes the `initdb` command. See `initdb` for details.

`start` mode launches a new server. The server is started in the background, and its standard input is attached to `/dev/null` (or `null` on Windows). On Unix-like systems, by default, the server's standard output and standard error are sent to pg_ctl's standard output (not standard error). The standard output of pg_ctl should then be redirected to a file or piped to another process such as a log rotating program like `rotatelogs`; otherwise `postgres` will write its output to the controlling terminal (from the background) and will not leave the shell's process group. On Windows, by default the server's standard output and standard error are sent to the terminal. These default behaviors can be changed by using `-l` to append the server's output to a log file. Use of either `-l` or output redirection is recommended.

`stop` mode shuts down the server that is running in the specified data directory. Three different shutdown methods can be selected with the `-m` option. “Smart” mode waits for all active clients to disconnect and any online backup to finish. If the server is in hot standby, recovery and streaming

replication will be terminated once all clients have disconnected. “Fast” mode (the default) does not wait for clients to disconnect and will terminate an online backup in progress. All active transactions are rolled back and clients are forcibly disconnected, then the server is shut down. “Immediate” mode will abort all server processes immediately, without a clean shutdown. This choice will lead to a crash-recovery cycle during the next server start.

`restart` mode effectively executes a stop followed by a start. This allows changing the `postgres` command-line options, or changing configuration-file options that cannot be changed without restarting the server. If relative paths were used on the command line during server start, `restart` might fail unless `pg_ctl` is executed in the same current directory as it was during server start.

`reload` mode simply sends the `postgres` server process a `SIGHUP` signal, causing it to reread its configuration files (`postgresql.conf`, `pg_hba.conf`, etc.). This allows changing configuration-file options that do not require a full server restart to take effect.

`status` mode checks whether a server is running in the specified data directory. If it is, the server's PID and the command line options that were used to invoke it are displayed. If the server is not running, `pg_ctl` returns an exit status of 3. If an accessible data directory is not specified, `pg_ctl` returns an exit status of 4.

`promote` mode commands the standby server that is running in the specified data directory to end standby mode and begin read-write operations.

`logrotate` mode rotates the server log file. For details on how to use this mode with external log rotation tools, see Section 24.3.

`kill` mode sends a signal to a specified process. This is primarily valuable on Microsoft Windows which does not have a built-in kill command. Use `--help` to see a list of supported signal names.

`register` mode registers the PostgreSQL server as a system service on Microsoft Windows. The `-S` option allows selection of service start type, either “auto” (start service automatically on system startup) or “demand” (start service on demand).

`unregister` mode unregisters a system service on Microsoft Windows. This undoes the effects of the `register` command.

Options

`-c`
`--core-files`

Attempt to allow server crashes to produce core files, on platforms where this is possible, by lifting any soft resource limit placed on core files. This is useful in debugging or diagnosing problems by allowing a stack trace to be obtained from a failed server process.

`-D datadir`
`--pgdata=datadir`

Specifies the file system location of the database configuration files. If this option is omitted, the environment variable `PGDATA` is used.

`-l filename`
`--log=filename`

Append the server log output to *filename*. If the file does not exist, it is created. The umask is set to 077, so access to the log file is disallowed to other users by default.

`-m mode`
`--mode=mode`

Specifies the shutdown mode. *mode* can be `smart`, `fast`, or `immediate`, or the first letter of one of these three. If this option is omitted, `fast` is the default.

`-o options`
`--options=options`

Specifies options to be passed directly to the `postgres` command. `-o` can be specified multiple times, with all the given options being passed through.

The `options` should usually be surrounded by single or double quotes to ensure that they are passed through as a group.

`-o initdb-options`
`--options=initdb-options`

Specifies options to be passed directly to the `initdb` command. `-o` can be specified multiple times, with all the given options being passed through.

The `initdb-options` should usually be surrounded by single or double quotes to ensure that they are passed through as a group.

`-p path`

Specifies the location of the `postgres` executable. By default the `postgres` executable is taken from the same directory as `pg_ctl`, or failing that, the hard-wired installation directory. It is not necessary to use this option unless you are doing something unusual and get errors that the `postgres` executable was not found.

In `init` mode, this option analogously specifies the location of the `initdb` executable.

`-s`
`--silent`

Print only errors, no informational messages.

`-t seconds`
`--timeout=seconds`

Specifies the maximum number of seconds to wait when waiting for an operation to complete (see option `-w`). Defaults to the value of the `PGCTLTIMEOUT` environment variable or, if not set, to 60 seconds.

`-V`
`--version`

Print the `pg_ctl` version and exit.

`-w`
`--wait`

Wait for the operation to complete. This is supported for the modes `start`, `stop`, `restart`, `promote`, and `register`, and is the default for those modes.

When waiting, `pg_ctl` repeatedly checks the server's PID file, sleeping for a short amount of time between checks. Startup is considered complete when the PID file indicates that the server is ready to accept connections. Shutdown is considered complete when the server removes the PID file. `pg_ctl` returns an exit code based on the success of the startup or shutdown.

If the operation does not complete within the timeout (see option `-t`), then `pg_ctl` exits with a nonzero exit status. But note that the operation might continue in the background and eventually succeed.

`-W`
`--no-wait`

Do not wait for the operation to complete. This is the opposite of the option `-w`.

If waiting is disabled, the requested action is triggered, but there is no feedback about its success. In that case, the server log file or an external monitoring system would have to be used to check the progress and success of the operation.

In prior releases of PostgreSQL, this was the default except for the `stop` mode.

-?
--help

Show help about `pg_ctl` command line arguments, and exit.

If an option is specified that is valid, but not relevant to the selected operating mode, `pg_ctl` ignores it.

Options for Windows

-e *source*

Name of the event source for `pg_ctl` to use for logging to the event log when running as a Windows service. The default is `PostgreSQL`. Note that this only controls messages sent from `pg_ctl` itself; once started, the server will use the event source specified by its `event_source` parameter. Should the server fail very early in startup, before that parameter has been set, it might also log using the default event source name `PostgreSQL`.

-N *servicename*

Name of the system service to register. This name will be used as both the service name and the display name. The default is `PostgreSQL`.

-P *password*

Password for the user to run the service as.

-S *start-type*

Start type of the system service. *start-type* can be `auto`, or `demand`, or the first letter of one of these two. If this option is omitted, `auto` is the default.

-U *username*

User name for the user to run the service as. For domain users, use the format `DOMAIN\user-name`.

Environment

PGCTLTIMEOUT

Default limit on the number of seconds to wait when waiting for startup or shutdown to complete. If not set, the default is 60 seconds.

PGDATA

Default data directory location.

Most `pg_ctl` modes require knowing the data directory location; therefore, the `-D` option is required unless `PGDATA` is set.

`pg_ctl`, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

For additional variables that affect the server, see `postgres`.

Files

`postmaster.pid`

`pg_ctl` examines this file in the data directory to determine whether the server is currently running.

`postmaster.opts`

If this file exists in the data directory, `pg_ctl` (in `restart` mode) will pass the contents of the file as options to `postgres`, unless overridden by the `-o` option. The contents of this file are also displayed in `status` mode.

Examples

Starting the Server

To start the server, waiting until the server is accepting connections:

```
$ pg_ctl start
```

To start the server using port 5433, and running without `fsync`, use:

```
$ pg_ctl -o "-F -p 5433" start
```

Stopping the Server

To stop the server, use:

```
$ pg_ctl stop
```

The `-m` option allows control over *how* the server shuts down:

```
$ pg_ctl stop -m smart
```

Restarting the Server

Restarting the server is almost equivalent to stopping the server and starting it again, except that by default, `pg_ctl` saves and reuses the command line options that were passed to the previously-running instance. To restart the server using the same options as before, use:

```
$ pg_ctl restart
```

But if `-o` is specified, that replaces any previous options. To restart using port 5433, disabling `fsync` upon restart:

```
$ pg_ctl -o "-F -p 5433" restart
```

Showing the Server Status

Here is sample status output from `pg_ctl`:

```
$ pg_ctl status
```

```
pg_ctl: server is running (PID: 13718)
/usr/local/pgsql/bin/postgres "-D" "/usr/local/pgsql/data" "-p"
"5433" "-B" "128"
```

The second line is the command that would be invoked in restart mode.

See Also

initdb, postgres

pg_resetwal

`pg_resetwal` — reset the write-ahead log and other control information of a PostgreSQL database cluster

Synopsis

```
pg_resetwal [ --force | -f ] [ --dry-run | -n ] [option...] [ --pgdata | -D ] datadir
```

Description

`pg_resetwal` clears the write-ahead log (WAL) and optionally resets some other control information stored in the `pg_control` file. This function is sometimes needed if these files have become corrupted. It should be used only as a last resort, when the server will not start due to such corruption.

After running this command, it should be possible to start the server, but bear in mind that the database might contain inconsistent data due to partially-committed transactions. You should immediately dump your data, run `initdb`, and reload. After reload, check for inconsistencies and repair as needed.

This utility can only be run by the user who installed the server, because it requires read/write access to the data directory. For safety reasons, you must specify the data directory on the command line. `pg_resetwal` does not use the environment variable `PGDATA`.

If `pg_resetwal` complains that it cannot determine valid data for `pg_control`, you can force it to proceed anyway by specifying the `-f` (force) option. In this case plausible values will be substituted for the missing data. Most of the fields can be expected to match, but manual assistance might be needed for the next OID, next transaction ID and epoch, next multitransaction ID and offset, and WAL starting location fields. These fields can be set using the options discussed below. If you are not able to determine correct values for all these fields, `-f` can still be used, but the recovered database must be treated with even more suspicion than usual: an immediate dump and reload is imperative. *Do not* execute any data-modifying operations in the database before you dump, as any such action is likely to make the corruption worse.

Options

`-f`
`--force`

Force `pg_resetwal` to proceed even if it cannot determine valid data for `pg_control`, as explained above.

`-n`
`--dry-run`

The `-n/--dry-run` option instructs `pg_resetwal` to print the values reconstructed from `pg_control` and values about to be changed, and then exit without modifying anything. This is mainly a debugging tool, but can be useful as a sanity check before allowing `pg_resetwal` to proceed for real.

`-V`
`--version`

Display version information, then exit.

`-?`
`--help`

Show help, then exit.

The following options are only needed when `pg_resetwal` is unable to determine appropriate values by reading `pg_control`. Safe values can be determined as described below. For values that take numeric arguments, hexadecimal values can be specified by using the prefix `0x`.

```
-c xid,xid  
--commit-timestamp-ids=xid,xid
```

Manually set the oldest and newest transaction IDs for which the commit time can be retrieved.

A safe value for the oldest transaction ID for which the commit time can be retrieved (first part) can be determined by looking for the numerically smallest file name in the directory `pg_commit_ts` under the data directory. Conversely, a safe value for the newest transaction ID for which the commit time can be retrieved (second part) can be determined by looking for the numerically greatest file name in the same directory. The file names are in hexadecimal.

```
-e xid_epoch  
--epoch=xid_epoch
```

Manually set the next transaction ID's epoch.

The transaction ID epoch is not actually stored anywhere in the database except in the field that is set by `pg_resetwal`, so any value will work so far as the database itself is concerned. You might need to adjust this value to ensure that replication systems such as Slony-I and Skytools work correctly — if so, an appropriate value should be obtainable from the state of the downstream replicated database.

```
-l walfile  
--next-wal-file=walfile
```

Manually set the WAL starting location by specifying the name of the next WAL segment file.

The name of next WAL segment file should be larger than any WAL segment file name currently existing in the directory `pg_wal` under the data directory. These names are also in hexadecimal and have three parts. The first part is the “timeline ID” and should usually be kept the same. For example, if `00000001000000320000004A` is the largest entry in `pg_wal`, use `-l 00000001000000320000004B` or higher.

Note that when using nondefault WAL segment sizes, the numbers in the WAL file names are different from the LSNs that are reported by system functions and system views. This option takes a WAL file name, not an LSN.

Note

`pg_resetwal` itself looks at the files in `pg_wal` and chooses a default `-l` setting beyond the last existing file name. Therefore, manual adjustment of `-l` should only be needed if you are aware of WAL segment files that are not currently present in `pg_wal`, such as entries in an offline archive; or if the contents of `pg_wal` have been lost entirely.

```
-m mxid,mxid  
--multixact-ids=mxid,mxid
```

Manually set the next and oldest multitransaction ID.

A safe value for the next multitransaction ID (first part) can be determined by looking for the numerically largest file name in the directory `pg_multixact/offsets` under the data directory, adding one, and then multiplying by 65536 (`0x10000`). Conversely, a safe value for the oldest multitransaction ID (second part of `-m`) can be determined by looking for the numerically smallest

file name in the same directory and multiplying by 65536. The file names are in hexadecimal, so the easiest way to do this is to specify the option value in hexadecimal and append four zeroes.

```
-o oid  
--next-oid=oid
```

Manually set the next OID.

There is no comparably easy way to determine a next OID that's beyond the largest one in the database, but fortunately it is not critical to get the next-OID setting right.

```
-O mxoff  
--multixact-offset=mxoff
```

Manually set the next multitransaction offset.

A safe value can be determined by looking for the numerically largest file name in the directory `pg_multixact/members` under the data directory, adding one, and then multiplying by 52352 (0xCC80). The file names are in hexadecimal. There is no simple recipe such as the ones for other options of appending zeroes.

```
--wal-segsize=wal_segment_size
```

Set the new WAL segment size, in megabytes. The value must be set to a power of 2 between 1 and 1024 (megabytes). See the same option of `initdb` for more information.

Note

While `pg_resetwal` will set the WAL starting address beyond the latest existing WAL segment file, some segment size changes can cause previous WAL file names to be reused. It is recommended to use `-l` together with this option to manually set the WAL starting address if WAL file name overlap will cause problems with your archiving strategy.

```
-x xid  
--next-transaction-id=xid
```

Manually set the next transaction ID.

A safe value can be determined by looking for the numerically largest file name in the directory `pg_xact` under the data directory, adding one, and then multiplying by 1048576 (0x100000). Note that the file names are in hexadecimal. It is usually easiest to specify the option value in hexadecimal too. For example, if 0011 is the largest entry in `pg_xact`, `-x 0x1200000` will work (five trailing zeroes provide the proper multiplier).

Environment

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

This command must not be used when the server is running. `pg_resetwal` will refuse to start up if it finds a server lock file in the data directory. If the server crashed then a lock file might have been left behind; in that case you can remove the lock file to allow `pg_resetwal` to run. But before you do so, make doubly certain that there is no server process still alive.

pg_resetwal works only with servers of the same major version.

See Also

pg_controldata

pg_rewind

`pg_rewind` — synchronize a PostgreSQL data directory with another data directory that was forked from it

Synopsis

```
pg_rewind [option...] { -D | --target-pgdata } directory { --source-pgdata=directory | --source-server=connstr }
```

Description

`pg_rewind` is a tool for synchronizing a PostgreSQL cluster with another copy of the same cluster, after the clusters' timelines have diverged. A typical scenario is to bring an old master server back online after failover as a standby that follows the new master.

The result is equivalent to replacing the target data directory with the source one. Only changed blocks from relation files are copied; all other files are copied in full, including configuration files. The advantage of `pg_rewind` over taking a new base backup, or tools like `rsync`, is that `pg_rewind` does not require reading through unchanged blocks in the cluster. This makes it a lot faster when the database is large and only a small fraction of blocks differ between the clusters.

`pg_rewind` examines the timeline histories of the source and target clusters to determine the point where they diverged, and expects to find WAL in the target cluster's `pg_wal` directory reaching all the way back to the point of divergence. The point of divergence can be found either on the target timeline, the source timeline, or their common ancestor. In the typical failover scenario where the target cluster was shut down soon after the divergence, this is not a problem, but if the target cluster ran for a long time after the divergence, the old WAL files might no longer be present. In that case, they can be manually copied from the WAL archive to the `pg_wal` directory, or fetched on startup by configuring `primary_conninfo` or `restore_command`. The use of `pg_rewind` is not limited to failover, e.g. a standby server can be promoted, run some write transactions, and then rewinded to become a standby again.

When the target server is started for the first time after running `pg_rewind`, it will go into recovery mode and replay all WAL generated in the source server after the point of divergence. If some of the WAL was no longer available in the source server when `pg_rewind` was run, and therefore could not be copied by the `pg_rewind` session, it must be made available when the target server is started. This can be done by creating a `recovery.signal` file in the target data directory and configuring suitable `restore_command` in `postgresql.conf`.

`pg_rewind` requires that the target server either has the `wal_log_hints` option enabled in `postgresql.conf` or data checksums enabled when the cluster was initialized with `initdb`. Neither of these are currently on by default. `full_page_writes` must also be set to `on`, but is enabled by default.

Warning

If `pg_rewind` fails while processing, then the data folder of the target is likely not in a state that can be recovered. In such a case, taking a new fresh backup is recommended.

`pg_rewind` will fail immediately if it finds files it cannot write directly to. This can happen for example when the source and the target server use the same file mapping for read-only SSL keys and certificates. If such files are present on the target server it is recommended to remove them before running `pg_rewind`. After doing the rewind, some of those files may have been copied from the source, in which case it may be

necessary to remove the data copied and restore back the set of links used before the rewind.

Options

pg_rewind accepts the following command-line arguments:

`-D directory`
`--target-pgdata=directory`

This option specifies the target data directory that is synchronized with the source. The target server must be shut down cleanly before running pg_rewind

`--source-pgdata=directory`

Specifies the file system path to the data directory of the source server to synchronize the target with. This option requires the source server to be cleanly shut down.

`--source-server=connstr`

Specifies a libpq connection string to connect to the source PostgreSQL server to synchronize the target with. The connection must be a normal (non-replication) connection with a role having sufficient permissions to execute the functions used by pg_rewind on the source server (see Notes section for details) or a superuser role. This option requires the source server to be running and not in recovery mode.

`-n`
`--dry-run`

Do everything except actually modifying the target directory.

`-N`
`--no-sync`

By default, pg_rewind will wait for all files to be written safely to disk. This option causes pg_rewind to return without waiting, which is faster, but means that a subsequent operating system crash can leave the synchronized data directory corrupt. Generally, this option is useful for testing but should not be used when creating a production installation.

`-P`
`--progress`

Enables progress reporting. Turning this on will deliver an approximate progress report while copying data from the source cluster.

`--debug`

Print verbose debugging output that is mostly useful for developers debugging pg_rewind.

`-V`
`--version`

Display version information, then exit.

`-?`
`--help`

Show help, then exit.

Environment

When `--source-server` option is used, `pg_rewind` also uses the environment variables supported by `libpq` (see Section 33.14).

The environment variable `PG_COLOR` specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

When executing `pg_rewind` using an online cluster as source, a role having sufficient permissions to execute the functions used by `pg_rewind` on the source cluster can be used instead of a superuser. Here is how to create such a role, named `rewind_user` here:

```
CREATE USER rewind_user LOGIN;
GRANT EXECUTE ON function pg_catalog.pg_ls_dir(text, boolean,
boolean) TO rewind_user;
GRANT EXECUTE ON function pg_catalog.pg_stat_file(text, boolean) TO
rewind_user;
GRANT EXECUTE ON function pg_catalog.pg_read_binary_file(text) TO
rewind_user;
GRANT EXECUTE ON function pg_catalog.pg_read_binary_file(text,
bigint, bigint, boolean) TO rewind_user;
```

When executing `pg_rewind` using an online cluster as source which has been recently promoted, it is necessary to execute a `CHECKPOINT` after promotion so as its control file reflects up-to-date timeline information, which is used by `pg_rewind` to check if the target cluster can be rewound using the designated source cluster.

How It Works

The basic idea is to copy all file system-level changes from the source cluster to the target cluster:

1. Scan the WAL log of the target cluster, starting from the last checkpoint before the point where the source cluster's timeline history forked off from the target cluster. For each WAL record, record each data block that was touched. This yields a list of all the data blocks that were changed in the target cluster, after the source cluster forked off.
2. Copy all those changed blocks from the source cluster to the target cluster, either using direct file system access (`--source-pgdata`) or SQL (`--source-server`).
3. Copy all other files such as `pg_xact` and configuration files from the source cluster to the target cluster (everything except the relation files). Similarly to base backups, the contents of the directories `pg_dynshmem/`, `pg_notify/`, `pg_replslot/`, `pg_serial/`, `pg_snapshots/`, `pg_stat_tmp/`, and `pg_subtrans/` are omitted from the data copied from the source cluster. Any file or directory beginning with `pgsql_tmp` is omitted, as well as are `backup_label`, `tablespace_map`, `pg_internal.init`, `postmaster.opts` and `postmaster.pid`.
4. Apply the WAL from the source cluster, starting from the checkpoint created at failover. (Strictly speaking, `pg_rewind` doesn't apply the WAL, it just creates a backup label file that makes PostgreSQL start by replaying all WAL from that checkpoint forward.)

pg_test_fsync

pg_test_fsync — determine fastest wal_sync_method for PostgreSQL

Synopsis

```
pg_test_fsync [option...]
```

Description

pg_test_fsync is intended to give you a reasonable idea of what the fastest wal_sync_method is on your specific system, as well as supplying diagnostic information in the event of an identified I/O problem. However, differences shown by pg_test_fsync might not make any significant difference in real database throughput, especially since many database servers are not speed-limited by their write-ahead logs. pg_test_fsync reports average file sync operation time in microseconds for each wal_sync_method, which can also be used to inform efforts to optimize the value of commit_delay.

Options

pg_test_fsync accepts the following command-line options:

-f
--filename

Specifies the file name to write test data in. This file should be in the same file system that the pg_wal directory is or will be placed in. (pg_wal contains the WAL files.) The default is pg_test_fsync.out in the current directory.

-s
--secs-per-test

Specifies the number of seconds for each test. The more time per test, the greater the test's accuracy, but the longer it takes to run. The default is 5 seconds, which allows the program to complete in under 2 minutes.

-V
--version

Print the pg_test_fsync version and exit.

-?
--help

Show help about pg_test_fsync command line arguments, and exit.

See Also

postgres

pg_test_timing

pg_test_timing — measure timing overhead

Synopsis

pg_test_timing [*option...*]

Description

pg_test_timing is a tool to measure the timing overhead on your system and confirm that the system time never moves backwards. Systems that are slow to collect timing data can give less accurate EXPLAIN ANALYZE results.

Options

pg_test_timing accepts the following command-line options:

-d *duration*
--duration=*duration*

Specifies the test duration, in seconds. Longer durations give slightly better accuracy, and are more likely to discover problems with the system clock moving backwards. The default test duration is 3 seconds.

-V
--version

Print the pg_test_timing version and exit.

-?
--help

Show help about pg_test_timing command line arguments, and exit.

Usage

Interpreting Results

Good results will show most (>90%) individual timing calls take less than one microsecond. Average per loop overhead will be even lower, below 100 nanoseconds. This example from an Intel i7-860 system using a TSC clock source shows excellent performance:

```
Testing timing overhead for 3 seconds.  
Per loop time including overhead: 35.96 ns  
Histogram of timing durations:  
  < us    % of total    count  
    1      96.40465    80435604  
    2       3.59518     2999652  
    4       0.00015        126  
    8       0.00002         13  
   16       0.00000          2
```

Note that different units are used for the per loop time than the histogram. The loop can have resolution within a few nanoseconds (ns), while the individual timing calls can only resolve down to one microsecond (us).

Measuring Executor Timing Overhead

When the query executor is running a statement using `EXPLAIN ANALYZE`, individual operations are timed as well as showing a summary. The overhead of your system can be checked by counting rows with the `psql` program:

```
CREATE TABLE t AS SELECT * FROM generate_series(1,100000);
\timing
SELECT COUNT(*) FROM t;
EXPLAIN ANALYZE SELECT COUNT(*) FROM t;
```

The i7-860 system measured runs the count query in 9.8 ms while the `EXPLAIN ANALYZE` version takes 16.6 ms, each processing just over 100,000 rows. That 6.8 ms difference means the timing overhead per row is 68 ns, about twice what `pg_test_timing` estimated it would be. Even that relatively small amount of overhead is making the fully timed count statement take almost 70% longer. On more substantial queries, the timing overhead would be less problematic.

Changing Time Sources

On some newer Linux systems, it's possible to change the clock source used to collect timing data at any time. A second example shows the slowdown possible from switching to the slower `acpi_pm` time source, on the same system used for the fast results above:

```
# cat /sys/devices/system/clocksource/clocksource0/
available_clocksource
tsc hpet acpi_pm
# echo acpi_pm > /sys/devices/system/clocksource/clocksource0/
current_clocksource
# pg_test_timing
Per loop time including overhead: 722.92 ns
Histogram of timing durations:
  < us   % of total   count
    1    27.84870   1155682
    2    72.05956   2990371
    4     0.07810     3241
    8     0.01357     563
   16     0.00007         3
```

In this configuration, the sample `EXPLAIN ANALYZE` above takes 115.9 ms. That's 1061 ns of timing overhead, again a small multiple of what's measured directly by this utility. That much timing overhead means the actual query itself is only taking a tiny fraction of the accounted for time, most of it is being consumed in overhead instead. In this configuration, any `EXPLAIN ANALYZE` totals involving many timed operations would be inflated significantly by timing overhead.

FreeBSD also allows changing the time source on the fly, and it logs information about the timer selected during boot:

```
# dmesg | grep "Timecounter"
Timecounter "ACPI-fast" frequency 3579545 Hz quality 900
Timecounter "i8254" frequency 1193182 Hz quality 0
Timecounters tick every 10.000 msec
Timecounter "TSC" frequency 2531787134 Hz quality 800
# sysctl kern.timecounter.hardware=TSC
kern.timecounter.hardware: ACPI-fast -> TSC
```

Other systems may only allow setting the time source on boot. On older Linux systems the "clock" kernel setting is the only way to make this sort of change. And even on some more recent ones,

the only option you'll see for a clock source is "jiffies". Jiffies are the older Linux software clock implementation, which can have good resolution when it's backed by fast enough timing hardware, as in this example:

```
$ cat /sys/devices/system/clocksource/clocksource0/
available_clocksource
jiffies
$ dmesg | grep time.c
time.c: Using 3.579545 MHz WALL PM GTOD PIT/TSC timer.
time.c: Detected 2400.153 MHz processor.
$ pg_test_timing
Testing timing overhead for 3 seconds.
Per timing duration including loop overhead: 97.75 ns
Histogram of timing durations:
  < us    % of total    count
    1      90.23734    27694571
    2       9.75277     2993204
    4       0.00981       3010
    8       0.00007         22
   16       0.00000          1
   32       0.00000          1
```

Clock Hardware and Timing Accuracy

Collecting accurate timing information is normally done on computers using hardware clocks with various levels of accuracy. With some hardware the operating systems can pass the system clock time almost directly to programs. A system clock can also be derived from a chip that simply provides timing interrupts, periodic ticks at some known time interval. In either case, operating system kernels provide a clock source that hides these details. But the accuracy of that clock source and how quickly it can return results varies based on the underlying hardware.

Inaccurate time keeping can result in system instability. Test any change to the clock source very carefully. Operating system defaults are sometimes made to favor reliability over best accuracy. And if you are using a virtual machine, look into the recommended time sources compatible with it. Virtual hardware faces additional difficulties when emulating timers, and there are often per operating system settings suggested by vendors.

The Time Stamp Counter (TSC) clock source is the most accurate one available on current generation CPUs. It's the preferred way to track the system time when it's supported by the operating system and the TSC clock is reliable. There are several ways that TSC can fail to provide an accurate timing source, making it unreliable. Older systems can have a TSC clock that varies based on the CPU temperature, making it unusable for timing. Trying to use TSC on some older multicore CPUs can give a reported time that's inconsistent among multiple cores. This can result in the time going backwards, a problem this program checks for. And even the newest systems can fail to provide accurate TSC timing with very aggressive power saving configurations.

Newer operating systems may check for the known TSC problems and switch to a slower, more stable clock source when they are seen. If your system supports TSC time but doesn't default to that, it may be disabled for a good reason. And some operating systems may not detect all the possible problems correctly, or will allow using TSC even in situations where it's known to be inaccurate.

The High Precision Event Timer (HPET) is the preferred timer on systems where it's available and TSC is not accurate. The timer chip itself is programmable to allow up to 100 nanosecond resolution, but you may not see that much accuracy in your system clock.

Advanced Configuration and Power Interface (ACPI) provides a Power Management (PM) Timer, which Linux refers to as the `acpi_pm`. The clock derived from `acpi_pm` will at best provide 300 nanosecond resolution.

Timers used on older PC hardware include the 8254 Programmable Interval Timer (PIT), the real-time clock (RTC), the Advanced Programmable Interrupt Controller (APIC) timer, and the Cyclone timer. These timers aim for millisecond resolution.

See Also

EXPLAIN

pg_upgrade

pg_upgrade — upgrade a PostgreSQL server instance

Synopsis

```
pg_upgrade -b oldbindir -B newbindir -d oldconfigdir -D newconfigdir [option...]
```

Description

pg_upgrade (formerly called pg_migrator) allows data stored in PostgreSQL data files to be upgraded to a later PostgreSQL major version without the data dump/reload typically required for major version upgrades, e.g. from 9.5.8 to 9.6.4 or from 10.7 to 11.2. It is not required for minor version upgrades, e.g. from 9.6.2 to 9.6.3 or from 10.1 to 10.2.

Major PostgreSQL releases regularly add new features that often change the layout of the system tables, but the internal data storage format rarely changes. pg_upgrade uses this fact to perform rapid upgrades by creating new system tables and simply reusing the old user data files. If a future major release ever changes the data storage format in a way that makes the old data format unreadable, pg_upgrade will not be usable for such upgrades. (The community will attempt to avoid such situations.)

pg_upgrade does its best to make sure the old and new clusters are binary-compatible, e.g. by checking for compatible compile-time settings, including 32/64-bit binaries. It is important that any external modules are also binary compatible, though this cannot be checked by pg_upgrade.

pg_upgrade supports upgrades from 8.4.X and later to the current major release of PostgreSQL, including snapshot and beta releases.

Options

pg_upgrade accepts the following command-line arguments:

`-b bindir`

`--old-bindir=bindir`

the old PostgreSQL executable directory; environment variable PGBINOLD

`-B bindir`

`--new-bindir=bindir`

the new PostgreSQL executable directory; environment variable PGBINNEW

`-c`

`--check`

check clusters only, don't change any data

`-d configdir`

`--old-datadir=configdir`

the old database cluster configuration directory; environment variable PGDATAOLD

`-D configdir`

`--new-datadir=configdir`

the new database cluster configuration directory; environment variable PGDATANEW

`-j`
`--jobs`

number of simultaneous processes or threads to use

`-k`
`--link`

use hard links instead of copying files to the new cluster

`-o options`
`--old-options options`

options to be passed directly to the old `postgres` command; multiple option invocations are appended

`-O options`
`--new-options options`

options to be passed directly to the new `postgres` command; multiple option invocations are appended

`-p port`
`--old-port=port`

the old cluster port number; environment variable `PGPORTOLD`

`-P port`
`--new-port=port`

the new cluster port number; environment variable `PGPORTNEW`

`-r`
`--retain`

retain SQL and log files even after successful completion

`-s dir`
`--socketdir=dir`

directory to use for postmaster sockets during upgrade; default is current working directory; environment variable `PGSOCKETDIR`

`-U username`
`--username=username`

cluster's install user name; environment variable `PGUSER`

`-v`
`--verbose`

enable verbose internal logging

`-V`
`--version`

display version information, then exit

`--clone`

Use efficient file cloning (also known as “reflinks” on some systems) instead of copying files to the new cluster. This can result in near-instantaneous copying of the data files, giving the speed advantages of `-k/--link` while leaving the old cluster untouched.

File cloning is only supported on some operating systems and file systems. If it is selected but not supported, the `pg_upgrade` run will error. At present, it is supported on Linux (kernel 4.5 or later) with Btrfs and XFS (on file systems created with reflink support), and on macOS with APFS.

-?
--help

show help, then exit

Usage

These are the steps to perform an upgrade with `pg_upgrade`:

1. **Optionally move the old cluster**

If you are using a version-specific installation directory, e.g. `/opt/PostgreSQL/12`, you do not need to move the old cluster. The graphical installers all use version-specific installation directories.

If your installation directory is not version-specific, e.g. `/usr/local/pgsql`, it is necessary to move the current PostgreSQL install directory so it does not interfere with the new PostgreSQL installation. Once the current PostgreSQL server is shut down, it is safe to rename the PostgreSQL installation directory; assuming the old directory is `/usr/local/pgsql`, you can do:

```
mv /usr/local/pgsql /usr/local/pgsql.old
```

to rename the directory.

2. **For source installs, build the new version**

Build the new PostgreSQL source with `configure` flags that are compatible with the old cluster. `pg_upgrade` will check `pg_controldata` to make sure all settings are compatible before starting the upgrade.

3. **Install the new PostgreSQL binaries**

Install the new server's binaries and support files. `pg_upgrade` is included in a default installation.

For source installs, if you wish to install the new server in a custom location, use the `prefix` variable:

```
make prefix=/usr/local/pgsql.new install
```

4. **Initialize the new PostgreSQL cluster**

Initialize the new cluster using `initdb`. Again, use compatible `initdb` flags that match the old cluster. Many prebuilt installers do this step automatically. There is no need to start the new cluster.

5. **Install custom shared object files**

Install any custom shared object files (or DLLs) used by the old cluster into the new cluster, e.g. `pgcrypto.so`, whether they are from `contrib` or some other source. Do not install the schema definitions, e.g. `CREATE EXTENSION pgcrypto`, because these will be upgraded from the old cluster. Also, any custom full text search files (dictionary, synonym, thesaurus, stop words) must also be copied to the new cluster.

6. Adjust authentication

`pg_upgrade` will connect to the old and new servers several times, so you might want to set authentication to `peer` in `pg_hba.conf` or use a `~/.pgpass` file (see Section 33.15).

7. Stop both servers

Make sure both database servers are stopped using, on Unix, e.g.:

```
pg_ctl -D /opt/PostgreSQL/9.6 stop
pg_ctl -D /opt/PostgreSQL/12 stop
```

or on Windows, using the proper service names:

```
NET STOP postgresql-9.6
NET STOP postgresql-12
```

Streaming replication and log-shipping standby servers can remain running until a later step.

8. Prepare for standby server upgrades

If you are upgrading standby servers using methods outlined in section Step 10, verify that the old standby servers are caught up by running `pg_controldata` against the old primary and standby clusters. Verify that the “Latest checkpoint location” values match in all clusters. (There will be a mismatch if old standby servers were shut down before the old primary or if the old standby servers are still running.) Also, change `wal_level` to `replica` in the `postgresql.conf` file on the new primary cluster.

9. Run pg_upgrade

Always run the `pg_upgrade` binary of the new server, not the old one. `pg_upgrade` requires the specification of the old and new cluster's data and executable (`bin`) directories. You can also specify user and port values, and whether you want the data files linked or cloned instead of the default copy behavior.

If you use link mode, the upgrade will be much faster (no file copying) and use less disk space, but you will not be able to access your old cluster once you start the new cluster after the upgrade. Link mode also requires that the old and new cluster data directories be in the same file system. (Tablespaces and `pg_wal` can be on different file systems.) Clone mode provides the same speed and disk space advantages but does not cause the old cluster to be unusable once the new cluster is started. Clone mode also requires that the old and new data directories be in the same file system. This mode is only available on certain operating systems and file systems.

The `--jobs` option allows multiple CPU cores to be used for copying/linking of files and to dump and reload database schemas in parallel; a good place to start is the maximum of the number of CPU cores and tablespaces. This option can dramatically reduce the time to upgrade a multi-database server running on a multiprocessor machine.

For Windows users, you must be logged into an administrative account, and then start a shell as the `postgres` user and set the proper path:

```
RUNAS /USER:postgres "CMD.EXE"
SET PATH=%PATH%;C:\Program Files\PostgreSQL\12\bin;
```

and then run `pg_upgrade` with quoted directories, e.g.:

```
pg_upgrade.exe
```

```
--old-datadir "C:/Program Files/PostgreSQL/9.6/data"  
--new-datadir "C:/Program Files/PostgreSQL/12/data"  
--old-bindir "C:/Program Files/PostgreSQL/9.6/bin"  
--new-bindir "C:/Program Files/PostgreSQL/12/bin"
```

Once started, `pg_upgrade` will verify the two clusters are compatible and then do the upgrade. You can use `pg_upgrade --check` to perform only the checks, even if the old server is still running. `pg_upgrade --check` will also outline any manual adjustments you will need to make after the upgrade. If you are going to be using link or clone mode, you should use the option `--link` or `--clone` with `--check` to enable mode-specific checks. `pg_upgrade` requires write permission in the current directory.

Obviously, no one should be accessing the clusters during the upgrade. `pg_upgrade` defaults to running servers on port 50432 to avoid unintended client connections. You can use the same port number for both clusters when doing an upgrade because the old and new clusters will not be running at the same time. However, when checking an old running server, the old and new port numbers must be different.

If an error occurs while restoring the database schema, `pg_upgrade` will exit and you will have to revert to the old cluster as outlined in Step 16 below. To try `pg_upgrade` again, you will need to modify the old cluster so the `pg_upgrade` schema restore succeeds. If the problem is a `contrib` module, you might need to uninstall the `contrib` module from the old cluster and install it in the new cluster after the upgrade, assuming the module is not being used to store user data.

10. Upgrade streaming replication and log-shipping standby servers

If you used link mode and have Streaming Replication (see Section 26.2.5) or Log-Shipping (see Section 26.2) standby servers, you can follow these steps to quickly upgrade them. You will not be running `pg_upgrade` on the standby servers, but rather `rsync` on the primary. Do not start any servers yet.

If you did *not* use link mode, do not have or do not want to use `rsync`, or want an easier solution, skip the instructions in this section and simply recreate the standby servers once `pg_upgrade` completes and the new primary is running.

a. Install the new PostgreSQL binaries on standby servers

Make sure the new binaries and support files are installed on all standby servers.

b. Make sure the new standby data directories do *not* exist

Make sure the new standby data directories do *not* exist or are empty. If `initdb` was run, delete the standby servers' new data directories.

c. Install custom shared object files

Install the same custom shared object files on the new standbys that you installed in the new primary cluster.

d. Stop standby servers

If the standby servers are still running, stop them now using the above instructions.

e. Save configuration files

Save any configuration files from the old standbys' configuration directories you need to keep, e.g. `postgresql.conf`, `pg_hba.conf`, because these will be overwritten or removed in the next step.

f. Run rsync

When using link mode, standby servers can be quickly upgraded using rsync. To accomplish this, from a directory on the primary server that is above the old and new database cluster directories, run this on the *primary* for each standby server:

```
rsync --archive --delete --hard-links --size-only --no-inc-recursive old_cluster new_cluster remote_dir
```

where `old_cluster` and `new_cluster` are relative to the current directory on the primary, and `remote_dir` is *above* the old and new cluster directories on the standby. The directory structure under the specified directories on the primary and standbys must match. Consult the rsync manual page for details on specifying the remote directory, e.g.

```
rsync --archive --delete --hard-links --size-only --no-inc-recursive /opt/PostgreSQL/9.5 \
/opt/PostgreSQL/9.6 standby.example.com:/opt/PostgreSQL
```

You can verify what the command will do using rsync's `--dry-run` option. While rsync must be run on the primary for at least one standby, it is possible to run rsync on an upgraded standby to upgrade other standbys, as long as the upgraded standby has not been started.

What this does is to record the links created by `pg_upgrade`'s link mode that connect files in the old and new clusters on the primary server. It then finds matching files in the standby's old cluster and creates links for them in the standby's new cluster. Files that were not linked on the primary are copied from the primary to the standby. (They are usually small.) This provides rapid standby upgrades. Unfortunately, rsync needlessly copies files associated with temporary and unlogged tables because these files don't normally exist on standby servers.

If you have tablespaces, you will need to run a similar rsync command for each tablespace directory, e.g.:

```
rsync --archive --delete --hard-links --size-only --no-inc-recursive /voll/pg_tblsp/Pg_9.5_201510051 \
/voll/pg_tblsp/Pg_9.6_201608131 standby.example.com:/voll/pg_tblsp
```

If you have relocated `pg_wal` outside the data directories, rsync must be run on those directories too.

g. Configure streaming replication and log-shipping standby servers

Configure the servers for log shipping. (You do not need to run `pg_start_backup()` and `pg_stop_backup()` or take a file system backup as the standbys are still synchronized with the primary.)

11. Restore pg_hba.conf

If you modified `pg_hba.conf`, restore its original settings. It might also be necessary to adjust other configuration files in the new cluster to match the old cluster, e.g. `postgresql.conf`.

12. Start the new server

The new server can now be safely started, and then any rsync'ed standby servers.

13. Post-upgrade processing

If any post-upgrade processing is required, `pg_upgrade` will issue warnings as it completes. It will also generate script files that must be run by the administrator. The script files will connect to each database that needs post-upgrade processing. Each script should be run using:

```
psql --username=postgres --file=script.sql postgres
```

The scripts can be run in any order and can be deleted once they have been run.

Caution

In general it is unsafe to access tables referenced in rebuild scripts until the rebuild scripts have run to completion; doing so could yield incorrect results or poor performance. Tables not referenced in rebuild scripts can be accessed immediately.

14. Statistics

Because optimizer statistics are not transferred by `pg_upgrade`, you will be instructed to run a command to regenerate that information at the end of the upgrade. You might need to set connection parameters to match your new cluster.

15. Delete old cluster

Once you are satisfied with the upgrade, you can delete the old cluster's data directories by running the script mentioned when `pg_upgrade` completes. (Automatic deletion is not possible if you have user-defined tablespaces inside the old data directory.) You can also delete the old installation directories (e.g. `bin`, `share`).

16. Reverting to old cluster

If, after running `pg_upgrade`, you wish to revert to the old cluster, there are several options:

- If the `--check` option was used, the old cluster was unmodified; it can be restarted.
- If the `--link` option was *not* used, the old cluster was unmodified; it can be restarted.
- If the `--link` option was used, the data files might be shared between the old and new cluster:
 - If `pg_upgrade` aborted before linking started, the old cluster was unmodified; it can be restarted.
 - If you did *not* start the new cluster, the old cluster was unmodified except that, when linking started, a `.old` suffix was appended to `$PGDATA/global/pg_control`. To reuse the old cluster, remove the `.old` suffix from `$PGDATA/global/pg_control`; you can then restart the old cluster.
 - If you did start the new cluster, it has written to shared files and it is unsafe to use the old cluster. The old cluster will need to be restored from backup in this case.

Notes

`pg_upgrade` creates various working files, such as schema dumps, in the current working directory. For security, be sure that that directory is not readable or writable by any other users.

`pg_upgrade` launches short-lived postmasters in the old and new data directories. Temporary Unix socket files for communication with these postmasters are, by default, made in the current working

directory. In some situations the path name for the current directory might be too long to be a valid socket name. In that case you can use the `-s` option to put the socket files in some directory with a shorter path name. For security, be sure that that directory is not readable or writable by any other users. (This is not relevant on Windows.)

All failure, rebuild, and reindex cases will be reported by `pg_upgrade` if they affect your installation; post-upgrade scripts to rebuild tables and indexes will be generated automatically. If you are trying to automate the upgrade of many clusters, you should find that clusters with identical database schemas require the same post-upgrade steps for all cluster upgrades; this is because the post-upgrade steps are based on the database schemas, and not user data.

For deployment testing, create a schema-only copy of the old cluster, insert dummy data, and upgrade that.

`pg_upgrade` does not support upgrading of databases containing table columns using these `reg*` OID-referencing system data types: `regproc`, `regprocedure`, `regoper`, `regoperator`, `regconfig`, and `regdictionary`. (`regtype` can be upgraded.)

If you are upgrading a pre-PostgreSQL 9.2 cluster that uses a configuration-file-only directory, you must pass the real data directory location to `pg_upgrade`, and pass the configuration directory location to the server, e.g. `-d /real-data-directory -o '-D /configuration-directory'`.

If using a pre-9.1 old server that is using a non-default Unix-domain socket directory or a default that differs from the default of the new cluster, set `PGHOST` to point to the old server's socket location. (This is not relevant on Windows.)

If you want to use link mode and you do not want your old cluster to be modified when the new cluster is started, consider using the clone mode. If that is not available, make a copy of the old cluster and upgrade that in link mode. To make a valid copy of the old cluster, use `rsync` to create a dirty copy of the old cluster while the server is running, then shut down the old server and run `rsync --checksum` again to update the copy with any changes to make it consistent. (`--checksum` is necessary because `rsync` only has file modification-time granularity of one second.) You might want to exclude some files, e.g. `postmaster.pid`, as documented in Section 25.3.3. If your file system supports file system snapshots or copy-on-write file copies, you can use that to make a backup of the old cluster and tablespaces, though the snapshot and copies must be created simultaneously or while the database server is down.

See Also

`initdb`, `pg_ctl`, `pg_dump`, `postgres`

pg_waldump

`pg_waldump` — display a human-readable rendering of the write-ahead log of a PostgreSQL database cluster

Synopsis

```
pg_waldump [option...] [startseg [endseg]]
```

Description

`pg_waldump` displays the write-ahead log (WAL) and is mainly useful for debugging or educational purposes.

This utility can only be run by the user who installed the server, because it requires read-only access to the data directory.

Options

The following command-line options control the location and format of the output:

startseg

Start reading at the specified log segment file. This implicitly determines the path in which files will be searched for, and the timeline to use.

endseg

Stop after reading the specified log segment file.

`-b`

`--bkp-details`

Output detailed information about backup blocks.

`-e end`

`--end=end`

Stop reading at the specified WAL location, instead of reading to the end of the log stream.

`-f`

`--follow`

After reaching the end of valid WAL, keep polling once per second for new WAL to appear.

`-n limit`

`--limit=limit`

Display the specified number of records, then stop.

`-p path`

`--path=path`

Specifies a directory to search for log segment files or a directory with a `pg_wal` subdirectory that contains such files. The default is to search in the current directory, the `pg_wal` subdirectory of the current directory, and the `pg_wal` subdirectory of PGDATA.

`-r rmgr`
`--rmgr=rmgr`

Only display records generated by the specified resource manager. If `list` is passed as name, print a list of valid resource manager names, and exit.

`-s start`
`--start=start`

WAL location at which to start reading. The default is to start reading the first valid log record found in the earliest file found.

`-t timeline`
`--timeline=timeline`

Timeline from which to read log records. The default is to use the value in `startseg`, if that is specified; otherwise, the default is 1.

`-V`
`--version`

Print the `pg_waldump` version and exit.

`-x xid`
`--xid=xid`

Only display records marked with the given transaction ID.

`-z`
`--stats[=record]`

Display summary statistics (number and size of records and full-page images) instead of individual records. Optionally generate statistics per-record instead of per-`rmgr`.

`-?`
`--help`

Show help about `pg_waldump` command line arguments, and exit.

Environment

`PGDATA`

Data directory; see also the `-p` option.

`PG_COLOR`

Specifies whether to use color in diagnostics messages. Possible values are `always`, `auto`, `never`.

Notes

Can give wrong results when the server is running.

Only the specified timeline is displayed (or the default, if none is specified). Records in other timelines are ignored.

`pg_waldump` cannot read WAL files with suffix `.partial`. If those files need to be read, `.partial` suffix needs to be removed from the file name.

See Also

Section 29.5

postgres

postgres — PostgreSQL database server

Synopsis

```
postgres [option...]
```

Description

`postgres` is the PostgreSQL database server. In order for a client application to access a database it connects (over a network or locally) to a running `postgres` instance. The `postgres` instance then starts a separate server process to handle the connection.

One `postgres` instance always manages the data of exactly one database cluster. A database cluster is a collection of databases that is stored at a common file system location (the “data area”). More than one `postgres` instance can run on a system at one time, so long as they use different data areas and different communication ports (see below). When `postgres` starts it needs to know the location of the data area. The location must be specified by the `-D` option or the `PGDATA` environment variable; there is no default. Typically, `-D` or `PGDATA` points directly to the data area directory created by `initdb`. Other possible file layouts are discussed in Section 19.2.

By default `postgres` starts in the foreground and prints log messages to the standard error stream. In practical applications `postgres` should be started as a background process, perhaps at boot time.

The `postgres` command can also be called in single-user mode. The primary use for this mode is during bootstrapping by `initdb`. Sometimes it is used for debugging or disaster recovery; note that running a single-user server is not truly suitable for debugging the server, since no realistic interprocess communication and locking will happen. When invoked in single-user mode from the shell, the user can enter queries and the results will be printed to the screen, but in a form that is more useful for developers than end users. In the single-user mode, the session user will be set to the user with ID 1, and implicit superuser powers are granted to this user. This user does not actually have to exist, so the single-user mode can be used to manually recover from certain kinds of accidental damage to the system catalogs.

Options

`postgres` accepts the following command-line arguments. For a detailed discussion of the options consult Chapter 19. You can save typing most of these options by setting up a configuration file. Some (safe) options can also be set from the connecting client in an application-dependent way to apply only for that session. For example, if the environment variable `PGOPTIONS` is set, then libpq-based clients will pass that string to the server, which will interpret it as `postgres` command-line options.

General Purpose

`-B nbuffers`

Sets the number of shared buffers for use by the server processes. The default value of this parameter is chosen automatically by `initdb`. Specifying this option is equivalent to setting the `shared_buffers` configuration parameter.

`-c name=value`

Sets a named run-time parameter. The configuration parameters supported by PostgreSQL are described in Chapter 19. Most of the other command line options are in fact short forms of such a parameter assignment. `-c` can appear multiple times to set multiple parameters.

`-C name`

Prints the value of the named run-time parameter, and exits. (See the `-c` option above for details.) This can be used on a running server, and returns values from `postgresql.conf`, modified by any parameters supplied in this invocation. It does not reflect parameters supplied when the cluster was started.

This option is meant for other programs that interact with a server instance, such as `pg_ctl`, to query configuration parameter values. User-facing applications should instead use `SHOW` or the `pg_settings` view.

`-d debug-level`

Sets the debug level. The higher this value is set, the more debugging output is written to the server log. Values are from 1 to 5. It is also possible to pass `-d 0` for a specific session, which will prevent the server log level of the parent `postgres` process from being propagated to this session.

`-D datadir`

Specifies the file system location of the database configuration files. See Section 19.2 for details.

`-e`

Sets the default date style to “European”, that is `DMY` ordering of input date fields. This also causes the day to be printed before the month in certain date output formats. See Section 8.5 for more information.

`-F`

Disables `fsync` calls for improved performance, at the risk of data corruption in the event of a system crash. Specifying this option is equivalent to disabling the `fsync` configuration parameter. Read the detailed documentation before using this!

`-h hostname`

Specifies the IP host name or address on which `postgres` is to listen for TCP/IP connections from client applications. The value can also be a comma-separated list of addresses, or `*` to specify listening on all available interfaces. An empty value specifies not listening on any IP addresses, in which case only Unix-domain sockets can be used to connect to the server. Defaults to listening only on localhost. Specifying this option is equivalent to setting the `listen_addresses` configuration parameter.

`-i`

Allows remote clients to connect via TCP/IP (Internet domain) connections. Without this option, only local connections are accepted. This option is equivalent to setting `listen_addresses` to `*` in `postgresql.conf` or via `-h`.

This option is deprecated since it does not allow access to the full functionality of `listen_addresses`. It's usually better to set `listen_addresses` directly.

`-k directory`

Specifies the directory of the Unix-domain socket on which `postgres` is to listen for connections from client applications. The value can also be a comma-separated list of directories. An empty value specifies not listening on any Unix-domain sockets, in which case only TCP/IP sockets can be used to connect to the server. The default value is normally `/tmp`, but that can be changed at build time. Specifying this option is equivalent to setting the `unix_socket_directories` configuration parameter.

-l

Enables secure connections using SSL. PostgreSQL must have been compiled with support for SSL for this option to be available. For more information on using SSL, refer to Section 18.9.

-N *max-connections*

Sets the maximum number of client connections that this server will accept. The default value of this parameter is chosen automatically by initdb. Specifying this option is equivalent to setting the `max_connections` configuration parameter.

-o *extra-options*

The command-line-style arguments specified in *extra-options* are passed to all server processes started by this `postgres` process.

Spaces within *extra-options* are considered to separate arguments, unless escaped with a backslash (`\`); write `\\` to represent a literal backslash. Multiple arguments can also be specified via multiple uses of `-o`.

The use of this option is obsolete; all command-line options for server processes can be specified directly on the `postgres` command line.

-p *port*

Specifies the TCP/IP port or local Unix domain socket file extension on which `postgres` is to listen for connections from client applications. Defaults to the value of the `PGPORT` environment variable, or if `PGPORT` is not set, then defaults to the value established during compilation (normally 5432). If you specify a port other than the default port, then all client applications must specify the same port using either command-line options or `PGPORT`.

-s

Print time information and other statistics at the end of each command. This is useful for benchmarking or for use in tuning the number of buffers.

-S *work-mem*

Specifies the amount of memory to be used by internal sorts and hashes before resorting to temporary disk files. See the description of the `work_mem` configuration parameter in Section 19.4.1.

-V

--version

Print the `postgres` version and exit.

--name=*value*

Sets a named run-time parameter; a shorter form of `-c`.

--describe-config

This option dumps out the server's internal configuration variables, descriptions, and defaults in tab-delimited COPY format. It is designed primarily for use by administration tools.

-?

--help

Show help about `postgres` command line arguments, and exit.

Semi-Internal Options

The options described here are used mainly for debugging purposes, and in some cases to assist with recovery of severely damaged databases. There should be no reason to use them in a production data-

base setup. They are listed here only for use by PostgreSQL system developers. Furthermore, these options might change or be removed in a future release without notice.

`-f { s | i | o | b | t | n | m | h }`

Forbids the use of particular scan and join methods: `s` and `i` disable sequential and index scans respectively, `o`, `b` and `t` disable index-only scans, bitmap index scans, and TID scans respectively, while `n`, `m`, and `h` disable nested-loop, merge and hash joins respectively.

Neither sequential scans nor nested-loop joins can be disabled completely; the `-fs` and `-fn` options simply discourage the optimizer from using those plan types if it has any other alternative.

`-n`

This option is for debugging problems that cause a server process to die abnormally. The ordinary strategy in this situation is to notify all other server processes that they must terminate and then reinitialize the shared memory and semaphores. This is because an errant server process could have corrupted some shared state before terminating. This option specifies that `postgres` will not reinitialize shared data structures. A knowledgeable system programmer can then use a debugger to examine shared memory and semaphore state.

`-O`

Allows the structure of system tables to be modified. This is used by `initdb`.

`-P`

Ignore system indexes when reading system tables, but still update the indexes when modifying the tables. This is useful when recovering from damaged system indexes.

`-t pa[rser] | pl[anner] | e[xecutor]`

Print timing statistics for each query relating to each of the major system modules. This option cannot be used together with the `-s` option.

`-T`

This option is for debugging problems that cause a server process to die abnormally. The ordinary strategy in this situation is to notify all other server processes that they must terminate and then reinitialize the shared memory and semaphores. This is because an errant server process could have corrupted some shared state before terminating. This option specifies that `postgres` will stop all other server processes by sending the signal `SIGSTOP`, but will not cause them to terminate. This permits system programmers to collect core dumps from all server processes by hand.

`-v protocol`

Specifies the version number of the frontend/backend protocol to be used for a particular session. This option is for internal use only.

`-W seconds`

A delay of this many seconds occurs when a new server process is started, after it conducts the authentication procedure. This is intended to give an opportunity to attach to the server process with a debugger.

Options for Single-User Mode

The following options only apply to the single-user mode (see Single-User Mode).

`--single`

Selects the single-user mode. This must be the first argument on the command line.

database

Specifies the name of the database to be accessed. This must be the last argument on the command line. If it is omitted it defaults to the user name.

-E

Echo all commands to standard output before executing them.

-j

Use semicolon followed by two newlines, rather than just newline, as the command entry terminator.

-r *filename*

Send all server log output to *filename*. This option is only honored when supplied as a command-line option.

Environment

PGCLIENTENCODING

Default character encoding used by clients. (The clients can override this individually.) This value can also be set in the configuration file.

PGDATA

Default data directory location

PGDATESTYLE

Default value of the `DateStyle` run-time parameter. (The use of this environment variable is deprecated.)

PGPORT

Default port number (preferably set in the configuration file)

Diagnostics

A failure message mentioning `semget` or `shmget` probably indicates you need to configure your kernel to provide adequate shared memory and semaphores. For more discussion see Section 18.4. You might be able to postpone reconfiguring your kernel by decreasing `shared_buffers` to reduce the shared memory consumption of PostgreSQL, and/or by reducing `max_connections` to reduce the semaphore consumption.

A failure message suggesting that another server is already running should be checked carefully, for example by using the command

```
$ ps ax | grep postgres
```

or

```
$ ps -ef | grep postgres
```

depending on your system. If you are certain that no conflicting server is running, you can remove the lock file mentioned in the message and try again.

A failure message indicating inability to bind to a port might indicate that that port is already in use by some non-PostgreSQL process. You might also get this error if you terminate `postgres` and immediately restart it using the same port; in this case, you must simply wait a few seconds until the operating system closes the port before trying again. Finally, you might get this error if you specify a port number that your operating system considers to be reserved. For example, many versions of Unix consider port numbers under 1024 to be “trusted” and only permit the Unix superuser to access them.

Notes

The utility command `pg_ctl` can be used to start and shut down the `postgres` server safely and comfortably.

If at all possible, *do not* use `SIGKILL` to kill the main `postgres` server. Doing so will prevent `postgres` from freeing the system resources (e.g., shared memory and semaphores) that it holds before terminating. This might cause problems for starting a fresh `postgres` run.

To terminate the `postgres` server normally, the signals `SIGTERM`, `SIGINT`, or `SIGQUIT` can be used. The first will wait for all clients to terminate before quitting, the second will forcefully disconnect all clients, and the third will quit immediately without proper shutdown, resulting in a recovery run during restart.

The `SIGHUP` signal will reload the server configuration files. It is also possible to send `SIGHUP` to an individual server process, but that is usually not sensible.

To cancel a running query, send the `SIGINT` signal to the process running that command. To terminate a backend process cleanly, send `SIGTERM` to that process. See also `pg_cancel_backend` and `pg_terminate_backend` in Section 9.26.2 for the SQL-callable equivalents of these two actions.

The `postgres` server uses `SIGQUIT` to tell subordinate server processes to terminate without normal cleanup. This signal *should not* be used by users. It is also unwise to send `SIGKILL` to a server process — the main `postgres` process will interpret this as a crash and will force all the sibling processes to quit as part of its standard crash-recovery procedure.

Bugs

The `--` options will not work on FreeBSD or OpenBSD. Use `-c` instead. This is a bug in the affected operating systems; a future release of PostgreSQL will provide a workaround if this is not fixed.

Single-User Mode

To start a single-user mode server, use a command like

```
postgres --single -D /usr/local/pgsql/data other-options
my_database
```

Provide the correct path to the database directory with `-D`, or make sure that the environment variable `PGDATA` is set. Also specify the name of the particular database you want to work in.

Normally, the single-user mode server treats newline as the command entry terminator; there is no intelligence about semicolons, as there is in `psql`. To continue a command across multiple lines, you must type backslash just before each newline except the last one. The backslash and adjacent newline are both dropped from the input command. Note that this will happen even when within a string literal or comment.

But if you use the `-j` command line switch, a single newline does not terminate command entry; instead, the sequence semicolon-newline-newline does. That is, type a semicolon immediately followed by a completely empty line. Backslash-newline is not treated specially in this mode. Again, there is no intelligence about such a sequence appearing within a string literal or comment.

In either input mode, if you type a semicolon that is not just before or part of a command entry terminator, it is considered a command separator. When you do type a command entry terminator, the multiple statements you've entered will be executed as a single transaction.

To quit the session, type EOF (**Control+D**, usually). If you've entered any text since the last command entry terminator, then EOF will be taken as a command entry terminator, and another EOF will be needed to exit.

Note that the single-user mode server does not provide sophisticated line-editing features (no command history, for example). Single-user mode also does not do any background processing, such as automatic checkpoints or replication.

Examples

To start `postgres` in the background using default values, type:

```
$ nohup postgres >logfile 2>&1 </dev/null &
```

To start `postgres` with a specific port, e.g. 1234:

```
$ postgres -p 1234
```

To connect to this server using `psql`, specify this port with the `-p` option:

```
$ psql -p 1234
```

or set the environment variable `PGPORT`:

```
$ export PGPORT=1234
$ psql
```

Named run-time parameters can be set in either of these styles:

```
$ postgres -c work_mem=1234
$ postgres --work-mem=1234
```

Either form overrides whatever setting might exist for `work_mem` in `postgresql.conf`. Notice that underscores in parameter names can be written as either underscore or dash on the command line. Except for short-term experiments, it's probably better practice to edit the setting in `postgresql.conf` than to rely on a command-line switch to set a parameter.

See Also

`initdb`, `pg_ctl`

postmaster

postmaster — PostgreSQL database server

Synopsis

`postmaster` [*option...*]

Description

`postmaster` is a deprecated alias of `postgres`.

See Also

`postgres`

Part VII. Internals

This part contains assorted information that might be of use to PostgreSQL developers.

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Chapter 50. Overview of PostgreSQL Internals

Author

This chapter originated as part of [sim98], Stefan Simkovic's Master's Thesis prepared at Vienna University of Technology under the direction of O.Univ.Prof.Dr. Georg Gottlob and Univ.Ass. Mag. Katrin Seyr.

This chapter gives an overview of the internal structure of the backend of PostgreSQL. After having read the following sections you should have an idea of how a query is processed. This chapter does not aim to provide a detailed description of the internal operation of PostgreSQL, as such a document would be very extensive. Rather, this chapter is intended to help the reader understand the general sequence of operations that occur within the backend from the point at which a query is received, to the point at which the results are returned to the client.

50.1. The Path of a Query

Here we give a short overview of the stages a query has to pass in order to obtain a result.

1. A connection from an application program to the PostgreSQL server has to be established. The application program transmits a query to the server and waits to receive the results sent back by the server.
2. The *parser stage* checks the query transmitted by the application program for correct syntax and creates a *query tree*.
3. The *rewrite system* takes the query tree created by the parser stage and looks for any *rules* (stored in the *system catalogs*) to apply to the query tree. It performs the transformations given in the *rule bodies*.

One application of the rewrite system is in the realization of *views*. Whenever a query against a view (i.e., a *virtual table*) is made, the rewrite system rewrites the user's query to a query that accesses the *base tables* given in the *view definition* instead.

4. The *planner/optimizer* takes the (rewritten) query tree and creates a *query plan* that will be the input to the *executor*.

It does so by first creating all possible *paths* leading to the same result. For example if there is an index on a relation to be scanned, there are two paths for the scan. One possibility is a simple sequential scan and the other possibility is to use the index. Next the cost for the execution of each path is estimated and the cheapest path is chosen. The cheapest path is expanded into a complete plan that the executor can use.

5. The executor recursively steps through the *plan tree* and retrieves rows in the way represented by the plan. The executor makes use of the *storage system* while scanning relations, performs *sorts* and *joins*, evaluates *qualifications* and finally hands back the rows derived.

In the following sections we will cover each of the above listed items in more detail to give a better understanding of PostgreSQL's internal control and data structures.

50.2. How Connections Are Established

PostgreSQL is implemented using a simple “process per user” client/server model. In this model there is one *client process* connected to exactly one *server process*. As we do not know ahead of time

how many connections will be made, we have to use a *master process* that spawns a new server process every time a connection is requested. This master process is called `postgres` and listens at a specified TCP/IP port for incoming connections. Whenever a request for a connection is detected the `postgres` process spawns a new server process. The server tasks communicate with each other using *semaphores* and *shared memory* to ensure data integrity throughout concurrent data access.

The client process can be any program that understands the PostgreSQL protocol described in Chapter 52. Many clients are based on the C-language library `libpq`, but several independent implementations of the protocol exist, such as the Java JDBC driver.

Once a connection is established the client process can send a query to the *backend* (server). The query is transmitted using plain text, i.e., there is no parsing done in the *frontend* (client). The server parses the query, creates an *execution plan*, executes the plan and returns the retrieved rows to the client by transmitting them over the established connection.

50.3. The Parser Stage

The *parser stage* consists of two parts:

- The *parser* defined in `gram.y` and `scan.l` is built using the Unix tools `bison` and `flex`.
- The *transformation process* does modifications and augmentations to the data structures returned by the parser.

50.3.1. Parser

The parser has to check the query string (which arrives as plain text) for valid syntax. If the syntax is correct a *parse tree* is built up and handed back; otherwise an error is returned. The parser and lexer are implemented using the well-known Unix tools `bison` and `flex`.

The *lexer* is defined in the file `scan.l` and is responsible for recognizing *identifiers*, the *SQL key words* etc. For every key word or identifier that is found, a *token* is generated and handed to the parser.

The parser is defined in the file `gram.y` and consists of a set of *grammar rules* and *actions* that are executed whenever a rule is fired. The code of the actions (which is actually C code) is used to build up the parse tree.

The file `scan.l` is transformed to the C source file `scan.c` using the program `flex` and `gram.y` is transformed to `gram.c` using `bison`. After these transformations have taken place a normal C compiler can be used to create the parser. Never make any changes to the generated C files as they will be overwritten the next time `flex` or `bison` is called.

Note

The mentioned transformations and compilations are normally done automatically using the *makefiles* shipped with the PostgreSQL source distribution.

A detailed description of `bison` or the grammar rules given in `gram.y` would be beyond the scope of this paper. There are many books and documents dealing with `flex` and `bison`. You should be familiar with `bison` before you start to study the grammar given in `gram.y` otherwise you won't understand what happens there.

50.3.2. Transformation Process

The parser stage creates a parse tree using only fixed rules about the syntactic structure of SQL. It does not make any lookups in the system catalogs, so there is no possibility to understand the detailed

semantics of the requested operations. After the parser completes, the *transformation process* takes the tree handed back by the parser as input and does the semantic interpretation needed to understand which tables, functions, and operators are referenced by the query. The data structure that is built to represent this information is called the *query tree*.

The reason for separating raw parsing from semantic analysis is that system catalog lookups can only be done within a transaction, and we do not wish to start a transaction immediately upon receiving a query string. The raw parsing stage is sufficient to identify the transaction control commands (BEGIN, ROLLBACK, etc), and these can then be correctly executed without any further analysis. Once we know that we are dealing with an actual query (such as SELECT or UPDATE), it is okay to start a transaction if we're not already in one. Only then can the transformation process be invoked.

The query tree created by the transformation process is structurally similar to the raw parse tree in most places, but it has many differences in detail. For example, a FuncCall node in the parse tree represents something that looks syntactically like a function call. This might be transformed to either a FuncExpr or Aggref node depending on whether the referenced name turns out to be an ordinary function or an aggregate function. Also, information about the actual data types of columns and expression results is added to the query tree.

50.4. The PostgreSQL Rule System

PostgreSQL supports a powerful *rule system* for the specification of *views* and ambiguous *view updates*. Originally the PostgreSQL rule system consisted of two implementations:

- The first one worked using *row level* processing and was implemented deep in the *executor*. The rule system was called whenever an individual row had been accessed. This implementation was removed in 1995 when the last official release of the Berkeley Postgres project was transformed into Postgres95.
- The second implementation of the rule system is a technique called *query rewriting*. The *rewrite system* is a module that exists between the *parser stage* and the *planner/optimizer*. This technique is still implemented.

The query rewriter is discussed in some detail in Chapter 40, so there is no need to cover it here. We will only point out that both the input and the output of the rewriter are query trees, that is, there is no change in the representation or level of semantic detail in the trees. Rewriting can be thought of as a form of macro expansion.

50.5. Planner/Optimizer

The task of the *planner/optimizer* is to create an optimal execution plan. A given SQL query (and hence, a query tree) can be actually executed in a wide variety of different ways, each of which will produce the same set of results. If it is computationally feasible, the query optimizer will examine each of these possible execution plans, ultimately selecting the execution plan that is expected to run the fastest.

Note

In some situations, examining each possible way in which a query can be executed would take an excessive amount of time and memory space. In particular, this occurs when executing queries involving large numbers of join operations. In order to determine a reasonable (not necessarily optimal) query plan in a reasonable amount of time, PostgreSQL uses a *Genetic Query Optimizer* (see Chapter 59) when the number of joins exceeds a threshold (see `geqo_threshold`).

The planner's search procedure actually works with data structures called *paths*, which are simply cut-down representations of plans containing only as much information as the planner needs to make its decisions. After the cheapest path is determined, a full-fledged *plan tree* is built to pass to the executor. This represents the desired execution plan in sufficient detail for the executor to run it. In the rest of this section we'll ignore the distinction between paths and plans.

50.5.1. Generating Possible Plans

The planner/optimizer starts by generating plans for scanning each individual relation (table) used in the query. The possible plans are determined by the available indexes on each relation. There is always the possibility of performing a sequential scan on a relation, so a sequential scan plan is always created. Assume an index is defined on a relation (for example a B-tree index) and a query contains the restriction `relation.attribute OPR constant`. If `relation.attribute` happens to match the key of the B-tree index and `OPR` is one of the operators listed in the index's *operator class*, another plan is created using the B-tree index to scan the relation. If there are further indexes present and the restrictions in the query happen to match a key of an index, further plans will be considered. Index scan plans are also generated for indexes that have a sort ordering that can match the query's `ORDER BY` clause (if any), or a sort ordering that might be useful for merge joining (see below).

If the query requires joining two or more relations, plans for joining relations are considered after all feasible plans have been found for scanning single relations. The three available join strategies are:

- *nested loop join*: The right relation is scanned once for every row found in the left relation. This strategy is easy to implement but can be very time consuming. (However, if the right relation can be scanned with an index scan, this can be a good strategy. It is possible to use values from the current row of the left relation as keys for the index scan of the right.)
- *merge join*: Each relation is sorted on the join attributes before the join starts. Then the two relations are scanned in parallel, and matching rows are combined to form join rows. This kind of join is more attractive because each relation has to be scanned only once. The required sorting might be achieved either by an explicit sort step, or by scanning the relation in the proper order using an index on the join key.
- *hash join*: the right relation is first scanned and loaded into a hash table, using its join attributes as hash keys. Next the left relation is scanned and the appropriate values of every row found are used as hash keys to locate the matching rows in the table.

When the query involves more than two relations, the final result must be built up by a tree of join steps, each with two inputs. The planner examines different possible join sequences to find the cheapest one.

If the query uses fewer than `geqo_threshold` relations, a near-exhaustive search is conducted to find the best join sequence. The planner preferentially considers joins between any two relations for which there exist a corresponding join clause in the `WHERE` qualification (i.e., for which a restriction like `where rel1.attr1=rel2.attr2` exists). Join pairs with no join clause are considered only when there is no other choice, that is, a particular relation has no available join clauses to any other relation. All possible plans are generated for every join pair considered by the planner, and the one that is (estimated to be) the cheapest is chosen.

When `geqo_threshold` is exceeded, the join sequences considered are determined by heuristics, as described in Chapter 59. Otherwise the process is the same.

The finished plan tree consists of sequential or index scans of the base relations, plus nested-loop, merge, or hash join nodes as needed, plus any auxiliary steps needed, such as sort nodes or aggregate-function calculation nodes. Most of these plan node types have the additional ability to do *selection* (discarding rows that do not meet a specified Boolean condition) and *projection* (computation of a derived column set based on given column values, that is, evaluation of scalar expressions where needed). One of the responsibilities of the planner is to attach selection conditions from the `WHERE` clause and computation of required output expressions to the most appropriate nodes of the plan tree.

50.6. Executor

The *executor* takes the plan created by the planner/optimizer and recursively processes it to extract the required set of rows. This is essentially a demand-pull pipeline mechanism. Each time a plan node is called, it must deliver one more row, or report that it is done delivering rows.

To provide a concrete example, assume that the top node is a `MergeJoin` node. Before any merge can be done two rows have to be fetched (one from each subplan). So the executor recursively calls itself to process the subplans (it starts with the subplan attached to `lefttree`). The new top node (the top node of the left subplan) is, let's say, a `Sort` node and again recursion is needed to obtain an input row. The child node of the `Sort` might be a `SeqScan` node, representing actual reading of a table. Execution of this node causes the executor to fetch a row from the table and return it up to the calling node. The `Sort` node will repeatedly call its child to obtain all the rows to be sorted. When the input is exhausted (as indicated by the child node returning a `NULL` instead of a row), the `Sort` code performs the sort, and finally is able to return its first output row, namely the first one in sorted order. It keeps the remaining rows stored so that it can deliver them in sorted order in response to later demands.

The `MergeJoin` node similarly demands the first row from its right subplan. Then it compares the two rows to see if they can be joined; if so, it returns a join row to its caller. On the next call, or immediately if it cannot join the current pair of inputs, it advances to the next row of one table or the other (depending on how the comparison came out), and again checks for a match. Eventually, one subplan or the other is exhausted, and the `MergeJoin` node returns `NULL` to indicate that no more join rows can be formed.

Complex queries can involve many levels of plan nodes, but the general approach is the same: each node computes and returns its next output row each time it is called. Each node is also responsible for applying any selection or projection expressions that were assigned to it by the planner.

The executor mechanism is used to evaluate all four basic SQL query types: `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. For `SELECT`, the top-level executor code only needs to send each row returned by the query plan tree off to the client. For `INSERT`, each returned row is inserted into the target table specified for the `INSERT`. This is done in a special top-level plan node called `ModifyTable`. (A simple `INSERT . . . VALUES` command creates a trivial plan tree consisting of a single `Result` node, which computes just one result row, and `ModifyTable` above it to perform the insertion. But `INSERT . . . SELECT` can demand the full power of the executor mechanism.) For `UPDATE`, the planner arranges that each computed row includes all the updated column values, plus the *TID* (tuple ID, or row ID) of the original target row; this data is fed into a `ModifyTable` node, which uses the information to create a new updated row and mark the old row deleted. For `DELETE`, the only column that is actually returned by the plan is the *TID*, and the `ModifyTable` node simply uses the *TID* to visit each target row and mark it deleted.

Chapter 51. System Catalogs

The system catalogs are the place where a relational database management system stores schema metadata, such as information about tables and columns, and internal bookkeeping information. PostgreSQL's system catalogs are regular tables. You can drop and recreate the tables, add columns, insert and update values, and severely mess up your system that way. Normally, one should not change the system catalogs by hand, there are normally SQL commands to do that. (For example, CREATE DATABASE inserts a row into the pg_database catalog — and actually creates the database on disk.) There are some exceptions for particularly esoteric operations, but many of those have been made available as SQL commands over time, and so the need for direct manipulation of the system catalogs is ever decreasing.

51.1. Overview

Table 51.1 lists the system catalogs. More detailed documentation of each catalog follows below.

Most system catalogs are copied from the template database during database creation and are thereafter database-specific. A few catalogs are physically shared across all databases in a cluster; these are noted in the descriptions of the individual catalogs.

Table 51.1. System Catalogs

Catalog Name	Purpose
pg_aggregate	aggregate functions
pg_am	relation access methods
pg_amop	access method operators
pg_amproc	access method support functions
pg_attrdef	column default values
pg_attribute	table columns (“attributes”)
pg_authid	authorization identifiers (roles)
pg_auth_members	authorization identifier membership relationships
pg_cast	casts (data type conversions)
pg_class	tables, indexes, sequences, views (“relations”)
pg_collation	collations (locale information)
pg_constraint	check constraints, unique constraints, primary key constraints, foreign key constraints
pg_conversion	encoding conversion information
pg_database	databases within this database cluster
pg_db_role_setting	per-role and per-database settings
pg_default_acl	default privileges for object types
pg_depend	dependencies between database objects
pg_description	descriptions or comments on database objects
pg_enum	enum label and value definitions
pg_event_trigger	event triggers
pg_extension	installed extensions
pg_foreign_data_wrapper	foreign-data wrapper definitions
pg_foreign_server	foreign server definitions
pg_foreign_table	additional foreign table information

Catalog Name	Purpose
pg_index	additional index information
pg_inherits	table inheritance hierarchy
pg_init_privs	object initial privileges
pg_language	languages for writing functions
pg_largeobject	data pages for large objects
pg_largeobject_metadata	metadata for large objects
pg_namespace	schemas
pg_opclass	access method operator classes
pg_operator	operators
pg_opfamily	access method operator families
pg_partitioned_table	information about partition key of tables
pg_pltemplate	template data for procedural languages
pg_policy	row-security policies
pg_proc	functions and procedures
pg_publication	publications for logical replication
pg_publication_rel	relation to publication mapping
pg_range	information about range types
pg_replication_origin	registered replication origins
pg_rewrite	query rewrite rules
pg_seclabel	security labels on database objects
pg_sequence	information about sequences
pg_shdepend	dependencies on shared objects
pg_shdescription	comments on shared objects
pg_shseclabel	security labels on shared database objects
pg_statistic	planner statistics
pg_statistic_ext	extended planner statistics (definition)
pg_statistic_ext_data	extended planner statistics (built statistics)
pg_subscription	logical replication subscriptions
pg_subscription_rel	relation state for subscriptions
pg_tablespace	tablespaces within this database cluster
pg_transform	transforms (data type to procedural language conversions)
pg_trigger	triggers
pg_ts_config	text search configurations
pg_ts_config_map	text search configurations' token mappings
pg_ts_dict	text search dictionaries
pg_ts_parser	text search parsers
pg_ts_template	text search templates
pg_type	data types
pg_user_mapping	mappings of users to foreign servers

51.2. pg_aggregate

The catalog `pg_aggregate` stores information about aggregate functions. An aggregate function is a function that operates on a set of values (typically one column from each row that matches a query condition) and returns a single value computed from all these values. Typical aggregate functions are `sum`, `count`, and `max`. Each entry in `pg_aggregate` is an extension of an entry in `pg_proc`. The `pg_proc` entry carries the aggregate's name, input and output data types, and other information that is similar to ordinary functions.

Table 51.2. pg_aggregate Columns

Name	Type	References	Description
<code>aggfnoid</code>	<code>regproc</code>	<code>pg_proc.oid</code>	<code>pg_proc</code> OID of the aggregate function
<code>aggkind</code>	<code>char</code>		Aggregate kind: <code>n</code> for “normal” aggregates, <code>o</code> for “ordered-set” aggregates, or <code>h</code> for “hypothetical-set” aggregates
<code>aggnumdirectargs</code>	<code>int2</code>		Number of direct (non-aggregated) arguments of an ordered-set or hypothetical-set aggregate, counting a variadic array as one argument. If equal to <code>pronargs</code> , the aggregate must be variadic and the variadic array describes the aggregated arguments as well as the final direct arguments. Always zero for normal aggregates.
<code>aggtransfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Transition function
<code>aggfinalfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Final function (zero if none)
<code>aggcombinefn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Combine function (zero if none)
<code>aggserialfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Serialization function (zero if none)
<code>aggdeserialfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Deserialization function (zero if none)
<code>aggmtransfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Forward transition function for moving-aggregate mode (zero if none)
<code>aggminvtransfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Inverse transition function for moving-aggregate mode (zero if none)
<code>aggmfinalfn</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Final function for moving-aggregate mode (zero if none)

Name	Type	References	Description
aggfinalextra	bool		True to pass extra dummy arguments to <code>aggfinalfn</code>
aggmfinalextra	bool		True to pass extra dummy arguments to <code>aggmfinalfn</code>
aggfinalmodify	char		Whether <code>aggfinalfn</code> modifies the transition state value: <code>r</code> if it is read-only, <code>s</code> if the <code>aggtransfn</code> cannot be applied after the <code>aggfinalfn</code> , or <code>w</code> if it writes on the value
aggmfinalmodify	char		Like <code>aggfinalmodify</code> , but for the <code>aggmfinalfn</code>
aggstortop	oid	<code>pg_operator.oid</code>	Associated sort operator (zero if none)
aggtranstype	oid	<code>pg_type.oid</code>	Data type of the aggregate function's internal transition (state) data
aggtransspace	int4		Approximate average size (in bytes) of the transition state data, or zero to use a default estimate
aggmtranstype	oid	<code>pg_type.oid</code>	Data type of the aggregate function's internal transition (state) data for moving-aggregate mode (zero if none)
aggmtransspace	int4		Approximate average size (in bytes) of the transition state data for moving-aggregate mode, or zero to use a default estimate
agginitval	text		The initial value of the transition state. This is a text field containing the initial value in its external string representation. If this field is null, the transition state value starts out null.
aggminitval	text		The initial value of the transition state for moving-aggregate mode. This is a text field containing the initial value in its ex-

Name	Type	References	Description
			ternal string representation. If this field is null, the transition state value starts out null.

New aggregate functions are registered with the `CREATE AGGREGATE` command. See Section 37.12 for more information about writing aggregate functions and the meaning of the transition functions, etc.

51.3. `pg_am`

The catalog `pg_am` stores information about relation access methods. There is one row for each access method supported by the system. Currently, only tables and indexes have access methods. The requirements for table and index access methods are discussed in detail in Chapter 60 and Chapter 61 respectively.

Table 51.3. `pg_am` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>amname</code>	<code>name</code>		Name of the access method
<code>amhandler</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of a handler function that is responsible for supplying information about the access method
<code>amtype</code>	<code>char</code>		<code>t</code> = table (including materialized views), <code>i</code> = index.

Note

Before PostgreSQL 9.6, `pg_am` contained many additional columns representing properties of index access methods. That data is now only directly visible at the C code level. However, `pg_index_column_has_property()` and related functions have been added to allow SQL queries to inspect index access method properties; see Table 9.68.

51.4. `pg_amop`

The catalog `pg_amop` stores information about operators associated with access method operator families. There is one row for each operator that is a member of an operator family. A family member can be either a *search* operator or an *ordering* operator. An operator can appear in more than one family, but cannot appear in more than one search position nor more than one ordering position within a family. (It is allowed, though unlikely, for an operator to be used for both search and ordering purposes.)

Table 51.4. `pg_amop` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier

Name	Type	References	Description
amopfamily	oid	pg_opfamily.oid	The operator family this entry is for
amoplefttype	oid	pg_type.oid	Left-hand input data type of operator
amoprightrighttype	oid	pg_type.oid	Right-hand input data type of operator
amopstrategy	int2		Operator strategy number
amoppurpose	char		Operator purpose, either s for search or o for ordering
amopopr	oid	pg_operator.oid	OID of the operator
amopmethod	oid	pg_am.oid	Index access method operator family is for
amopsortfamily	oid	pg_opfamily.oid	The B-tree operator family this entry sorts according to, if an ordering operator; zero if a search operator

A “search” operator entry indicates that an index of this operator family can be searched to find all rows satisfying `WHERE indexed_column operator constant`. Obviously, such an operator must return `boolean`, and its left-hand input type must match the index's column data type.

An “ordering” operator entry indicates that an index of this operator family can be scanned to return rows in the order represented by `ORDER BY indexed_column operator constant`. Such an operator could return any sortable data type, though again its left-hand input type must match the index's column data type. The exact semantics of the `ORDER BY` are specified by the `amopsortfamily` column, which must reference a B-tree operator family for the operator's result type.

Note

At present, it's assumed that the sort order for an ordering operator is the default for the referenced operator family, i.e., `ASC NULLS LAST`. This might someday be relaxed by adding additional columns to specify sort options explicitly.

An entry's `amopmethod` must match the `opfmethod` of its containing operator family (including `amopmethod` here is an intentional denormalization of the catalog structure for performance reasons). Also, `amoplefttype` and `amoprightrighttype` must match the `oprleft` and `oprright` fields of the referenced `pg_operator` entry.

51.5. pg_amproc

The catalog `pg_amproc` stores information about support functions associated with access method operator families. There is one row for each support function belonging to an operator family.

Table 51.5. pg_amproc Columns

Name	Type	References	Description
oid	oid		Row identifier
amprocfamily	oid	pg_opfamily.oid	The operator family this entry is for

Name	Type	References	Description
amproclefttype	oid	pg_type.oid	Left-hand input data type of associated operator
amprocrighttype	oid	pg_type.oid	Right-hand input data type of associated operator
amprocnum	int2		Support function number
amproc	regproc	pg_proc.oid	OID of the function

The usual interpretation of the `amproclefttype` and `amprocrighttype` fields is that they identify the left and right input types of the operator(s) that a particular support function supports. For some access methods these match the input data type(s) of the support function itself, for others not. There is a notion of “default” support functions for an index, which are those with `amproclefttype` and `amprocrighttype` both equal to the index operator class's `opcintype`.

51.6. pg_attrdef

The catalog `pg_attrdef` stores column default values. The main information about columns is stored in `pg_attribute`. Only columns for which a default value has been explicitly set will have an entry here.

Table 51.6. pg_attrdef Columns

Name	Type	References	Description
oid	oid		Row identifier
adrelid	oid	pg_class.oid	The table this column belongs to
adnum	int2	pg_attribute.attnum	The number of the column
adbin	pg_node_tree		The column default value, in <code>nodeToString()</code> representation. Use <code>pg_get_expr(adbin, adrelid)</code> to convert it to an SQL expression.

51.7. pg_attribute

The catalog `pg_attribute` stores information about table columns. There will be exactly one `pg_attribute` row for every column in every table in the database. (There will also be attribute entries for indexes, and indeed all objects that have `pg_class` entries.)

The term `attribute` is equivalent to `column` and is used for historical reasons.

Table 51.7. pg_attribute Columns

Name	Type	References	Description
attrelid	oid	pg_class.oid	The table this column belongs to
attname	name		The column name

Name	Type	References	Description
atttypid	oid	pg_type.oid	The data type of this column
attstattarget	int4		attstattarget controls the level of detail of statistics accumulated for this column by ANALYZE. A zero value indicates that no statistics should be collected. A negative value says to use the system default statistics target. The exact meaning of positive values is data type-dependent. For scalar data types, attstattarget is both the target number of “most common values” to collect, and the target number of histogram bins to create.
attlen	int2		A copy of pg_type.typelen of this column's type
attnum	int2		The number of the column. Ordinary columns are numbered from 1 up. System columns, such as ctid, have (arbitrary) negative numbers.
attndims	int4		Number of dimensions, if the column is an array type; otherwise 0. (Presently, the number of dimensions of an array is not enforced, so any nonzero value effectively means “it's an array”.)
attcacheoff	int4		Always -1 in storage, but when loaded into a row descriptor in memory this might be updated to cache the offset of the attribute within the row
atttypmod	int4		atttypmod records type-specific data supplied at table creation time (for example, the maximum length of a varchar column). It

Name	Type	References	Description
			is passed to type-specific input functions and length coercion functions. The value will generally be -1 for types that do not need <code>atttypmod</code> .
<code>attbyval</code>	<code>bool</code>		A copy of <code>pg_type.typbyval</code> of this column's type
<code>attstorage</code>	<code>char</code>		Normally a copy of <code>pg_type.typstorage</code> of this column's type. For TOAST-able data types, this can be altered after column creation to control storage policy.
<code>attalign</code>	<code>char</code>		A copy of <code>pg_type.typalign</code> of this column's type
<code>attnotnull</code>	<code>bool</code>		This represents a not-null constraint.
<code>atthasdef</code>	<code>bool</code>		This column has a default expression or generation expression, in which case there will be a corresponding entry in the <code>pg_attrdef</code> catalog that actually defines the expression. (Check <code>attgenerated</code> to determine whether this is a default or a generation expression.)
<code>atthasmissing</code>	<code>bool</code>		This column has a value which is used where the column is entirely missing from the row, as happens when a column is added with a non-volatile <code>DEFAULT</code> value after the row is created. The actual value used is stored in the <code>attmissingval</code> column.
<code>attidentity</code>	<code>char</code>		If a zero byte (' '), then not an identity column. Otherwise, a = generated always, d = generated by default.

Name	Type	References	Description
attgenerated	char		If a zero byte (' '), then not a generated column. Otherwise, s = stored. (Other values might be added in the future.)
attisdropped	bool		This column has been dropped and is no longer valid. A dropped column is still physically present in the table, but is ignored by the parser and so cannot be accessed via SQL.
attislocal	bool		This column is defined locally in the relation. Note that a column can be locally defined and inherited simultaneously.
attinhcount	int4		The number of direct ancestors this column has. A column with a nonzero number of ancestors cannot be dropped nor renamed.
attcollation	oid	pg_collation.oid	The defined collation of the column, or zero if the column is not of a collatable data type.
attacl	aclitem[]		Column-level access privileges, if any have been granted specifically on this column
attoptions	text[]		Attribute-level options, as “keyword=value” strings
atfdwoptions	text[]		Attribute-level foreign data wrapper options, as “keyword=value” strings
attmissingval	anyarray		This column has a one element array containing the value used when the column is entirely missing from the row, as happens when the column is added with a non-volatile DEFAULT value after the row is created. The value is only used when atthasmissing is true. If

Name	Type	References	Description
			there is no value the column is null.

In a dropped column's `pg_attribute` entry, `atttypid` is reset to zero, but `attlen` and the other fields copied from `pg_type` are still valid. This arrangement is needed to cope with the situation where the dropped column's data type was later dropped, and so there is no `pg_type` row anymore. `attlen` and the other fields can be used to interpret the contents of a row of the table.

51.8. `pg_authid`

The catalog `pg_authid` contains information about database authorization identifiers (roles). A role subsumes the concepts of “users” and “groups”. A user is essentially just a role with the `rolcanlogin` flag set. Any role (with or without `rolcanlogin`) can have other roles as members; see `pg_auth_members`.

Since this catalog contains passwords, it must not be publicly readable. `pg_roles` is a publicly readable view on `pg_authid` that blanks out the password field.

Chapter 21 contains detailed information about user and privilege management.

Because user identities are cluster-wide, `pg_authid` is shared across all databases of a cluster: there is only one copy of `pg_authid` per cluster, not one per database.

Table 51.8. `pg_authid` Columns

Name	Type	Description
<code>oid</code>	<code>oid</code>	Row identifier
<code>rolname</code>	<code>name</code>	Role name
<code>rolsuper</code>	<code>bool</code>	Role has superuser privileges
<code>rolinherit</code>	<code>bool</code>	Role automatically inherits privileges of roles it is a member of
<code>rolcreaterole</code>	<code>bool</code>	Role can create more roles
<code>rolcreatedb</code>	<code>bool</code>	Role can create databases
<code>rolcanlogin</code>	<code>bool</code>	Role can log in. That is, this role can be given as the initial session authorization identifier
<code>rolreplication</code>	<code>bool</code>	Role is a replication role. A replication role can initiate replication connections and create and drop replication slots.
<code>rolbypassrls</code>	<code>bool</code>	Role bypasses every row level security policy, see Section 5.8 for more information.
<code>rolconlimit</code>	<code>int4</code>	For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit.
<code>rolpassword</code>	<code>text</code>	Password (possibly encrypted); null if none. The format depends on the form of encryption used.
<code>rolvaliduntil</code>	<code>timestampz</code>	Password expiry time (only used for password authentication); null if no expiration

For an MD5 encrypted password, `rolpassword` column will begin with the string `md5` followed by a 32-character hexadecimal MD5 hash. The MD5 hash will be of the user's password concatenated to their user name. For example, if user `joe` has password `xyzyzy`, PostgreSQL will store the md5 hash of `xyzyzyjoe`.

If the password is encrypted with SCRAM-SHA-256, it has the format:

```
SCRAM-SHA-256$<iteration count>:<salt>$<StoredKey>:<ServerKey>
```

where `salt`, `StoredKey` and `ServerKey` are in Base64 encoded format. This format is the same as that specified by RFC 5803.

A password that does not follow either of those formats is assumed to be unencrypted.

51.9. `pg_auth_members`

The catalog `pg_auth_members` shows the membership relations between roles. Any non-circular set of relationships is allowed.

Because user identities are cluster-wide, `pg_auth_members` is shared across all databases of a cluster: there is only one copy of `pg_auth_members` per cluster, not one per database.

Table 51.9. `pg_auth_members` Columns

Name	Type	References	Description
<code>roleid</code>	<code>oid</code>	<code>pg_authid.oid</code>	ID of a role that has a member
<code>member</code>	<code>oid</code>	<code>pg_authid.oid</code>	ID of a role that is a member of <code>roleid</code>
<code>grantor</code>	<code>oid</code>	<code>pg_authid.oid</code>	ID of the role that granted this membership
<code>admin_option</code>	<code>bool</code>		True if member can grant membership in <code>roleid</code> to others

51.10. `pg_cast`

The catalog `pg_cast` stores data type conversion paths, both built-in and user-defined.

It should be noted that `pg_cast` does not represent every type conversion that the system knows how to perform; only those that cannot be deduced from some generic rule. For example, casting between a domain and its base type is not explicitly represented in `pg_cast`. Another important exception is that “automatic I/O conversion casts”, those performed using a data type's own I/O functions to convert to or from `text` or other string types, are not explicitly represented in `pg_cast`.

Table 51.10. `pg_cast` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>castsource</code>	<code>oid</code>	<code>pg_type.oid</code>	OID of the source data type
<code>casttarget</code>	<code>oid</code>	<code>pg_type.oid</code>	OID of the target data type
<code>castfunc</code>	<code>oid</code>	<code>pg_proc.oid</code>	The OID of the function to use to perform this

Name	Type	References	Description
			cast. Zero is stored if the cast method doesn't require a function.
castcontext	char		Indicates what contexts the cast can be invoked in. <i>e</i> means only as an explicit cast (using <code>CAST</code> or <code>::</code> syntax). <i>a</i> means implicitly in assignment to a target column, as well as explicitly. <i>i</i> means implicitly in expressions, as well as the other cases.
castmethod	char		Indicates how the cast is performed. <i>f</i> means that the function specified in the <code>castfunc</code> field is used. <i>i</i> means that the input/output functions are used. <i>b</i> means that the types are binary-coercible, thus no conversion is required.

The cast functions listed in `pg_cast` must always take the cast source type as their first argument type, and return the cast destination type as their result type. A cast function can have up to three arguments. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or -1 if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise.

It is legitimate to create a `pg_cast` entry in which the source and target types are the same, if the associated function takes more than one argument. Such entries represent “length coercion functions” that coerce values of the type to be legal for a particular type modifier value.

When a `pg_cast` entry has different source and target types and a function that takes more than one argument, it represents converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

51.11. `pg_class`

The catalog `pg_class` catalogs tables and most everything else that has columns or is otherwise similar to a table. This includes indexes (but see also `pg_index`), sequences (but see also `pg_sequence`), views, materialized views, composite types, and TOAST tables; see `relkind`. Below, when we mean all of these kinds of objects we speak of “relations”. Not all columns are meaningful for all relation types.

Table 51.11. `pg_class` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>relname</code>	<code>name</code>		Name of the table, index, view, etc.

Name	Type	References	Description
relnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this relation
reltype	oid	pg_type.oid	The OID of the data type that corresponds to this table's row type, if any (zero for indexes, which have no pg_type entry)
reloftype	oid	pg_type.oid	For typed tables, the OID of the underlying composite type, zero for all other relations
relowner	oid	pg_authid.oid	Owner of the relation
relam	oid	pg_am.oid	If this is a table or an index, the access method used (heap, B-tree, hash, etc.)
relfilenode	oid		Name of the on-disk file of this relation; zero means this is a "mapped" relation whose disk file name is determined by low-level state
reltablespace	oid	pg_tablespace.oid	The tablespace in which this relation is stored. If zero, the database's default tablespace is implied. (Not meaningful if the relation has no on-disk file.)
relpages	int4		Size of the on-disk representation of this table in pages (of size BLCKSZ). This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
reltuples	float4		Number of live rows in the table. This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
relallvisible	int4		Number of pages that are marked all-visible in the table's visibili-

Name	Type	References	Description
			ty map. This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
reltoastrelid	oid	pg_class.oid	OID of the TOAST table associated with this table, 0 if none. The TOAST table stores large attributes “out of line” in a secondary table.
relhasindex	bool		True if this is a table and it has (or recently had) any indexes
relisshared	bool		True if this table is shared across all databases in the cluster. Only certain system catalogs (such as pg_database) are shared.
relpersistence	char		p = permanent table, u = unlogged table, t = temporary table
relkind	char		r = ordinary table, i = index, S = sequence, t = TOAST table, v = view, m = materialized view, c = composite type, f = foreign table, p = partitioned table, I = partitioned index
relnatts	int2		Number of user columns in the relation (system columns not counted). There must be this many corresponding entries in pg_attribute. See also pg_attribute.attnum.
relchecks	int2		Number of CHECK constraints on the table; see pg_constraint catalog
relhasrules	bool		True if table has (or once had) rules; see pg_rewrite catalog

Name	Type	References	Description
relhastriggers	bool		True if table has (or once had) triggers; see <code>pg_trigger</code> catalog
relhas subclass	bool		True if table or index has (or once had) any inheritance children
relrowsecurity	bool		True if table has row level security enabled; see <code>pg_policy</code> catalog
relforcerowsecurity	bool		True if row level security (when enabled) will also apply to table owner; see <code>pg_policy</code> catalog
relispopulated	bool		True if relation is populated (this is true for all relations other than some materialized views)
relreplident	char		Columns used to form “replica identity” for rows: d = default (primary key, if any), n = nothing, f = all columns i = index with indis-replident set, or default
relispartition	bool		True if table or index is a partition
relrewrite	oid	<code>pg_class.oid</code>	For new relations being written during a DDL operation that requires a table rewrite, this contains the OID of the original relation; otherwise 0. That state is only visible internally; this field should never contain anything other than 0 for a user-visible relation.
relfrozenxid	xid		All transaction IDs before this one have been replaced with a permanent (“frozen”) transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound or to allow <code>pg_x-</code>

Name	Type	References	Description
			act to be shrunk. Zero (InvalidTransactionId) if the relation is not a table.
relminmxid	xid		All multixact IDs before this one have been replaced by a transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent multixact ID wraparound or to allow <code>pg_multixact</code> to be shrunk. Zero (InvalidMultiXactId) if the relation is not a table.
relacl	aclitem[]		Access privileges; see Section 5.7 for details
reloptions	text[]		Access-method-specific options, as “keyword=value” strings
relpartbound	pg_node_tree		If table is a partition (see <code>relispartition</code>), internal representation of the partition bound

Several of the Boolean flags in `pg_class` are maintained lazily: they are guaranteed to be true if that's the correct state, but may not be reset to false immediately when the condition is no longer true. For example, `relhasindex` is set by `CREATE INDEX`, but it is never cleared by `DROP INDEX`. Instead, `VACUUM` clears `relhasindex` if it finds the table has no indexes. This arrangement avoids race conditions and improves concurrency.

51.12. `pg_collation`

The catalog `pg_collation` describes the available collations, which are essentially mappings from an SQL name to operating system locale categories. See Section 23.2 for more information.

Table 51.12. `pg_collation` Columns

Name	Type	References	Description
oid	oid		Row identifier
collname	name		Collation name (unique per namespace and encoding)
collnamespace	oid	<code>pg_namespace.oid</code>	The OID of the namespace that contains this collation
collowner	oid	<code>pg_authid.oid</code>	Owner of the collation

Name	Type	References	Description
collprovider	char		Provider of the collation: d = database default, c = libc, i = icu
collisdeterministic	bool		Is the collation deterministic?
collencoding	int4		Encoding in which the collation is applicable, or -1 if it works for any encoding
collcollate	name		LC_COLLATE for this collation object
collctype	name		LC_CTYPE for this collation object
collversion	text		Provider-specific version of the collation. This is recorded when the collation is created and then checked when it is used, to detect changes in the collation definition that could lead to data corruption.

Note that the unique key on this catalog is (collname, collencoding, collnamespace) not just (collname, collnamespace). PostgreSQL generally ignores all collations that do not have collencoding equal to either the current database's encoding or -1, and creation of new entries with the same name as an entry with collencoding = -1 is forbidden. Therefore it is sufficient to use a qualified SQL name (*schema.name*) to identify a collation, even though this is not unique according to the catalog definition. The reason for defining the catalog this way is that initdb fills it in at cluster initialization time with entries for all locales available on the system, so it must be able to hold entries for all encodings that might ever be used in the cluster.

In the `template0` database, it could be useful to create collations whose encoding does not match the database encoding, since they could match the encodings of databases later cloned from `template0`. This would currently have to be done manually.

51.13. pg_constraint

The catalog `pg_constraint` stores check, primary key, unique, foreign key, and exclusion constraints on tables. (Column constraints are not treated specially. Every column constraint is equivalent to some table constraint.) Not-null constraints are represented in the `pg_attribute` catalog, not here.

User-defined constraint triggers (created with `CREATE CONSTRAINT TRIGGER`) also give rise to an entry in this table.

Check constraints on domains are stored here, too.

Table 51.13. pg_constraint Columns

Name	Type	References	Description
oid	oid		Row identifier

Name	Type	References	Description
conname	name		Constraint name (not necessarily unique!)
connamespace	oid	pg_namespace.oid	The OID of the namespace that contains this constraint
contype	char		c = check constraint, f = foreign key constraint, p = primary key constraint, u = unique constraint, t = constraint trigger, x = exclusion constraint
condeferrable	bool		Is the constraint deferrable?
condeferred	bool		Is the constraint deferred by default?
convalidated	bool		Has the constraint been validated? Currently, can only be false for foreign keys and CHECK constraints
conrelid	oid	pg_class.oid	The table this constraint is on; 0 if not a table constraint
contypid	oid	pg_type.oid	The domain this constraint is on; 0 if not a domain constraint
conindid	oid	pg_class.oid	The index supporting this constraint, if it's a unique, primary key, foreign key, or exclusion constraint; else 0
conparentid	oid	pg_constraint.oid	The corresponding constraint in the parent partitioned table, if this is a constraint in a partition; else 0
confrelid	oid	pg_class.oid	If a foreign key, the referenced table; else 0
confupdtype	char		Foreign key update action code: a = no action, r = restrict, c = cascade, n = set null, d = set default
confdeltype	char		Foreign key deletion action code: a = no action, r = restrict, c = cascade, n = set null, d = set default

Name	Type	References	Description
confmacthtype	char		Foreign key match type: f = full, p = partial, s = simple
conislocal	bool		This constraint is defined locally for the relation. Note that a constraint can be locally defined and inherited simultaneously.
coninhcount	int4		The number of direct inheritance ancestors this constraint has. A constraint with a nonzero number of ancestors cannot be dropped nor renamed.
connoinherit	bool		This constraint is defined locally for the relation. It is a non-inheritable constraint.
conkey	int2[]	pg_attribute.attnum	If a table constraint (including foreign keys, but not constraint triggers), list of the constrained columns
confkey	int2[]	pg_attribute.attnum	If a foreign key, list of the referenced columns
conpfeqop	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for PK = FK comparisons
conppeqop	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for PK = PK comparisons
conffeqop	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for FK = FK comparisons
conexclop	oid[]	pg_operator.oid	If an exclusion constraint, list of the per-column exclusion operators
conbin	pg_node_tree		If a check constraint, an internal representation of the expression. (It's recommended to use pg_get_constraintdef() to extract the definition of a check constraint.)

In the case of an exclusion constraint, `conkey` is only useful for constraint elements that are simple column references. For other cases, a zero appears in `conkey` and the associated index must be consulted to discover the expression that is constrained. (`conkey` thus has the same contents as `pg_index.indkey` for the index.)

Note

`pg_class.relchecks` needs to agree with the number of check-constraint entries found in this table for each relation.

51.14. `pg_conversion`

The catalog `pg_conversion` describes encoding conversion functions. See `CREATE CONVERSION` for more information.

Table 51.14. `pg_conversion` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>conname</code>	<code>name</code>		Conversion name (unique within a namespace)
<code>connamespace</code>	<code>oid</code>	<code>pg_namespace.oid</code>	The OID of the namespace that contains this conversion
<code>conowner</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the conversion
<code>conforencoding</code>	<code>int4</code>		Source encoding ID
<code>contoencoding</code>	<code>int4</code>		Destination encoding ID
<code>conproc</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Conversion function
<code>condefault</code>	<code>bool</code>		True if this is the default conversion

51.15. `pg_database`

The catalog `pg_database` stores information about the available databases. Databases are created with the `CREATE DATABASE` command. Consult Chapter 22 for details about the meaning of some of the parameters.

Unlike most system catalogs, `pg_database` is shared across all databases of a cluster: there is only one copy of `pg_database` per cluster, not one per database.

Table 51.15. `pg_database` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>datname</code>	<code>name</code>		Database name
<code>datdba</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the database, usually the user who created it

Name	Type	References	Description
encoding	int4		Character encoding for this database (<code>pg_encoding_to_char()</code> can translate this number to the encoding name)
datcollate	name		LC_COLLATE for this database
datctype	name		LC_CTYPE for this database
datistemplate	bool		If true, then this database can be cloned by any user with CREATEDB privileges; if false, then only superusers or the owner of the database can clone it.
dataallowconn	bool		If false then no one can connect to this database. This is used to protect the <code>template0</code> database from being altered.
datconlimit	int4		Sets maximum number of concurrent connections that can be made to this database. -1 means no limit.
datlastsysoid	oid		Last system OID in the database; useful particularly to <code>pg_dump</code>
datfrozenxid	xid		All transaction IDs before this one have been replaced with a permanent (“frozen”) transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent transaction ID wraparound or to allow <code>pg_xact</code> to be shrunk. It is the minimum of the per-table <code>pg_class.rel_frozenxid</code> values.
datminmxid	xid		All multixact IDs before this one have been replaced with a transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to pre-

Name	Type	References	Description
			vent multixact ID wrap-around or to allow <code>pg_multixact</code> to be shrunk. It is the minimum of the per-table <code>pg_class.relminmxid</code> values.
<code>dattablespace</code>	<code>oid</code>	<code>pg_tablespace.oid</code>	The default tablespace for the database. Within this database, all tables for which <code>pg_class.reltablespace</code> is zero will be stored in this tablespace; in particular, all the non-shared system catalogs will be there.
<code>datacl</code>	<code>aclitem[]</code>		Access privileges; see Section 5.7 for details

51.16. `pg_db_role_setting`

The catalog `pg_db_role_setting` records the default values that have been set for run-time configuration variables, for each role and database combination.

Unlike most system catalogs, `pg_db_role_setting` is shared across all databases of a cluster: there is only one copy of `pg_db_role_setting` per cluster, not one per database.

Table 51.16. `pg_db_role_setting` Columns

Name	Type	References	Description
<code>setdatabase</code>	<code>oid</code>	<code>pg_database.oid</code>	The OID of the database the setting is applicable to, or zero if not database-specific
<code>setrole</code>	<code>oid</code>	<code>pg_authid.oid</code>	The OID of the role the setting is applicable to, or zero if not role-specific
<code>setconfig</code>	<code>text[]</code>		Defaults for run-time configuration variables

51.17. `pg_default_acl`

The catalog `pg_default_acl` stores initial privileges to be assigned to newly created objects.

Table 51.17. `pg_default_acl` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>defaclrole</code>	<code>oid</code>	<code>pg_authid.oid</code>	The OID of the role associated with this entry

Name	Type	References	Description
defaclnamespace	oid	pg_namespace.oid	The OID of the namespace associated with this entry, or 0 if none
defaclobjtype	char		Type of object this entry is for: r = relation (table, view), S = sequence, f = function, T = type, n = schema
defaclacl	aclitem[]		Access privileges that this type of object should have on creation

A `pg_default_acl` entry shows the initial privileges to be assigned to an object belonging to the indicated user. There are currently two types of entry: “global” entries with `defaclnamespace = 0`, and “per-schema” entries that reference a particular schema. If a global entry is present then it *overrides* the normal hard-wired default privileges for the object type. A per-schema entry, if present, represents privileges to be *added to* the global or hard-wired default privileges.

Note that when an ACL entry in another catalog is null, it is taken to represent the hard-wired default privileges for its object, *not* whatever might be in `pg_default_acl` at the moment. `pg_default_acl` is only consulted during object creation.

51.18. pg_depend

The catalog `pg_depend` records the dependency relationships between database objects. This information allows `DROP` commands to find which other objects must be dropped by `DROP CASCADE` or prevent dropping in the `DROP RESTRICT` case.

See also `pg_shdepend`, which performs a similar function for dependencies involving objects that are shared across a database cluster.

Table 51.18. pg_depend Columns

Name	Type	References	Description
classid	oid	pg_class.oid	The OID of the system catalog the dependent object is in
objid	oid	any OID column	The OID of the specific dependent object
objsubid	int4		For a table column, this is the column number (the <code>objid</code> and <code>classid</code> refer to the table itself). For all other object types, this column is zero.
refclassid	oid	pg_class.oid	The OID of the system catalog the referenced object is in
refobjid	oid	any OID column	The OID of the specific referenced object
refobjsubid	int4		For a table column, this is the column number (the <code>refobjid</code> and

Name	Type	References	Description
			refclassid refer to the table itself). For all other object types, this column is zero.
deptype	char		A code defining the specific semantics of this dependency relationship; see text

In all cases, a `pg_depend` entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors identified by `deptype`:

DEPENDENCY_NORMAL (n)

A normal relationship between separately-created objects. The dependent object can be dropped without affecting the referenced object. The referenced object can only be dropped by specifying `CASCADE`, in which case the dependent object is dropped, too. Example: a table column has a normal dependency on its data type.

DEPENDENCY_AUTO (a)

The dependent object can be dropped separately from the referenced object, and should be automatically dropped (regardless of `RESTRICT` or `CASCADE` mode) if the referenced object is dropped. Example: a named constraint on a table is made auto-dependent on the table, so that it will go away if the table is dropped.

DEPENDENCY_INTERNAL (i)

The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation. A direct `DROP` of the dependent object will be disallowed outright (we'll tell the user to issue a `DROP` against the referenced object, instead). A `DROP` of the referenced object will result in automatically dropping the dependent object whether `CASCADE` is specified or not. If the dependent object has to be dropped due to a dependency on some other object being removed, its drop is converted to a drop of the referenced object, so that `NORMAL` and `AUTO` dependencies of the dependent object behave much like they were dependencies of the referenced object. Example: a view's `ON SELECT` rule is made internally dependent on the view, preventing it from being dropped while the view remains. Dependencies of the rule (such as tables it refers to) act as if they were dependencies of the view.

DEPENDENCY_PARTITION_PRI (P)

DEPENDENCY_PARTITION_SEC (S)

The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation; however, unlike `INTERNAL`, there is more than one such referenced object. The dependent object must not be dropped unless at least one of these referenced objects is dropped; if any one is, the dependent object should be dropped whether or not `CASCADE` is specified. Also unlike `INTERNAL`, a drop of some other object that the dependent object depends on does not result in automatic deletion of any partition-referenced object. Hence, if the drop does not cascade to at least one of these objects via some other path, it will be refused. (In most cases, the dependent object shares all its non-partition dependencies with at least one partition-referenced object, so that this restriction does not result in blocking any cascaded delete.) Primary and secondary partition dependencies behave identically except that the primary dependency is preferred for use in error messages; hence, a partition-dependent object should have one primary partition dependency and one or more secondary partition dependencies. Note that partition dependencies are made in addition to, not instead of, any dependencies the object would normally have. This simplifies `ATTACH/DETACH PARTITION` operations: the partition dependencies need only be added or removed. Example: a child partitioned index is made partition-dependent on both the partition table it is on and the parent partitioned index, so that it goes

away if either of those is dropped, but not otherwise. The dependency on the parent index is primary, so that if the user tries to drop the child partitioned index, the error message will suggest dropping the parent index instead (not the table).

DEPENDENCY_EXTENSION (e)

The dependent object is a member of the *extension* that is the referenced object (see `pg_extension`). The dependent object can be dropped only via `DROP EXTENSION` on the referenced object. Functionally this dependency type acts the same as an `INTERNAL` dependency, but it's kept separate for clarity and to simplify `pg_dump`.

DEPENDENCY_AUTO_EXTENSION (x)

The dependent object is not a member of the extension that is the referenced object (and so it should not be ignored by `pg_dump`), but it cannot function without the extension and should be auto-dropped if the extension is. The dependent object may be dropped on its own as well. Functionally this dependency type acts the same as an `AUTO` dependency, but it's kept separate for clarity and to simplify `pg_dump`.

DEPENDENCY_PIN (p)

There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by `initdb`. The columns for the dependent object contain zeroes.

Other dependency flavors might be needed in future.

Note that it's quite possible for two objects to be linked by more than one `pg_depend` entry. For example, a child partitioned index would have both a partition-type dependency on its associated partition table, and an auto dependency on each column of that table that it indexes. This sort of situation expresses the union of multiple dependency semantics. A dependent object can be dropped without `CASCADE` if any of its dependencies satisfies its condition for automatic dropping. Conversely, all the dependencies' restrictions about which objects must be dropped together must be satisfied.

51.19. pg_description

The catalog `pg_description` stores optional descriptions (comments) for each database object. Descriptions can be manipulated with the `COMMENT` command and viewed with `psql`'s `\d` commands. Descriptions of many built-in system objects are provided in the initial contents of `pg_description`.

See also `pg_shdescription`, which performs a similar function for descriptions involving objects that are shared across a database cluster.

Table 51.19. pg_description Columns

Name	Type	References	Description
<code>objoid</code>	<code>oid</code>	any OID column	The OID of the object this description pertains to
<code>classoid</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the system catalog this object appears in
<code>objsubid</code>	<code>int4</code>		For a comment on a table column, this is the column number (the <code>objoid</code> and <code>classoid</code> refer to the table itself). For all other ob-

Name	Type	References	Description
			ject types, this column is zero.
description	text		Arbitrary text that serves as the description of this object

51.20. pg_enum

The `pg_enum` catalog contains entries showing the values and labels for each enum type. The internal representation of a given enum value is actually the OID of its associated row in `pg_enum`.

Table 51.20. pg_enum Columns

Name	Type	References	Description
oid	oid		Row identifier
enumtypid	oid	<code>pg_type.oid</code>	The OID of the <code>pg_type</code> entry owning this enum value
enumsortorder	float4		The sort position of this enum value within its enum type
enumlabel	name		The textual label for this enum value

The OIDs for `pg_enum` rows follow a special rule: even-numbered OIDs are guaranteed to be ordered in the same way as the sort ordering of their enum type. That is, if two even OIDs belong to the same enum type, the smaller OID must have the smaller `enumsortorder` value. Odd-numbered OID values need bear no relationship to the sort order. This rule allows the enum comparison routines to avoid catalog lookups in many common cases. The routines that create and alter enum types attempt to assign even OIDs to enum values whenever possible.

When an enum type is created, its members are assigned sort-order positions 1..n. But members added later might be given negative or fractional values of `enumsortorder`. The only requirement on these values is that they be correctly ordered and unique within each enum type.

51.21. pg_event_trigger

The catalog `pg_event_trigger` stores event triggers. See Chapter 39 for more information.

Table 51.21. pg_event_trigger Columns

Name	Type	References	Description
evtname	name		Trigger name (must be unique)
evtevent	name		Identifies the event for which this trigger fires
evtowner	oid	<code>pg_authid.oid</code>	Owner of the event trigger
evtfoid	oid	<code>pg_proc.oid</code>	The function to be called
evtenabled	char		Controls in which <code>session_replication_role</code> modes the event trig-

Name	Type	References	Description
			ger fires. O = trigger fires in “origin” and “local” modes, D = trigger is disabled, R = trigger fires in “replica” mode, A = trigger fires always.
evttags	text[]		Command tags for which this trigger will fire. If NULL, the firing of this trigger is not restricted on the basis of the command tag.

51.22. pg_extension

The catalog `pg_extension` stores information about the installed extensions. See Section 37.17 for details about extensions.

Table 51.22. pg_extension Columns

Name	Type	References	Description
oid	oid		Row identifier
extname	name		Name of the extension
extowner	oid	pg_authid.oid	Owner of the extension
extnamespace	oid	pg_namespace.oid	Schema containing the extension's exported objects
extrelocatable	bool		True if extension can be relocated to another schema
extversion	text		Version name for the extension
extconfig	oid[]	pg_class.oid	Array of <code>regclass</code> OIDs for the extension's configuration table(s), or NULL if none
extcondition	text[]		Array of WHERE-clause filter conditions for the extension's configuration table(s), or NULL if none

Note that unlike most catalogs with a “namespace” column, `extnamespace` is not meant to imply that the extension belongs to that schema. Extension names are never schema-qualified. Rather, `extnamespace` indicates the schema that contains most or all of the extension's objects. If `extrelocatable` is true, then this schema must in fact contain all schema-qualifiable objects belonging to the extension.

51.23. pg_foreign_data_wrapper

The catalog `pg_foreign_data_wrapper` stores foreign-data wrapper definitions. A foreign-data wrapper is the mechanism by which external data, residing on foreign servers, is accessed.

Table 51.23. pg_foreign_data_wrapper Columns

Name	Type	References	Description
oid	oid		Row identifier
fdwname	name		Name of the foreign-data wrapper
fdwowner	oid	pg_authid.oid	Owner of the foreign-data wrapper
fdwhandler	oid	pg_proc.oid	References a handler function that is responsible for supplying execution routines for the foreign-data wrapper. Zero if no handler is provided
fdwvalidator	oid	pg_proc.oid	References a validator function that is responsible for checking the validity of the options given to the foreign-data wrapper, as well as options for foreign servers and user mappings using the foreign-data wrapper. Zero if no validator is provided
fdwaccl	aclitem[]		Access privileges; see Section 5.7 for details
fdwoptions	text[]		Foreign-data wrapper specific options, as “keyword=value” strings

51.24. pg_foreign_server

The catalog `pg_foreign_server` stores foreign server definitions. A foreign server describes a source of external data, such as a remote server. Foreign servers are accessed via foreign-data wrappers.

Table 51.24. pg_foreign_server Columns

Name	Type	References	Description
oid	oid		Row identifier
srvname	name		Name of the foreign server
srvowner	oid	pg_authid.oid	Owner of the foreign server
srvfdw	oid	pg_foreign_data_wrapper.oid	OID of the foreign-data wrapper of this foreign server
srvtype	text		Type of the server (optional)

Name	Type	References	Description
srvversion	text		Version of the server (optional)
srvacl	aclitem[]		Access privileges; see Section 5.7 for details
srvoptions	text[]		Foreign server specific options, as “keyword=value” strings

51.25. pg_foreign_table

The catalog `pg_foreign_table` contains auxiliary information about foreign tables. A foreign table is primarily represented by a `pg_class` entry, just like a regular table. Its `pg_foreign_table` entry contains the information that is pertinent only to foreign tables and not any other kind of relation.

Table 51.25. pg_foreign_table Columns

Name	Type	References	Description
ftrelid	oid	<code>pg_class.oid</code>	OID of the <code>pg_class</code> entry for this foreign table
ftserver	oid	<code>pg_foreign_server.oid</code>	OID of the foreign server for this foreign table
ftoptions	text[]		Foreign table options, as “keyword=value” strings

51.26. pg_index

The catalog `pg_index` contains part of the information about indexes. The rest is mostly in `pg_class`.

Table 51.26. pg_index Columns

Name	Type	References	Description
indexrelid	oid	<code>pg_class.oid</code>	The OID of the <code>pg_class</code> entry for this index
indrelid	oid	<code>pg_class.oid</code>	The OID of the <code>pg_class</code> entry for the table this index is for
indnatts	int2		The total number of columns in the index (duplicates <code>pg_class.relnatts</code>); this number includes both key and included attributes
indnkeyatts	int2		The number of <i>key columns</i> in the index, not counting any <i>included columns</i> , which are merely stored and do not

Name	Type	References	Description
			participate in the index semantics
<code>indisunique</code>	<code>bool</code>		If true, this is a unique index
<code>indisprimary</code>	<code>bool</code>		If true, this index represents the primary key of the table (<code>indisunique</code> should always be true when this is true)
<code>indisexclusion</code>	<code>bool</code>		If true, this index supports an exclusion constraint
<code>indimmediate</code>	<code>bool</code>		If true, the uniqueness check is enforced immediately on insertion (irrelevant if <code>indisunique</code> is not true)
<code>indisclustered</code>	<code>bool</code>		If true, the table was last clustered on this index
<code>indisvalid</code>	<code>bool</code>		If true, the index is currently valid for queries. False means the index is possibly incomplete: it must still be modified by <code>INSERT/UPDATE</code> operations, but it cannot safely be used for queries. If it is unique, the uniqueness property is not guaranteed true either.
<code>indcheckxmin</code>	<code>bool</code>		If true, queries must not use the index until the <code>xmin</code> of this <code>pg_index</code> row is below their <code>TransactionXmin</code> event horizon, because the table may contain broken <code>HOT</code> chains with incompatible rows that they can see
<code>indisready</code>	<code>bool</code>		If true, the index is currently ready for inserts. False means the index must be ignored by <code>INSERT/UPDATE</code> operations.
<code>indislive</code>	<code>bool</code>		If false, the index is in process of being dropped, and should be ignored for all purposes

Name	Type	References	Description
			es (including HOT-safety decisions)
<code>indisreplident</code>	<code>bool</code>		If true this index has been chosen as “replica identity” using <code>ALTER TABLE ... REPLICA IDENTITY USING INDEX ...</code>
<code>indkey</code>	<code>int2vector</code>	<code>pg_attribute.attnum</code>	This is an array of <code>indnatts</code> values that indicate which table columns this index indexes. For example a value of <code>1 3</code> would mean that the first and the third table columns make up the index entries. Key columns come before non-key (included) columns. A zero in this array indicates that the corresponding index attribute is an expression over the table columns, rather than a simple column reference.
<code>indcollation</code>	<code>oidvector</code>	<code>pg_collation.oid</code>	For each column in the index key (<code>indnkeyatts</code> values), this contains the OID of the collation to use for the index, or zero if the column is not of a collatable data type.
<code>indclass</code>	<code>oidvector</code>	<code>pg_opclass.oid</code>	For each column in the index key (<code>indnkeyatts</code> values), this contains the OID of the operator class to use. See <code>pg_opclass</code> for details.
<code>indoption</code>	<code>int2vector</code>		This is an array of <code>indnkeyatts</code> values that store per-column flag bits. The meaning of the bits is defined by the index's access method.
<code>indexprs</code>	<code>pg_node_tree</code>		Expression trees (in <code>nodeToString()</code> representation) for index attributes that are not simple column ref-

Name	Type	References	Description
			ences. This is a list with one element for each zero entry in <code>indkey</code> . Null if all index attributes are simple references.
<code>indpred</code>	<code>pg_node_tree</code>		Expression tree (in <code>nodeToString()</code> representation) for partial index predicate. Null if not a partial index.

51.27. `pg_inherits`

The catalog `pg_inherits` records information about table inheritance hierarchies. There is one entry for each direct parent-child table relationship in the database. (Indirect inheritance can be determined by following chains of entries.)

Table 51.27. `pg_inherits` Columns

Name	Type	References	Description
<code>inhrelid</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the child table
<code>inhparent</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the parent table
<code>inhseqno</code>	<code>int4</code>		If there is more than one direct parent for a child table (multiple inheritance), this number tells the order in which the inherited columns are to be arranged. The count starts at 1.

51.28. `pg_init_privs`

The catalog `pg_init_privs` records information about the initial privileges of objects in the system. There is one entry for each object in the database which has a non-default (non-NULL) initial set of privileges.

Objects can have initial privileges either by having those privileges set when the system is initialized (by `initdb`) or when the object is created during a `CREATE EXTENSION` and the extension script sets initial privileges using the `GRANT` system. Note that the system will automatically handle recording of the privileges during the extension script and that extension authors need only use the `GRANT` and `REVOKE` statements in their script to have the privileges recorded. The `privtype` column indicates if the initial privilege was set by `initdb` or during a `CREATE EXTENSION` command.

Objects which have initial privileges set by `initdb` will have entries where `privtype` is `'i'`, while objects which have initial privileges set by `CREATE EXTENSION` will have entries where `privtype` is `'e'`.

Table 51.28. pg_init_privs Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the specific object
classoid	oid	pg_class.oid	The OID of the system catalog the object is in
objsubid	int4		For a table column, this is the column number (the objoid and classoid refer to the table itself). For all other object types, this column is zero.
privtype	char		A code defining the type of initial privilege of this object; see text
initprivs	aclitem[]		The initial access privileges; see Section 5.7 for details

51.29. pg_language

The catalog `pg_language` registers languages in which you can write functions or stored procedures. See `CREATE LANGUAGE` and Chapter 41 for more information about language handlers.

Table 51.29. pg_language Columns

Name	Type	References	Description
oid	oid		Row identifier
lanname	name		Name of the language
lanowner	oid	pg_authid.oid	Owner of the language
lanispl	bool		This is false for internal languages (such as SQL) and true for user-defined languages. Currently, <code>pg_dump</code> still uses this to determine which languages need to be dumped, but this might be replaced by a different mechanism in the future.
lanpltrusted	bool		True if this is a trusted language, which means that it is believed not to grant access to anything outside the normal SQL execution environment. Only superusers can create functions in untrusted languages.
lanplcallfoid	oid	pg_proc.oid	For noninternal languages this references

Name	Type	References	Description
			the language handler, which is a special function that is responsible for executing all functions that are written in the particular language
laninline	oid	pg_proc.oid	This references a function that is responsible for executing “inline” anonymous code blocks (DO blocks). Zero if inline blocks are not supported.
lanvalidator	oid	pg_proc.oid	This references a language validator function that is responsible for checking the syntax and validity of new functions when they are created. Zero if no validator is provided.
lanacl	aclitem[]		Access privileges; see Section 5.7 for details

51.30. pg_largeobject

The catalog `pg_largeobject` holds the data making up “large objects”. A large object is identified by an OID assigned when it is created. Each large object is broken into segments or “pages” small enough to be conveniently stored as rows in `pg_largeobject`. The amount of data per page is defined to be `LOBLKSIZE` (which is currently `BLCKSZ/4`, or typically 2 kB).

Prior to PostgreSQL 9.0, there was no permission structure associated with large objects. As a result, `pg_largeobject` was publicly readable and could be used to obtain the OIDs (and contents) of all large objects in the system. This is no longer the case; use `pg_largeobject_metadata` to obtain a list of large object OIDs.

Table 51.30. pg_largeobject Columns

Name	Type	References	Description
loid	oid	pg_largeobject_metadata.oid	Identifier of the large object that includes this page
pageno	int4		Page number of this page within its large object (counting from zero)
data	bytea		Actual data stored in the large object. This will never be more than <code>LOBLKSIZE</code> bytes and might be less.

Each row of `pg_largeobject` holds data for one page of a large object, beginning at byte offset (`pageno * LOBLKSIZE`) within the object. The implementation allows sparse storage: pages might

be missing, and might be shorter than LOBLKSIZE bytes even if they are not the last page of the object. Missing regions within a large object read as zeroes.

51.31. pg_largeobject_metadata

The catalog `pg_largeobject_metadata` holds metadata associated with large objects. The actual large object data is stored in `pg_largeobject`.

Table 51.31. pg_largeobject_metadata Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>lomowner</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the large object
<code>lomacl</code>	<code>aclitem[]</code>		Access privileges; see Section 5.7 for details

51.32. pg_namespace

The catalog `pg_namespace` stores namespaces. A namespace is the structure underlying SQL schemas: each namespace can have a separate collection of relations, types, etc. without name conflicts.

Table 51.32. pg_namespace Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>nspname</code>	<code>name</code>		Name of the namespace
<code>nspowner</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the namespace
<code>nspacl</code>	<code>aclitem[]</code>		Access privileges; see Section 5.7 for details

51.33. pg_opclass

The catalog `pg_opclass` defines index access method operator classes. Each operator class defines semantics for index columns of a particular data type and a particular index access method. An operator class essentially specifies that a particular operator family is applicable to a particular indexable column data type. The set of operators from the family that are actually usable with the indexed column are whichever ones accept the column's data type as their left-hand input.

Operator classes are described at length in Section 37.16.

Table 51.33. pg_opclass Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>opcmethod</code>	<code>oid</code>	<code>pg_am.oid</code>	Index access method operator class is for
<code>opcname</code>	<code>name</code>		Name of this operator class

Name	Type	References	Description
opcnamespace	oid	pg_namespace.oid	Namespace of this operator class
opcowner	oid	pg_authid.oid	Owner of the operator class
opcfamily	oid	pg_opfamily.oid	Operator family containing the operator class
opcintype	oid	pg_type.oid	Data type that the operator class indexes
opcdefault	bool		True if this operator class is the default for opcintype
opckeytype	oid	pg_type.oid	Type of data stored in index, or zero if same as opcintype

An operator class's `opcmethod` must match the `opfmethod` of its containing operator family. Also, there must be no more than one `pg_opclass` row having `opcdefault` true for any given combination of `opcmethod` and `opcintype`.

51.34. pg_operator

The catalog `pg_operator` stores information about operators. See `CREATE OPERATOR` and Section 37.14 for more information.

Table 51.34. pg_operator Columns

Name	Type	References	Description
oid	oid		Row identifier
oprname	name		Name of the operator
oprnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this operator
oprowner	oid	pg_authid.oid	Owner of the operator
oprkind	char		b = infix (“both”), l = prefix (“left”), r = postfix (“right”)
oprcanmerge	bool		This operator supports merge joins
oprcanhash	bool		This operator supports hash joins
oprleft	oid	pg_type.oid	Type of the left operand
oprright	oid	pg_type.oid	Type of the right operand
oprresult	oid	pg_type.oid	Type of the result
oprcom	oid	pg_operator.oid	Commutator of this operator, if any
oprnegate	oid	pg_operator.oid	Negator of this operator, if any

Name	Type	References	Description
oprcode	regproc	pg_proc.oid	Function that implements this operator
oprrest	regproc	pg_proc.oid	Restriction selectivity estimation function for this operator
oprjoin	regproc	pg_proc.oid	Join selectivity estimation function for this operator

Unused column contain zeroes. For example, `oprleft` is zero for a prefix operator.

51.35. pg_opfamily

The catalog `pg_opfamily` defines operator families. Each operator family is a collection of operators and associated support routines that implement the semantics specified for a particular index access method. Furthermore, the operators in a family are all “compatible”, in a way that is specified by the access method. The operator family concept allows cross-data-type operators to be used with indexes and to be reasoned about using knowledge of access method semantics.

Operator families are described at length in Section 37.16.

Table 51.35. pg_opfamily Columns

Name	Type	References	Description
oid	oid		Row identifier
opfmethod	oid	pg_am.oid	Index access method operator family is for
opfname	name		Name of this operator family
opfnamespace	oid	pg_namespace.oid	Namespace of this operator family
opfowner	oid	pg_authid.oid	Owner of the operator family

The majority of the information defining an operator family is not in its `pg_opfamily` row, but in the associated rows in `pg_amop`, `pg_amproc`, and `pg_opclass`.

51.36. pg_partitioned_table

The catalog `pg_partitioned_table` stores information about how tables are partitioned.

Table 51.36. pg_partitioned_table Columns

Name	Type	References	Description
partrelid	oid	pg_class.oid	The OID of the <code>pg_class</code> entry for this partitioned table
partstrat	char		Partitioning strategy; h = hash partitioned table, l = list partitioned table,

Name	Type	References	Description
			r = range partitioned table
partnatts	int2		The number of columns in partition key
partdefid	oid	pg_class.oid	The OID of the pg_class entry for the default partition of this partitioned table, or zero if this partitioned table does not have a default partition.
partattrs	int2vector	pg_attribute.attnum	This is an array of partnatts values that indicate which table columns are part of the partition key. For example, a value of 1 3 would mean that the first and the third table columns make up the partition key. A zero in this array indicates that the corresponding partition key column is an expression, rather than a simple column reference.
partclass	oidvector	pg_opclass.oid	For each column in the partition key, this contains the OID of the operator class to use. See pg_opclass for details.
partcollation	oidvector	pg_opclass.oid	For each column in the partition key, this contains the OID of the collation to use for partitioning, or zero if the column is not of a collatable data type.
partexprs	pg_node_tree		Expression trees (in nodeToString() representation) for partition key columns that are not simple column references. This is a list with one element for each zero entry in partattrs. Null if all partition key columns are simple references.

51.37. pg_pltemplate

The catalog `pg_pltemplate` stores “template” information for procedural languages. A template for a language allows the language to be created in a particular database by a simple `CREATE LANGUAGE` command, with no need to specify implementation details.

Unlike most system catalogs, `pg_pltemplate` is shared across all databases of a cluster: there is only one copy of `pg_pltemplate` per cluster, not one per database. This allows the information to be accessible in each database as it is needed.

Table 51.37. `pg_pltemplate` Columns

Name	Type	Description
<code>tmplname</code>	<code>name</code>	Name of the language this template is for
<code>tmpltrusted</code>	<code>boolean</code>	True if language is considered trusted
<code>tmpldbacreate</code>	<code>boolean</code>	True if language may be created by a database owner
<code>tmplhandler</code>	<code>text</code>	Name of call handler function
<code>tmplinline</code>	<code>text</code>	Name of anonymous-block handler function, or null if none
<code>tmplvalidator</code>	<code>text</code>	Name of validator function, or null if none
<code>tmpllibrary</code>	<code>text</code>	Path of shared library that implements language
<code>tmplacl</code>	<code>aclitem[]</code>	Access privileges for template (not actually used)

There are not currently any commands that manipulate procedural language templates; to change the built-in information, a superuser must modify the table using ordinary `INSERT`, `DELETE`, or `UPDATE` commands.

Note

It is likely that `pg_pltemplate` will be removed in some future release of PostgreSQL, in favor of keeping this knowledge about procedural languages in their respective extension installation scripts.

51.38. `pg_policy`

The catalog `pg_policy` stores row level security policies for tables. A policy includes the kind of command that it applies to (possibly all commands), the roles that it applies to, the expression to be added as a security-barrier qualification to queries that include the table, and the expression to be added as a `WITH CHECK` option for queries that attempt to add new records to the table.

Table 51.38. `pg_policy` Columns

Name	Type	References	Description
<code>polname</code>	<code>name</code>		The name of the policy
<code>polrelid</code>	<code>oid</code>	<code>pg_class.oid</code>	The table to which the policy applies
<code>polcmd</code>	<code>char</code>		The command type to which the policy is applied: <code>r</code> for <code>SELECT</code> , a

Name	Type	References	Description
			for INSERT, w for UPDATE, d for DELETE, or * for all
polpermissive	boolean		Is the policy permissive or restrictive?
polroles	oid[]	pg_authid.oid	The roles to which the policy is applied
polqual	pg_node_tree		The expression tree to be added to the security barrier qualifications for queries that use the table
polwithcheck	pg_node_tree		The expression tree to be added to the WITH CHECK qualifications for queries that attempt to add rows to the table

Note

Policies stored in `pg_policy` are applied only when `pg_class.relrowsecurity` is set for their table.

51.39. pg_proc

The catalog `pg_proc` stores information about functions, procedures, aggregate functions, and window functions (collectively also known as routines). See `CREATE FUNCTION`, `CREATE PROCEDURE`, and Section 37.3 for more information.

If `prokind` indicates that the entry is for an aggregate function, there should be a matching row in `pg_aggregate`.

Table 51.39. pg_proc Columns

Name	Type	References	Description
oid	oid		Row identifier
proname	name		Name of the function
pronamespace	oid	pg_namespace.oid	The OID of the namespace that contains this function
proowner	oid	pg_authid.oid	Owner of the function
prolang	oid	pg_language.oid	Implementation language or call interface of this function
procost	float4		Estimated execution cost (in units of <code>cpu_operator_cost</code>); if <code>proretset</code> , this is cost per row returned
prorows	float4		Estimated number of result rows (zero if not <code>proretset</code>)

Name	Type	References	Description
provariadic	oid	pg_type.oid	Data type of the variadic array parameter's elements, or zero if the function does not have a variadic parameter
prosupport	regproc	pg_proc.oid	Optional planner support function for this function (see Section 37.11)
prokind	char		f for a normal function, p for a procedure, a for an aggregate function, or w for a window function
prosecdef	bool		Function is a security definer (i.e., a “setuid” function)
proleakproof	bool		The function has no side effects. No information about the arguments is conveyed except via the return value. Any function that might throw an error depending on the values of its arguments is not leak-proof.
proisstrict	bool		Function returns null if any call argument is null. In that case the function won't actually be called at all. Functions that are not “strict” must be prepared to handle null inputs.
proretset	bool		Function returns a set (i.e., multiple values of the specified data type)
provolatile	char		provolatile tells whether the function's result depends only on its input arguments, or is affected by outside factors. It is i for “immutable” functions, which always deliver the same result for the same inputs. It is s for “stable” functions, whose results (for fixed inputs) do not change within a scan. It is v for “volatile” functions, whose results

Name	Type	References	Description
			might change at any time. (Use <code>v</code> also for functions with side-effects, so that calls to them cannot get optimized away.)
<code>proparallel</code>	<code>char</code>		<code>proparallel</code> tells whether the function can be safely run in parallel mode. It is <code>s</code> for functions which are safe to run in parallel mode without restriction. It is <code>r</code> for functions which can be run in parallel mode, but their execution is restricted to the parallel group leader; parallel worker processes cannot invoke these functions. It is <code>u</code> for functions which are unsafe in parallel mode; the presence of such a function forces a serial execution plan.
<code>pronargs</code>	<code>int2</code>		Number of input arguments
<code>pronargdefaults</code>	<code>int2</code>		Number of arguments that have defaults
<code>prorettype</code>	<code>oid</code>	<code>pg_type.oid</code>	Data type of the return value
<code>proargtypes</code>	<code>oidvector</code>	<code>pg_type.oid</code>	An array with the data types of the function arguments. This includes only input arguments (including <code>INOUT</code> and <code>VARIADIC</code> arguments), and thus represents the call signature of the function.
<code>proallargtypes</code>	<code>oid[]</code>	<code>pg_type.oid</code>	An array with the data types of the function arguments. This includes all arguments (including <code>OUT</code> and <code>INOUT</code> arguments); however, if all the arguments are <code>IN</code> arguments, this field will be null. Note that subscripting is 1-based, whereas for historical reasons

Name	Type	References	Description
			proargtypes is subscripted from 0.
proargmodes	char[]		An array with the modes of the function arguments, encoded as <i>i</i> for IN arguments, <i>o</i> for OUT arguments, <i>b</i> for INOUT arguments, <i>v</i> for VARIADIC arguments, <i>t</i> for TABLE arguments. If all the arguments are IN arguments, this field will be null. Note that subscripts correspond to positions of proallargtypes not proargtypes.
proargnames	text[]		An array with the names of the function arguments. Arguments without a name are set to empty strings in the array. If none of the arguments have a name, this field will be null. Note that subscripts correspond to positions of proallargtypes not proargtypes.
proargdefaults	pg_node_tree		Expression trees (in nodeToString() representation) for default values. This is a list with pronargdefaults elements, corresponding to the last <i>N input</i> arguments (i.e., the last <i>N</i> proargtypes positions). If none of the arguments have defaults, this field will be null.
protrftypes	oid[]		Data type OIDs for which to apply transforms.
prosrc	text		This tells the function handler how to invoke the function. It might be the actual source code of the function for interpreted languages, a link symbol, a file name, or just about anything else,

Name	Type	References	Description
			depending on the implementation language/call convention.
probin	text		Additional information about how to invoke the function. Again, the interpretation is language-specific.
proconfig	text[]		Function's local settings for run-time configuration variables
proacl	aclitem[]		Access privileges; see Section 5.7 for details

For compiled functions, both built-in and dynamically loaded, `prosrc` contains the function's C-language name (link symbol). For all other currently-known language types, `prosrc` contains the function's source text. `probin` is unused except for dynamically-loaded C functions, for which it gives the name of the shared library file containing the function.

51.40. `pg_publication`

The catalog `pg_publication` contains all publications created in the database. For more on publications see Section 30.1.

Table 51.40. `pg_publication` Columns

Name	Type	References	Description
oid	oid		Row identifier
pubname	name		Name of the publication
pubowner	oid	<code>pg_authid.oid</code>	Owner of the publication
puballtables	bool		If true, this publication automatically includes all tables in the database, including any that will be created in the future.
pubinsert	bool		If true, INSERT operations are replicated for tables in the publication.
pubupdate	bool		If true, UPDATE operations are replicated for tables in the publication.
pubdelete	bool		If true, DELETE operations are replicated for tables in the publication.
pubtruncate	bool		If true, TRUNCATE operations are replicated for tables in the publication.

51.41. `pg_publication_rel`

The catalog `pg_publication_rel` contains the mapping between relations and publications in the database. This is a many-to-many mapping. See also Section 51.79 for a more user-friendly view of this information.

Table 51.41. `pg_publication_rel` Columns

Name	Type	References	Description
<code>prpubid</code>	<code>oid</code>	<code>pg_publication.oid</code>	Reference to publication
<code>prrelid</code>	<code>oid</code>	<code>pg_class.oid</code>	Reference to relation

51.42. `pg_range`

The catalog `pg_range` stores information about range types. This is in addition to the types' entries in `pg_type`.

Table 51.42. `pg_range` Columns

Name	Type	References	Description
<code>rngtypeid</code>	<code>oid</code>	<code>pg_type.oid</code>	OID of the range type
<code>rngsubtype</code>	<code>oid</code>	<code>pg_type.oid</code>	OID of the element type (subtype) of this range type
<code>rngcollation</code>	<code>oid</code>	<code>pg_collation.oid</code>	OID of the collation used for range comparisons, or 0 if none
<code>rngsubopc</code>	<code>oid</code>	<code>pg_opclass.oid</code>	OID of the subtype's operator class used for range comparisons
<code>rngcanonical</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the function to convert a range value into canonical form, or 0 if none
<code>rngsubdiff</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the function to return the difference between two element values as double precision, or 0 if none

`rngsubopc` (plus `rngcollation`, if the element type is collatable) determines the sort ordering used by the range type. `rngcanonical` is used when the element type is discrete. `rngsubdiff` is optional but should be supplied to improve performance of GiST indexes on the range type.

51.43. `pg_replication_origin`

The `pg_replication_origin` catalog contains all replication origins created. For more on replication origins see Chapter 49.

Unlike most system catalogs, `pg_replication_origin` is shared across all databases of a cluster: there is only one copy of `pg_replication_origin` per cluster, not one per database.

Table 51.43. pg_replication_origin Columns

Name	Type	References	Description
roident	Oid		A unique, cluster-wide identifier for the replication origin. Should never leave the system.
roname	text		The external, user defined, name of a replication origin.

51.44. pg_rewrite

The catalog `pg_rewrite` stores rewrite rules for tables and views.

Table 51.44. pg_rewrite Columns

Name	Type	References	Description
oid	oid		Row identifier
rulename	name		Rule name
ev_class	oid	<code>pg_class.oid</code>	The table this rule is for
ev_type	char		Event type that the rule is for: 1 = SELECT, 2 = UPDATE, 3 = INSERT, 4 = DELETE
ev_enabled	char		Controls in which session replication role modes the rule fires. O = rule fires in “origin” and “local” modes, D = rule is disabled, R = rule fires in “replica” mode, A = rule fires always.
is_instead	bool		True if the rule is an INSTEAD rule
ev_qual	pg_node_tree		Expression tree (in the form of a <code>nodeToString()</code> representation) for the rule's qualifying condition
ev_action	pg_node_tree		Query tree (in the form of a <code>nodeToString()</code> representation) for the rule's action

Note

`pg_class.relhasrules` must be true if a table has any rules in this catalog.

51.45. pg_seclabel

The catalog `pg_seclabel` stores security labels on database objects. Security labels can be manipulated with the `SECURITY LABEL` command. For an easier way to view security labels, see Section 51.84.

See also `pg_shseclabel`, which performs a similar function for security labels of database objects that are shared across a database cluster.

Table 51.45. pg_seclabel Columns

Name	Type	References	Description
<code>objoid</code>	<code>oid</code>	any OID column	The OID of the object this security label pertains to
<code>classoid</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the system catalog this object appears in
<code>objsubid</code>	<code>int4</code>		For a security label on a table column, this is the column number (the <code>objoid</code> and <code>classoid</code> refer to the table itself). For all other object types, this column is zero.
<code>provider</code>	<code>text</code>		The label provider associated with this label.
<code>label</code>	<code>text</code>		The security label applied to this object.

51.46. pg_sequence

The catalog `pg_sequence` contains information about sequences. Some of the information about sequences, such as the name and the schema, is in `pg_class`.

Table 51.46. pg_sequence Columns

Name	Type	References	Description
<code>seqrelid</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the <code>pg_class</code> entry for this sequence
<code>seqtypeid</code>	<code>oid</code>	<code>pg_type.oid</code>	Data type of the sequence
<code>seqstart</code>	<code>int8</code>		Start value of the sequence
<code>seqincrement</code>	<code>int8</code>		Increment value of the sequence
<code>seqmax</code>	<code>int8</code>		Maximum value of the sequence
<code>seqmin</code>	<code>int8</code>		Minimum value of the sequence

Name	Type	References	Description
seqcache	int8		Cache size of the sequence
seqcycle	bool		Whether the sequence cycles

51.47. pg_shdepend

The catalog `pg_shdepend` records the dependency relationships between database objects and shared objects, such as roles. This information allows PostgreSQL to ensure that those objects are unreferenced before attempting to delete them.

See also `pg_depend`, which performs a similar function for dependencies involving objects within a single database.

Unlike most system catalogs, `pg_shdepend` is shared across all databases of a cluster: there is only one copy of `pg_shdepend` per cluster, not one per database.

Table 51.47. pg_shdepend Columns

Name	Type	References	Description
dbid	oid	<code>pg_database.oid</code>	The OID of the database the dependent object is in, or zero for a shared object
classid	oid	<code>pg_class.oid</code>	The OID of the system catalog the dependent object is in
objid	oid	any OID column	The OID of the specific dependent object
objsubid	int4		For a table column, this is the column number (the <code>objid</code> and <code>classid</code> refer to the table itself). For all other object types, this column is zero.
refclassid	oid	<code>pg_class.oid</code>	The OID of the system catalog the referenced object is in (must be a shared catalog)
refobjid	oid	any OID column	The OID of the specific referenced object
deptype	char		A code defining the specific semantics of this dependency relationship; see text

In all cases, a `pg_shdepend` entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors identified by `deptype`:

`SHARED_DEPENDENCY_OWNER` (o)

The referenced object (which must be a role) is the owner of the dependent object.

SHARED_DEPENDENCY_ACL (a)

The referenced object (which must be a role) is mentioned in the ACL (access control list, i.e., privileges list) of the dependent object. (A `SHARED_DEPENDENCY_ACL` entry is not made for the owner of the object, since the owner will have a `SHARED_DEPENDENCY_OWNER` entry anyway.)

SHARED_DEPENDENCY_POLICY (r)

The referenced object (which must be a role) is mentioned as the target of a dependent policy object.

SHARED_DEPENDENCY_PIN (p)

There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by `initdb`. The columns for the dependent object contain zeroes.

Other dependency flavors might be needed in future. Note in particular that the current definition only supports roles as referenced objects.

51.48. `pg_shdescription`

The catalog `pg_shdescription` stores optional descriptions (comments) for shared database objects. Descriptions can be manipulated with the `COMMENT` command and viewed with `psql`'s `\d` commands.

See also `pg_description`, which performs a similar function for descriptions involving objects within a single database.

Unlike most system catalogs, `pg_shdescription` is shared across all databases of a cluster: there is only one copy of `pg_shdescription` per cluster, not one per database.

Table 51.48. `pg_shdescription` Columns

Name	Type	References	Description
<code>objoid</code>	<code>oid</code>	any OID column	The OID of the object this description pertains to
<code>classoid</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the system catalog this object appears in
<code>description</code>	<code>text</code>		Arbitrary text that serves as the description of this object

51.49. `pg_shseclabel`

The catalog `pg_shseclabel` stores security labels on shared database objects. Security labels can be manipulated with the `SECURITY LABEL` command. For an easier way to view security labels, see Section 51.84.

See also `pg_seclabel`, which performs a similar function for security labels involving objects within a single database.

Unlike most system catalogs, `pg_shseclabel` is shared across all databases of a cluster: there is only one copy of `pg_shseclabel` per cluster, not one per database.

Table 51.49. pg_shseclabel Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the object this security label pertains to
classoid	oid	pg_class.oid	The OID of the system catalog this object appears in
provider	text		The label provider associated with this label.
label	text		The security label applied to this object.

51.50. pg_statistic

The catalog `pg_statistic` stores statistical data about the contents of the database. Entries are created by `ANALYZE` and subsequently used by the query planner. Note that all the statistical data is inherently approximate, even assuming that it is up-to-date.

Normally there is one entry, with `stainherit = false`, for each table column that has been analyzed. If the table has inheritance children, a second entry with `stainherit = true` is also created. This row represents the column's statistics over the inheritance tree, i.e., statistics for the data you'd see with `SELECT column FROM table*`, whereas the `stainherit = false` row represents the results of `SELECT column FROM ONLY table`.

`pg_statistic` also stores statistical data about the values of index expressions. These are described as if they were actual data columns; in particular, `starelid` references the index. No entry is made for an ordinary non-expression index column, however, since it would be redundant with the entry for the underlying table column. Currently, entries for index expressions always have `stainherit = false`.

Since different kinds of statistics might be appropriate for different kinds of data, `pg_statistic` is designed not to assume very much about what sort of statistics it stores. Only extremely general statistics (such as nullness) are given dedicated columns in `pg_statistic`. Everything else is stored in "slots", which are groups of associated columns whose content is identified by a code number in one of the slot's columns. For more information see `src/include/catalog/pg_statistic.h`.

`pg_statistic` should not be readable by the public, since even statistical information about a table's contents might be considered sensitive. (Example: minimum and maximum values of a salary column might be quite interesting.) `pg_stats` is a publicly readable view on `pg_statistic` that only exposes information about those tables that are readable by the current user.

Table 51.50. pg_statistic Columns

Name	Type	References	Description
starelid	oid	pg_class.oid	The table or index that the described column belongs to
staattnum	int2	pg_attribute.attnum	The number of the described column
stainherit	bool		If true, the stats include inheritance child columns, not just the values in the specified relation

Name	Type	References	Description
stanullfrac	float4		The fraction of the column's entries that are null
stawidth	int4		The average stored width, in bytes, of non-null entries
stadistinct	float4		The number of distinct nonnull data values in the column. A value greater than zero is the actual number of distinct values. A value less than zero is the negative of a multiplier for the number of rows in the table; for example, a column in which about 80% of the values are nonnull and each nonnull value appears about twice on average could be represented by <code>stadistinct = -0.4</code> . A zero value means the number of distinct values is unknown.
stakindN	int2		A code number indicating the kind of statistics stored in the Nth "slot" of the <code>pg_statistic</code> row.
staopN	oid	<code>pg_operator.oid</code>	An operator used to derive the statistics stored in the Nth "slot". For example, a histogram slot would show the < operator that defines the sort order of the data.
stacollN	oid	<code>pg_collation.oid</code>	The collation used to derive the statistics stored in the Nth "slot". For example, a histogram slot for a collatable column would show the collation that defines the sort order of the data. Zero for noncollatable data.
stanumbersN	float4[]		Numerical statistics of the appropriate kind for the Nth "slot", or null if the slot kind does not involve numerical values

Name	Type	References	Description
stavalues N	anyarray		Column data values of the appropriate kind for the N th “slot”, or null if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, or a related type such as an array's element type, so there is no way to define these columns' type more specifically than anyarray.

51.51. pg_statistic_ext

The catalog `pg_statistic_ext` holds definitions of extended planner statistics. Each row in this catalog corresponds to a *statistics object* created with `CREATE STATISTICS`.

Table 51.51. pg_statistic_ext Columns

Name	Type	References	Description
stxrelid	oid	pg_class.oid	Table containing the columns described by this object
stxname	name		Name of the statistics object
stxnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this statistics object
stxowner	oid	pg_authid.oid	Owner of the statistics object
stxkeys	int2vector	pg_attribute.attnum	An array of attribute numbers, indicating which table columns are covered by this statistics object; for example a value of 1 3 would mean that the first and the third table columns are covered
stxkind	char[]		An array containing codes for the enabled statistic kinds; valid values are: <code>d</code> for <code>n</code> -distinct statistics, <code>f</code> for functional dependency statistics, and <code>m</code> for most common values (MCV) list statistics

The `pg_statistic_ext` entry is filled in completely during `CREATE STATISTICS`, but the actual statistical values are not computed then. Subsequent `ANALYZE` commands compute the desired values and populate an entry in the `pg_statistic_ext_data` catalog.

51.52. `pg_statistic_ext_data`

The catalog `pg_statistic_ext_data` holds data for extended planner statistics defined in `pg_statistic_ext`. Each row in this catalog corresponds to a *statistics object* created with `CREATE STATISTICS`.

Like `pg_statistic`, `pg_statistic_ext_data` should not be readable by the public, since the contents might be considered sensitive. (Example: most common combinations of values in columns might be quite interesting.) `pg_stats_ext` is a publicly readable view on `pg_statistic_ext_data` (after joining with `pg_statistic_ext`) that only exposes information about those tables and columns that are readable by the current user.

Table 51.52. `pg_statistic_ext_data` Columns

Name	Type	References	Description
<code>stxoid</code>	<code>oid</code>	<code>pg_statistic_ext.oid</code>	Extended statistic object containing the definition for this data
<code>stxdndistinct</code>	<code>pg_ndistinct</code>		N-distinct counts, serialized as <code>pg_ndistinct</code> type
<code>stxddependencies</code>	<code>pg_dependencies</code>		Functional dependency statistics, serialized as <code>pg_dependencies</code> type
<code>stxdmcv</code>	<code>pg_mcv_list</code>		MCV (most-common values) list statistics, serialized as <code>pg_mcv_list</code> type

51.53. `pg_subscription`

The catalog `pg_subscription` contains all existing logical replication subscriptions. For more information about logical replication see Chapter 30.

Unlike most system catalogs, `pg_subscription` is shared across all databases of a cluster: there is only one copy of `pg_subscription` per cluster, not one per database.

Access to the column `subconninfo` is revoked from normal users, because it could contain plaintext passwords.

Table 51.53. `pg_subscription` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>subdbid</code>	<code>oid</code>	<code>pg_database.oid</code>	OID of the database which the subscription resides in
<code>subname</code>	<code>name</code>		Name of the subscription

Name	Type	References	Description
subowner	oid	pg_authid.oid	Owner of the subscription
subenabled	bool		If true, the subscription is enabled and should be replicating.
subsynchronouscommit	text		Contains the value of the synchronous_commit setting for the subscription workers.
subconninfo	text		Connection string to the upstream database
subslotname	name		Name of the replication slot in the upstream database. Also used for local replication origin name.
subpublications	text[]		Array of subscribed publication names. These reference the publications on the publisher server. For more on publications see Section 30.1.

51.54. pg_subscription_rel

The catalog `pg_subscription_rel` contains the state for each replicated relation in each subscription. This is a many-to-many mapping.

This catalog only contains tables known to the subscription after running either `CREATE SUBSCRIPTION` or `ALTER SUBSCRIPTION ... REFRESH PUBLICATION`.

Table 51.54. pg_subscription_rel Columns

Name	Type	References	Description
srsubid	oid	pg_subscription.oid	Reference to subscription
srrelid	oid	pg_class.oid	Reference to relation
srsubstate	char		State code: i = initialize, d = data is being copied, s = synchronized, r = ready (normal replication)
srsublsn	pg_lsn		End LSN for s and r states.

51.55. pg_tablespace

The catalog `pg_tablespace` stores information about the available tablespaces. Tables can be placed in particular tablespaces to aid administration of disk layout.

Unlike most system catalogs, `pg_tablespace` is shared across all databases of a cluster: there is only one copy of `pg_tablespace` per cluster, not one per database.

Table 51.55. `pg_tablespace` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>spcname</code>	<code>name</code>		Tablespace name
<code>spcowner</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the tablespace, usually the user who created it
<code>spcacl</code>	<code>aclitem[]</code>		Access privileges; see Section 5.7 for details
<code>spcoptions</code>	<code>text[]</code>		Tablespace-level options, as “keyword=value” strings

51.56. `pg_transform`

The catalog `pg_transform` stores information about transforms, which are a mechanism to adapt data types to procedural languages. See `CREATE TRANSFORM` for more information.

Table 51.56. `pg_transform` Columns

Name	Type	References	Description
<code>trftype</code>	<code>oid</code>	<code>pg_type.oid</code>	OID of the data type this transform is for
<code>trflang</code>	<code>oid</code>	<code>pg_language.oid</code>	OID of the language this transform is for
<code>trffromsql</code>	<code>regproc</code>	<code>pg_proc.oid</code>	The OID of the function to use when converting the data type for input to the procedural language (e.g., function parameters). Zero is stored if this operation is not supported.
<code>trftosql</code>	<code>regproc</code>	<code>pg_proc.oid</code>	The OID of the function to use when converting output from the procedural language (e.g., return values) to the data type. Zero is stored if this operation is not supported.

51.57. `pg_trigger`

The catalog `pg_trigger` stores triggers on tables and views. See `CREATE TRIGGER` for more information.

Table 51.57. pg_trigger Columns

Name	Type	References	Description
oid	oid		Row identifier
tgrelid	oid	pg_class.oid	The table this trigger is on
tgname	name		Trigger name (must be unique among triggers of same table)
tgfoid	oid	pg_proc.oid	The function to be called
tgtype	int2		Bit mask identifying trigger firing conditions
tgenabled	char		Controls in which session_replication_role modes the trigger fires. O = trigger fires in “origin” and “local” modes, D = trigger is disabled, R = trigger fires in “replica” mode, A = trigger fires always.
tgisinternal	bool		True if trigger is internally generated (usually, to enforce the constraint identified by tgconstraint)
tgconstrrelid	oid	pg_class.oid	The table referenced by a referential integrity constraint
tgconstrindid	oid	pg_class.oid	The index supporting a unique, primary key, referential integrity, or exclusion constraint
tgconstraint	oid	pg_constraint.oid	The pg_constraint entry associated with the trigger, if any
tgdeferrable	bool		True if constraint trigger is deferrable
tginitdeferred	bool		True if constraint trigger is initially deferred
tgargs	int2		Number of argument strings passed to trigger function
tgattr	int2vector	pg_attribute.attnum	Column numbers, if trigger is column-specific; otherwise an empty array
tgargs	bytea		Argument strings to pass to trigger, each NULL-terminated

Name	Type	References	Description
tgqual	pg_node_tree		Expression tree (in <code>nodeToString()</code> representation) for the trigger's WHEN condition, or null if none
tgoldtable	name		REFERENCING clause name for OLD TABLE, or null if none
tgnewtable	name		REFERENCING clause name for NEW TABLE, or null if none

Currently, column-specific triggering is supported only for UPDATE events, and so `tgattr` is relevant only for that event type. `tgtype` might contain bits for other event types as well, but those are presumed to be table-wide regardless of what is in `tgattr`.

Note

When `tgconstraint` is nonzero, `tgconstrrelid`, `tgconstrindid`, `tgdeferrable`, and `tginitdeferred` are largely redundant with the referenced `pg_constraint` entry. However, it is possible for a non-deferrable trigger to be associated with a deferrable constraint: foreign key constraints can have some deferrable and some non-deferrable triggers.

Note

`pg_class.relhastriggers` must be true if a relation has any triggers in this catalog.

51.58. pg_ts_config

The `pg_ts_config` catalog contains entries representing text search configurations. A configuration specifies a particular text search parser and a list of dictionaries to use for each of the parser's output token types. The parser is shown in the `pg_ts_config` entry, but the token-to-dictionary mapping is defined by subsidiary entries in `pg_ts_config_map`.

PostgreSQL's text search features are described at length in Chapter 12.

Table 51.58. pg_ts_config Columns

Name	Type	References	Description
oid	oid		Row identifier
cfgname	name		Text search configuration name
cfgnamespace	oid	<code>pg_namespace.oid</code>	The OID of the namespace that contains this configuration
cfgowner	oid	<code>pg_authid.oid</code>	Owner of the configuration

Name	Type	References	Description
cfgparser	oid	pg_ts_parser.oid	The OID of the text search parser for this configuration

51.59. pg_ts_config_map

The `pg_ts_config_map` catalog contains entries showing which text search dictionaries should be consulted, and in what order, for each output token type of each text search configuration's parser.

PostgreSQL's text search features are described at length in Chapter 12.

Table 51.59. pg_ts_config_map Columns

Name	Type	References	Description
mapcfg	oid	pg_ts_config.oid	The OID of the <code>pg_ts_config</code> entry owning this map entry
maptokentype	integer		A token type emitted by the configuration's parser
mapseqno	integer		Order in which to consult this entry (lower <code>mapseqnos</code> first)
mapdict	oid	pg_ts_dict.oid	The OID of the text search dictionary to consult

51.60. pg_ts_dict

The `pg_ts_dict` catalog contains entries defining text search dictionaries. A dictionary depends on a text search template, which specifies all the implementation functions needed; the dictionary itself provides values for the user-settable parameters supported by the template. This division of labor allows dictionaries to be created by unprivileged users. The parameters are specified by a text string `dictinitoption`, whose format and meaning vary depending on the template.

PostgreSQL's text search features are described at length in Chapter 12.

Table 51.60. pg_ts_dict Columns

Name	Type	References	Description
oid	oid		Row identifier
dictname	name		Text search dictionary name
dictnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this dictionary
dictowner	oid	pg_authid.oid	Owner of the dictionary
dicttemplate	oid	pg_ts_template.oid	The OID of the text search template for this dictionary
dictinitoption	text		Initialization option string for the template

51.61. `pg_ts_parser`

The `pg_ts_parser` catalog contains entries defining text search parsers. A parser is responsible for splitting input text into lexemes and assigning a token type to each lexeme. Since a parser must be implemented by C-language-level functions, creation of new parsers is restricted to database superusers.

PostgreSQL's text search features are described at length in Chapter 12.

Table 51.61. `pg_ts_parser` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>prsname</code>	<code>name</code>		Text search parser name
<code>prsnamespace</code>	<code>oid</code>	<code>pg_namespace.oid</code>	The OID of the namespace that contains this parser
<code>prsstart</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the parser's start-up function
<code>prstoken</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the parser's next-token function
<code>prsend</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the parser's shut-down function
<code>prsheadline</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the parser's headline function
<code>prsllextype</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the parser's lex-type function

51.62. `pg_ts_template`

The `pg_ts_template` catalog contains entries defining text search templates. A template is the implementation skeleton for a class of text search dictionaries. Since a template must be implemented by C-language-level functions, creation of new templates is restricted to database superusers.

PostgreSQL's text search features are described at length in Chapter 12.

Table 51.62. `pg_ts_template` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>tplname</code>	<code>name</code>		Text search template name
<code>tplnamespace</code>	<code>oid</code>	<code>pg_namespace.oid</code>	The OID of the namespace that contains this template
<code>tplinit</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the template's initialization function
<code>tpllexize</code>	<code>regproc</code>	<code>pg_proc.oid</code>	OID of the template's lexize function

51.63. `pg_type`

The catalog `pg_type` stores information about data types. Base types and enum types (scalar types) are created with `CREATE TYPE`, and domains with `CREATE DOMAIN`. A composite type is automatically created for each table in the database, to represent the row structure of the table. It is also possible to create composite types with `CREATE TYPE AS`.

Table 51.63. `pg_type` Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>typname</code>	<code>name</code>		Data type name
<code>typnamespace</code>	<code>oid</code>	<code>pg_namespace.oid</code>	The OID of the namespace that contains this type
<code>typowner</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the type
<code>typlen</code>	<code>int2</code>		For a fixed-size type, <code>typlen</code> is the number of bytes in the internal representation of the type. But for a variable-length type, <code>typlen</code> is negative. <code>-1</code> indicates a “varlena” type (one that has a length word), <code>-2</code> indicates a null-terminated C string.
<code>typbyval</code>	<code>bool</code>		<code>typbyval</code> determines whether internal routines pass a value of this type by value or by reference. <code>typbyval</code> had better be false if <code>typlen</code> is not 1, 2, or 4 (or 8 on machines where Datum is 8 bytes). Variable-length types are always passed by reference. Note that <code>typbyval</code> can be false even if the length would allow pass-by-value.
<code>typtype</code>	<code>char</code>		<code>typtype</code> is <code>b</code> for a base type, <code>c</code> for a composite type (e.g., a table's row type), <code>d</code> for a domain, <code>e</code> for an enum type, <code>p</code> for a pseudo-type, or <code>r</code> for a range type. See also <code>typrelid</code> and <code>typbasetype</code> .
<code>typcategory</code>	<code>char</code>		<code>typcategory</code> is an arbitrary classification of data types that is used by the parser to

Name	Type	References	Description
			determine which implicit casts should be “preferred”. See Table 51.64.
<code>typispreferred</code>	<code>bool</code>		True if the type is a preferred cast target within its <code>typcategory</code>
<code>typisdefined</code>	<code>bool</code>		True if the type is defined, false if this is a placeholder entry for a not-yet-defined type. When <code>typisdefined</code> is false, nothing except the type name, namespace, and OID can be relied on.
<code>typdelim</code>	<code>char</code>		Character that separates two values of this type when parsing array input. Note that the delimiter is associated with the array element data type, not the array data type.
<code>typrelid</code>	<code>oid</code>	<code>pg_class.oid</code>	If this is a composite type (see <code>typtype</code>), then this column points to the <code>pg_class</code> entry that defines the corresponding table. (For a free-standing composite type, the <code>pg_class</code> entry doesn't really represent a table, but it is needed anyway for the type's <code>pg_attribute</code> entries to link to.) Zero for non-composite types.
<code>typelem</code>	<code>oid</code>	<code>pg_type.oid</code>	If <code>typelem</code> is not 0 then it identifies another row in <code>pg_type</code> . The current type can then be subscripted like an array yielding values of type <code>typelem</code> . A “true” array type is variable length (<code>typlen = -1</code>), but some fixed-length (<code>typlen > 0</code>) types also have nonzero <code>typelem</code> , for example <code>name</code> and <code>point</code> . If a fixed-length type has a

Name	Type	References	Description
			<code>typelem</code> then its internal representation must be some number of values of the <code>typelem</code> data type with no other data. Variable-length array types have a header defined by the array subroutines.
<code>typarray</code>	<code>oid</code>	<code>pg_type.oid</code>	If <code>typarray</code> is not 0 then it identifies another row in <code>pg_type</code> , which is the “true” array type having this type as element
<code>typinput</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Input conversion function (text format)
<code>typoutput</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Output conversion function (text format)
<code>typreceive</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Input conversion function (binary format), or 0 if none
<code>typsend</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Output conversion function (binary format), or 0 if none
<code>typmodin</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Type modifier input function, or 0 if type does not support modifiers
<code>typmodout</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Type modifier output function, or 0 to use the standard format
<code>typanalyze</code>	<code>regproc</code>	<code>pg_proc.oid</code>	Custom ANALYZE function, or 0 to use the standard function
<code>typalign</code>	<code>char</code>		<code>typalign</code> is the alignment required when storing a value of this type. It applies to storage on disk as well as most representations of the value inside PostgreSQL. When multiple values are stored consecutively, such as in the representation of a complete row on disk, padding is inserted before a datum of this type so that it begins on the specified boundary. The alignment reference is

Name	Type	References	Description
			<p>the beginning of the first datum in the sequence.</p> <p>Possible values are:</p> <ul style="list-style-type: none"> • <code>c</code> = char alignment, i.e., no alignment needed. • <code>s</code> = short alignment (2 bytes on most machines). • <code>i</code> = int alignment (4 bytes on most machines). • <code>d</code> = double alignment (8 bytes on many machines, but by no means all). <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p style="text-align: center;">Note</p> <p>For types used in system tables, it is critical that the size and alignment defined in <code>pg_type</code> agree with the way that the compiler will lay out the column in a structure representing a table row.</p> </div>
typstorage	char		typstorage tells for varlena types (those with <code>typlen = -1</code>) if

Name	Type	References	Description
			<p>the type is prepared for toasting and what the default strategy for attributes of this type should be. Possible values are</p> <ul style="list-style-type: none"> • <code>p</code>: Value must always be stored plain. • <code>e</code>: Value can be stored in a “secondary” relation (if relation has one, see <code>pg_class.relttoastrelid</code>). • <code>m</code>: Value can be stored compressed inline. • <code>x</code>: Value can be stored compressed inline or stored in “secondary” storage. <p>Note that <code>m</code> columns can also be moved out to secondary storage, but only as a last resort (<code>e</code> and <code>x</code> columns are moved first).</p>
<code>typnotnull</code>	<code>bool</code>		<code>typnotnull</code> represents a not-null constraint on a type. Used for domains only.
<code>typbasetype</code>	<code>oid</code>	<code>pg_type.oid</code>	If this is a domain (see <code>typtype</code>), then <code>typbasetype</code> identifies the type that this one is based on. Zero if this type is not a domain.
<code>typtypmod</code>	<code>int4</code>		Domains use <code>typtypmod</code> to record the <code>typmod</code> to be applied to their base type (-1 if base type does not use a <code>typmod</code>). -1 if this type is not a domain.
<code>typndims</code>	<code>int4</code>		<code>typndims</code> is the number of array dimensions for a domain over an array (that is, <code>typbasetype</code> is an array type). Zero for types other

Name	Type	References	Description
			than domains over array types.
typcollation	oid	pg_collation.oid	typcollation specifies the collation of the type. If the type does not support collations, this will be zero. A base type that supports collations will have a nonzero value here, typically DEFAULT_COLLATION_OID. A domain over a collatable type can have a collation OID different from its base type's, if one was specified for the domain.
typdefaultbin	pg_node_tree		If typdefaultbin is not null, it is the nodeToString() representation of a default expression for the type. This is only used for domains.
typdefault	text		typdefault is null if the type has no associated default value. If typdefaultbin is not null, typdefault must contain a human-readable version of the default expression represented by typdefaultbin. If typdefaultbin is null and typdefault is not, then typdefault is the external representation of the type's default value, which can be fed to the type's input converter to produce a constant.
typacl	aclitem[]		Access privileges; see Section 5.7 for details

Table 51.64 lists the system-defined values of `typcategory`. Any future additions to this list will also be upper-case ASCII letters. All other ASCII characters are reserved for user-defined categories.

Table 51.64. `typcategory` Codes

Code	Category
A	Array types

Code	Category
B	Boolean types
C	Composite types
D	Date/time types
E	Enum types
G	Geometric types
I	Network address types
N	Numeric types
P	Pseudo-types
R	Range types
S	String types
T	Timespan types
U	User-defined types
V	Bit-string types
X	unknown type

51.64. pg_user_mapping

The catalog `pg_user_mapping` stores the mappings from local user to remote. Access to this catalog is restricted from normal users, use the view `pg_user_mappings` instead.

Table 51.65. pg_user_mapping Columns

Name	Type	References	Description
<code>oid</code>	<code>oid</code>		Row identifier
<code>umuser</code>	<code>oid</code>	<code>pg_authid.oid</code>	OID of the local role being mapped, 0 if the user mapping is public
<code>umserver</code>	<code>oid</code>	<code>pg_foreign_server.oid</code>	The OID of the foreign server that contains this mapping
<code>umoptions</code>	<code>text[]</code>		User mapping specific options, as “keyword=value” strings

51.65. System Views

In addition to the system catalogs, PostgreSQL provides a number of built-in views. Some system views provide convenient access to some commonly used queries on the system catalogs. Other views provide access to internal server state.

The information schema (Chapter 36) provides an alternative set of views which overlap the functionality of the system views. Since the information schema is SQL-standard whereas the views described here are PostgreSQL-specific, it's usually better to use the information schema if it provides all the information you need.

Table 51.66 lists the system views described here. More detailed documentation of each view follows below. There are some additional views that provide access to the results of the statistics collector; they are described in Table 27.2.

Except where noted, all the views described here are read-only.

Table 51.66. System Views

View Name	Purpose
pg_available_extensions	available extensions
pg_available_extension_versions	available versions of extensions
pg_config	compile-time configuration parameters
pg_cursors	open cursors
pg_file_settings	summary of configuration file contents
pg_group	groups of database users
pg_hba_file_rules	summary of client authentication configuration file contents
pg_indexes	indexes
pg_locks	locks currently held or awaited
pg_matviews	materialized views
pg_policies	policies
pg_prepared_statements	prepared statements
pg_prepared_xacts	prepared transactions
pg_publication_tables	publications and their associated tables
pg_replication_origin_status	information about replication origins, including replication progress
pg_replication_slots	replication slot information
pg_roles	database roles
pg_rules	rules
pg_seclabels	security labels
pg_sequences	sequences
pg_settings	parameter settings
pg_shadow	database users
pg_stats	planner statistics
pg_stats_ext	extended planner statistics
pg_tables	tables
pg_timezone_abbrevs	time zone abbreviations
pg_timezone_names	time zone names
pg_user	database users
pg_user_mappings	user mappings
pg_views	views

51.66. pg_available_extensions

The `pg_available_extensions` view lists the extensions that are available for installation. See also the `pg_extension` catalog, which shows the extensions currently installed.

Table 51.67. pg_available_extensions Columns

Name	Type	Description
name	name	Extension name

Name	Type	Description
default_version	text	Name of default version, or NULL if none is specified
installed_version	text	Currently installed version of the extension, or NULL if not installed
comment	text	Comment string from the extension's control file

The `pg_available_extensions` view is read only.

51.67. `pg_available_extension_versions`

The `pg_available_extension_versions` view lists the specific extension versions that are available for installation. See also the `pg_extension` catalog, which shows the extensions currently installed.

Table 51.68. `pg_available_extension_versions` Columns

Name	Type	Description
name	name	Extension name
version	text	Version name
installed	bool	True if this version of this extension is currently installed
superuser	bool	True if only superusers are allowed to install this extension
relocatable	bool	True if extension can be relocated to another schema
schema	name	Name of the schema that the extension must be installed into, or NULL if partially or fully relocatable
requires	name[]	Names of prerequisite extensions, or NULL if none
comment	text	Comment string from the extension's control file

The `pg_available_extension_versions` view is read only.

51.68. `pg_config`

The view `pg_config` describes the compile-time configuration parameters of the currently installed version of PostgreSQL. It is intended, for example, to be used by software packages that want to interface to PostgreSQL to facilitate finding the required header files and libraries. It provides the same basic information as the `pg_config` PostgreSQL client application.

By default, the `pg_config` view can be read only by superusers.

Table 51.69. `pg_config` Columns

Name	Type	Description
name	text	The parameter name
setting	text	The parameter value

51.69. pg_cursors

The `pg_cursors` view lists the cursors that are currently available. Cursors can be defined in several ways:

- via the `DECLARE` statement in SQL
- via the Bind message in the frontend/backend protocol, as described in Section 52.2.3
- via the Server Programming Interface (SPI), as described in Section 46.1

The `pg_cursors` view displays cursors created by any of these means. Cursors only exist for the duration of the transaction that defines them, unless they have been declared `WITH HOLD`. Therefore non-holdable cursors are only present in the view until the end of their creating transaction.

Note

Cursors are used internally to implement some of the components of PostgreSQL, such as procedural languages. Therefore, the `pg_cursors` view might include cursors that have not been explicitly created by the user.

Table 51.70. pg_cursors Columns

Name	Type	Description
<code>name</code>	<code>text</code>	The name of the cursor
<code>statement</code>	<code>text</code>	The verbatim query string submitted to declare this cursor
<code>is_holdable</code>	<code>boolean</code>	<code>true</code> if the cursor is holdable (that is, it can be accessed after the transaction that declared the cursor has committed); <code>false</code> otherwise
<code>is_binary</code>	<code>boolean</code>	<code>true</code> if the cursor was declared <code>BINARY</code> ; <code>false</code> otherwise
<code>is_scrollable</code>	<code>boolean</code>	<code>true</code> if the cursor is scrollable (that is, it allows rows to be retrieved in a nonsequential manner); <code>false</code> otherwise
<code>creation_time</code>	<code>timestampz</code>	The time at which the cursor was declared

The `pg_cursors` view is read only.

51.70. pg_file_settings

The view `pg_file_settings` provides a summary of the contents of the server's configuration file(s). A row appears in this view for each “name = value” entry appearing in the files, with annotations indicating whether the value could be applied successfully. Additional row(s) may appear for problems not linked to a “name = value” entry, such as syntax errors in the files.

This view is helpful for checking whether planned changes in the configuration files will work, or for diagnosing a previous failure. Note that this view reports on the *current* contents of the files, not on what was last applied by the server. (The `pg_settings` view is usually sufficient to determine that.)

By default, the `pg_file_settings` view can be read only by superusers.

Table 51.71. `pg_file_settings` Columns

Name	Type	Description
<code>sourcefile</code>	text	Full path name of the configuration file
<code>sourceline</code>	integer	Line number within the configuration file where the entry appears
<code>seqno</code>	integer	Order in which the entries are processed (1..n)
<code>name</code>	text	Configuration parameter name
<code>setting</code>	text	Value to be assigned to the parameter
<code>applied</code>	boolean	True if the value can be applied successfully
<code>error</code>	text	If not null, an error message indicating why this entry could not be applied

If the configuration file contains syntax errors or invalid parameter names, the server will not attempt to apply any settings from it, and therefore all the `applied` fields will read as false. In such a case there will be one or more rows with non-null `error` fields indicating the problem(s). Otherwise, individual settings will be applied if possible. If an individual setting cannot be applied (e.g., invalid value, or the setting cannot be changed after server start) it will have an appropriate message in the `error` field. Another way that an entry might have `applied = false` is that it is overridden by a later entry for the same parameter name; this case is not considered an error so nothing appears in the `error` field.

See Section 19.1 for more information about the various ways to change run-time parameters.

51.71. `pg_group`

The view `pg_group` exists for backwards compatibility: it emulates a catalog that existed in PostgreSQL before version 8.1. It shows the names and members of all roles that are marked as not `rolcanlogin`, which is an approximation to the set of roles that are being used as groups.

Table 51.72. `pg_group` Columns

Name	Type	References	Description
<code>groname</code>	name	<code>pg_authid.rolname</code>	Name of the group
<code>grosysid</code>	oid	<code>pg_authid.oid</code>	ID of this group
<code>grolist</code>	oid[]	<code>pg_authid.oid</code>	An array containing the IDs of the roles in this group

51.72. `pg_hba_file_rules`

The view `pg_hba_file_rules` provides a summary of the contents of the client authentication configuration file, `pg_hba.conf`. A row appears in this view for each non-empty, non-comment line in the file, with annotations indicating whether the rule could be applied successfully.

This view can be helpful for checking whether planned changes in the authentication configuration file will work, or for diagnosing a previous failure. Note that this view reports on the *current* contents of the file, not on what was last loaded by the server.

By default, the `pg_hba_file_rules` view can be read only by superusers.

Table 51.73. `pg_hba_file_rules` Columns

Name	Type	Description
<code>line_number</code>	integer	Line number of this rule in <code>pg_hba.conf</code>
<code>type</code>	text	Type of connection
<code>database</code>	text[]	List of database name(s) to which this rule applies
<code>user_name</code>	text[]	List of user and group name(s) to which this rule applies
<code>address</code>	text	Host name or IP address, or one of <code>all</code> , <code>samehost</code> , or <code>samenet</code> , or null for local connections
<code>netmask</code>	text	IP address mask, or null if not applicable
<code>auth_method</code>	text	Authentication method
<code>options</code>	text[]	Options specified for authentication method, if any
<code>error</code>	text	If not null, an error message indicating why this line could not be processed

Usually, a row reflecting an incorrect entry will have values for only the `line_number` and `error` fields.

See Chapter 20 for more information about client authentication configuration.

51.73. `pg_indexes`

The view `pg_indexes` provides access to useful information about each index in the database.

Table 51.74. `pg_indexes` Columns

Name	Type	References	Description
<code>schemaname</code>	name	<code>pg_namespace.nspname</code>	Name of schema containing table and index
<code>tablename</code>	name	<code>pg_class.relname</code>	Name of table the index is for
<code>indexname</code>	name	<code>pg_class.relname</code>	Name of index
<code>tablespace</code>	name	<code>pg_tablespace.spcname</code>	Name of tablespace containing index (null if default for database)
<code>indexdef</code>	text		Index definition (a reconstructed <code>CREATE INDEX</code> command)

51.74. pg_locks

The view `pg_locks` provides access to information about the locks held by active processes within the database server. See Chapter 13 for more discussion of locking.

`pg_locks` contains one row per active lockable object, requested lock mode, and relevant process. Thus, the same lockable object might appear many times, if multiple processes are holding or waiting for locks on it. However, an object that currently has no locks on it will not appear at all.

There are several distinct types of lockable objects: whole relations (e.g., tables), individual pages of relations, individual tuples of relations, transaction IDs (both virtual and permanent IDs), and general database objects (identified by class OID and object OID, in the same way as in `pg_description` or `pg_depend`). Also, the right to extend a relation is represented as a separate lockable object. Also, “advisory” locks can be taken on numbers that have user-defined meanings.

Table 51.75. pg_locks Columns

Name	Type	References	Description
<code>locktype</code>	<code>text</code>		Type of the lockable object: <code>relation</code> , <code>extend</code> , <code>page</code> , <code>tuple</code> , <code>transactionid</code> , <code>virtualxid</code> , <code>object</code> , <code>userlock</code> , or <code>advisory</code>
<code>database</code>	<code>oid</code>	<code>pg_database.oid</code>	OID of the database in which the lock target exists, or zero if the target is a shared object, or null if the target is a transaction ID
<code>relation</code>	<code>oid</code>	<code>pg_class.oid</code>	OID of the relation targeted by the lock, or null if the target is not a relation or part of a relation
<code>page</code>	<code>integer</code>		Page number targeted by the lock within the relation, or null if the target is not a relation page or tuple
<code>tuple</code>	<code>smallint</code>		Tuple number targeted by the lock within the page, or null if the target is not a tuple
<code>virtualxid</code>	<code>text</code>		Virtual ID of the transaction targeted by the lock, or null if the target is not a virtual transaction ID
<code>transactionid</code>	<code>xid</code>		ID of the transaction targeted by the lock, or null if the target is not a transaction ID
<code>classid</code>	<code>oid</code>	<code>pg_class.oid</code>	OID of the system catalog containing the lock

Name	Type	References	Description
			target, or null if the target is not a general database object
objid	oid	any OID column	OID of the lock target within its system catalog, or null if the target is not a general database object
objsubid	smallint		Column number targeted by the lock (the <code>classid</code> and <code>objid</code> refer to the table itself), or zero if the target is some other general database object, or null if the target is not a general database object
virtualtransaction	text		Virtual ID of the transaction that is holding or awaiting this lock
pid	integer		Process ID of the server process holding or awaiting this lock, or null if the lock is held by a prepared transaction
mode	text		Name of the lock mode held or desired by this process (see Section 13.3.1 and Section 13.2.3)
granted	boolean		True if lock is held, false if lock is awaited
fastpath	boolean		True if lock was taken via fast path, false if taken via main lock table

`granted` is true in a row representing a lock held by the indicated process. False indicates that this process is currently waiting to acquire this lock, which implies that at least one other process is holding or waiting for a conflicting lock mode on the same lockable object. The waiting process will sleep until the other lock is released (or a deadlock situation is detected). A single process can be waiting to acquire at most one lock at a time.

Throughout running a transaction, a server process holds an exclusive lock on the transaction's virtual transaction ID. If a permanent ID is assigned to the transaction (which normally happens only if the transaction changes the state of the database), it also holds an exclusive lock on the transaction's permanent transaction ID until it ends. When a process finds it necessary to wait specifically for another transaction to end, it does so by attempting to acquire share lock on the other transaction's ID (either virtual or permanent ID depending on the situation). That will succeed only when the other transaction terminates and releases its locks.

Although tuples are a lockable type of object, information about row-level locks is stored on disk, not in memory, and therefore row-level locks normally do not appear in this view. If a process is waiting for a row-level lock, it will usually appear in the view as waiting for the permanent transaction ID of the current holder of that row lock.

Advisory locks can be acquired on keys consisting of either a single `bigint` value or two integer values. A `bigint` key is displayed with its high-order half in the `classid` column, its low-order half in the `objid` column, and `objsubid` equal to 1. The original `bigint` value can be reassembled with the expression `(classid::bigint << 32) | objid::bigint`. Integer keys are displayed with the first key in the `classid` column, the second key in the `objid` column, and `objsubid` equal to 2. The actual meaning of the keys is up to the user. Advisory locks are local to each database, so the database column is meaningful for an advisory lock.

`pg_locks` provides a global view of all locks in the database cluster, not only those relevant to the current database. Although its `relation` column can be joined against `pg_class.oid` to identify locked relations, this will only work correctly for relations in the current database (those for which the database column is either the current database's OID or zero).

The `pid` column can be joined to the `pid` column of the `pg_stat_activity` view to get more information on the session holding or awaiting each lock, for example

```
SELECT * FROM pg_locks pl LEFT JOIN pg_stat_activity psa
    ON pl.pid = psa.pid;
```

Also, if you are using prepared transactions, the `virtualtransaction` column can be joined to the `transaction` column of the `pg_prepared_xacts` view to get more information on prepared transactions that hold locks. (A prepared transaction can never be waiting for a lock, but it continues to hold the locks it acquired while running.) For example:

```
SELECT * FROM pg_locks pl LEFT JOIN pg_prepared_xacts ppx
    ON pl.virtualtransaction = '-1/' || ppx.transaction;
```

While it is possible to obtain information about which processes block which other processes by joining `pg_locks` against itself, this is very difficult to get right in detail. Such a query would have to encode knowledge about which lock modes conflict with which others. Worse, the `pg_locks` view does not expose information about which processes are ahead of which others in lock wait queues, nor information about which processes are parallel workers running on behalf of which other client sessions. It is better to use the `pg_blocking_pids()` function (see Table 9.63) to identify which process(es) a waiting process is blocked behind.

The `pg_locks` view displays data from both the regular lock manager and the predicate lock manager, which are separate systems; in addition, the regular lock manager subdivides its locks into regular and *fast-path* locks. This data is not guaranteed to be entirely consistent. When the view is queried, data on fast-path locks (with `fastpath = true`) is gathered from each backend one at a time, without freezing the state of the entire lock manager, so it is possible for locks to be taken or released while information is gathered. Note, however, that these locks are known not to conflict with any other lock currently in place. After all backends have been queried for fast-path locks, the remainder of the regular lock manager is locked as a unit, and a consistent snapshot of all remaining locks is collected as an atomic action. After unlocking the regular lock manager, the predicate lock manager is similarly locked and all predicate locks are collected as an atomic action. Thus, with the exception of fast-path locks, each lock manager will deliver a consistent set of results, but as we do not lock both lock managers simultaneously, it is possible for locks to be taken or released after we interrogate the regular lock manager and before we interrogate the predicate lock manager.

Locking the regular and/or predicate lock manager could have some impact on database performance if this view is very frequently accessed. The locks are held only for the minimum amount of time necessary to obtain data from the lock managers, but this does not completely eliminate the possibility of a performance impact.

51.75. `pg_matviews`

The view `pg_matviews` provides access to useful information about each materialized view in the database.

Table 51.76. pg_matviews Columns

Name	Type	References	Description
schemaname	name	pg_namespace.n- spname	Name of schema containing materialized view
matviewname	name	pg_class.relname	Name of materialized view
matviewowner	name	pg_authid.rol- name	Name of materialized view's owner
tablespace	name	pg_table- space.spcname	Name of tablespace containing materialized view (null if default for database)
hasindexes	boolean		True if materialized view has (or recently had) any indexes
ispopulated	boolean		True if materialized view is currently populated
definition	text		Materialized view definition (a reconstructed SELECT query)

51.76. pg_policies

The view `pg_policies` provides access to useful information about each row-level security policy in the database.

Table 51.77. pg_policies Columns

Name	Type	References	Description
schemaname	name	pg_namespace.n- spname	Name of schema containing table policy is on
tablename	name	pg_class.relname	Name of table policy is on
policyname	name	pg_policy.pol- name	Name of policy
polpermissive	text		Is the policy permissive or restrictive?
roles	name[]		The roles to which this policy applies
cmd	text		The command type to which the policy is applied
qual	text		The expression added to the security barrier qualifications for queries that this policy applies to
with_check	text		The expression added to the WITH

Name	Type	References	Description
			CHECK qualifications for queries that attempt to add rows to this table

51.77. pg_prepared_statements

The `pg_prepared_statements` view displays all the prepared statements that are available in the current session. See `PREPARE` for more information about prepared statements.

`pg_prepared_statements` contains one row for each prepared statement. Rows are added to the view when a new prepared statement is created and removed when a prepared statement is released (for example, via the `DEALLOCATE` command).

Table 51.78. pg_prepared_statements Columns

Name	Type	Description
<code>name</code>	<code>text</code>	The identifier of the prepared statement
<code>statement</code>	<code>text</code>	The query string submitted by the client to create this prepared statement. For prepared statements created via SQL, this is the <code>PREPARE</code> statement submitted by the client. For prepared statements created via the frontend/backend protocol, this is the text of the prepared statement itself.
<code>prepare_time</code>	<code>timestampz</code>	The time at which the prepared statement was created
<code>parameter_types</code>	<code>regtype[]</code>	The expected parameter types for the prepared statement in the form of an array of <code>regtype</code> . The OID corresponding to an element of this array can be obtained by casting the <code>regtype</code> value to <code>oid</code> .
<code>from_sql</code>	<code>boolean</code>	<code>true</code> if the prepared statement was created via the <code>PREPARE SQL</code> command; <code>false</code> if the statement was prepared via the frontend/backend protocol

The `pg_prepared_statements` view is read only.

51.78. pg_prepared_xacts

The view `pg_prepared_xacts` displays information about transactions that are currently prepared for two-phase commit (see `PREPARE TRANSACTION` for details).

`pg_prepared_xacts` contains one row per prepared transaction. An entry is removed when the transaction is committed or rolled back.

Table 51.79. pg_prepared_xacts Columns

Name	Type	References	Description
transaction	xid		Numeric transaction identifier of the prepared transaction
gid	text		Global transaction identifier that was assigned to the transaction
prepared	timestamp with time zone		Time at which the transaction was prepared for commit
owner	name	pg_authid.rolname	Name of the user that executed the transaction
database	name	pg_database.datname	Name of the database in which the transaction was executed

When the `pg_prepared_xacts` view is accessed, the internal transaction manager data structures are momentarily locked, and a copy is made for the view to display. This ensures that the view produces a consistent set of results, while not blocking normal operations longer than necessary. Nonetheless there could be some impact on database performance if this view is frequently accessed.

51.79. pg_publication_tables

The view `pg_publication_tables` provides information about the mapping between publications and the tables they contain. Unlike the underlying catalog `pg_publication_rel`, this view expands publications defined as `FOR ALL TABLES`, so for such publications there will be a row for each eligible table.

Table 51.80. pg_publication_tables Columns

Name	Type	References	Description
pubname	name	pg_publication.pubname	Name of publication
schemaname	name	pg_namespace.nspname	Name of schema containing table
tablename	name	pg_class.relname	Name of table

51.80. pg_replication_origin_status

The `pg_replication_origin_status` view contains information about how far replay for a certain origin has progressed. For more on replication origins see Chapter 49.

Table 51.81. pg_replication_origin_status Columns

Name	Type	References	Description
local_id	Oid	pg_replication_origin.roident	internal node identifier
external_id	text	pg_replication_origin.roname	external node identifier

Name	Type	References	Description
<code>remote_lsn</code>	<code>pg_lsn</code>		The origin node's LSN up to which data has been replicated.
<code>local_lsn</code>	<code>pg_lsn</code>		This node's LSN at which <code>remote_lsn</code> has been replicated. Used to flush commit records before persisting data to disk when using asynchronous commits.

51.81. `pg_replication_slots`

The `pg_replication_slots` view provides a listing of all replication slots that currently exist on the database cluster, along with their current state.

For more on replication slots, see Section 26.2.6 and Chapter 48.

Table 51.82. `pg_replication_slots` Columns

Name	Type	References	Description
<code>slot_name</code>	<code>name</code>		A unique, cluster-wide identifier for the replication slot
<code>plugin</code>	<code>name</code>		The base name of the shared object containing the output plugin this logical slot is using, or null for physical slots.
<code>slot_type</code>	<code>text</code>		The slot type - physical or logical
<code>datoid</code>	<code>oid</code>	<code>pg_database.oid</code>	The OID of the database this slot is associated with, or null. Only logical slots have an associated database.
<code>database</code>	<code>text</code>	<code>pg_database.datname</code>	The name of the database this slot is associated with, or null. Only logical slots have an associated database.
<code>temporary</code>	<code>boolean</code>		True if this is a temporary replication slot. Temporary slots are not saved to disk and are automatically dropped on error or when the session has finished.
<code>active</code>	<code>boolean</code>		True if this slot is currently actively being used

Name	Type	References	Description
active_pid	integer		The process ID of the session using this slot if the slot is currently actively being used. NULL if inactive.
xmin	xid		The oldest transaction that this slot needs the database to retain. VACUUM cannot remove tuples deleted by any later transaction.
catalog_xmin	xid		The oldest transaction affecting the system catalogs that this slot needs the database to retain. VACUUM cannot remove catalog tuples deleted by any later transaction.
restart_lsn	pg_lsn		The address (LSN) of oldest WAL which still might be required by the consumer of this slot and thus won't be automatically removed during checkpoints. NULL if the LSN of this slot has never been reserved.
confirmed_flush_lsn	pg_lsn		The address (LSN) up to which the logical slot's consumer has confirmed receiving data. Data older than this is not available anymore. NULL for physical slots.

51.82. pg_roles

The view `pg_roles` provides access to information about database roles. This is simply a publicly readable view of `pg_authid` that blanks out the password field.

Table 51.83. pg_roles Columns

Name	Type	References	Description
rolname	name		Role name
rolsuper	bool		Role has superuser privileges
rolinherit	bool		Role automatically inherits privileges of roles it is a member of
rolcreaterole	bool		Role can create more roles

Name	Type	References	Description
rolcreatedb	bool		Role can create databases
rolcanlogin	bool		Role can log in. That is, this role can be given as the initial session authorization identifier
rolreplication	bool		Role is a replication role. A replication role can initiate replication connections and create and drop replication slots.
rolconlimit	int4		For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit.
rolpassword	text		Not the password (always reads as <code>*****</code>)
rolvaliduntil	timestamptz		Password expiry time (only used for password authentication); null if no expiration
rolbypassrls	bool		Role bypasses every row level security policy, see Section 5.8 for more information.
rolconfig	text[]		Role-specific defaults for run-time configuration variables
oid	oid	pg_authid.oid	ID of role

51.83. pg_rules

The view `pg_rules` provides access to useful information about query rewrite rules.

Table 51.84. pg_rules Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing table
tablename	name	pg_class.relname	Name of table the rule is for
rulename	name	pg_rewrite.rulename	Name of rule
definition	text		Rule definition (a reconstructed creation command)

The `pg_rules` view excludes the ON SELECT rules of views and materialized views; those can be seen in `pg_views` and `pg_matviews`.

51.84. pg_seclabels

The view `pg_seclabels` provides information about security labels. It is an easier-to-query version of the `pg_seclabel` catalog.

Table 51.85. pg_seclabels Columns

Name	Type	References	Description
<code>objoid</code>	<code>oid</code>	any OID column	The OID of the object this security label pertains to
<code>classoid</code>	<code>oid</code>	<code>pg_class.oid</code>	The OID of the system catalog this object appears in
<code>objsubid</code>	<code>int4</code>		For a security label on a table column, this is the column number (the <code>objoid</code> and <code>classoid</code> refer to the table itself). For all other object types, this column is zero.
<code>objtype</code>	<code>text</code>		The type of object to which this label applies, as text.
<code>objnamespace</code>	<code>oid</code>	<code>pg_namespace.oid</code>	The OID of the namespace for this object, if applicable; otherwise NULL.
<code>objname</code>	<code>text</code>		The name of the object to which this label applies, as text.
<code>provider</code>	<code>text</code>	<code>pg_seclabel.provider</code>	The label provider associated with this label.
<code>label</code>	<code>text</code>	<code>pg_seclabel.label</code>	The security label applied to this object.

51.85. pg_sequences

The view `pg_sequences` provides access to useful information about each sequence in the database.

Table 51.86. pg_sequences Columns

Name	Type	References	Description
<code>schemaname</code>	<code>name</code>	<code>pg_namespace.nspname</code>	Name of schema containing sequence
<code>sequencename</code>	<code>name</code>	<code>pg_class.relname</code>	Name of sequence
<code>sequenceowner</code>	<code>name</code>	<code>pg_authid.rolname</code>	Name of sequence's owner
<code>data_type</code>	<code>regtype</code>	<code>pg_type.oid</code>	Data type of the sequence

Name	Type	References	Description
start_value	bigint		Start value of the sequence
min_value	bigint		Minimum value of the sequence
max_value	bigint		Maximum value of the sequence
increment_by	bigint		Increment value of the sequence
cycle	boolean		Whether the sequence cycles
cache_size	bigint		Cache size of the sequence
last_value	bigint		The last sequence value written to disk. If caching is used, this value can be greater than the last value handed out from the sequence. Null if the sequence has not been read from yet. Also, if the current user does not have <code>USAGE</code> or <code>SELECT</code> privilege on the sequence, the value is null.

51.86. pg_settings

The view `pg_settings` provides access to run-time parameters of the server. It is essentially an alternative interface to the `SHOW` and `SET` commands. It also provides access to some facts about each parameter that are not directly available from `SHOW`, such as minimum and maximum values.

Table 51.87. pg_settings Columns

Name	Type	Description
name	text	Run-time configuration parameter name
setting	text	Current value of the parameter
unit	text	Implicit unit of the parameter
category	text	Logical group of the parameter
short_desc	text	A brief description of the parameter
extra_desc	text	Additional, more detailed, description of the parameter
context	text	Context required to set the parameter's value (see below)
vartype	text	Parameter type (<code>bool</code> , <code>enum</code> , <code>integer</code> , <code>real</code> , or <code>string</code>)
source	text	Source of the current parameter value

Name	Type	Description
<code>min_val</code>	text	Minimum allowed value of the parameter (null for non-numeric values)
<code>max_val</code>	text	Maximum allowed value of the parameter (null for non-numeric values)
<code>enumvals</code>	text[]	Allowed values of an enum parameter (null for non-enum values)
<code>boot_val</code>	text	Parameter value assumed at server startup if the parameter is not otherwise set
<code>reset_val</code>	text	Value that RESET would reset the parameter to in the current session
<code>sourcefile</code>	text	Configuration file the current value was set in (null for values set from sources other than configuration files, or when examined by a user who is neither a superuser or a member of <code>pg_read_all_settings</code>); helpful when using <code>include</code> directives in configuration files
<code>sourceline</code>	integer	Line number within the configuration file the current value was set at (null for values set from sources other than configuration files, or when examined by a user who is neither a superuser or a member of <code>pg_read_all_settings</code>).
<code>pending_restart</code>	boolean	true if the value has been changed in the configuration file but needs a restart; or false otherwise.

There are several possible values of `context`. In order of decreasing difficulty of changing the setting, they are:

`internal`

These settings cannot be changed directly; they reflect internally determined values. Some of them may be adjustable by rebuilding the server with different configuration options, or by changing options supplied to `initdb`.

`postmaster`

These settings can only be applied when the server starts, so any change requires restarting the server. Values for these settings are typically stored in the `postgresql.conf` file, or passed on the command line when starting the server. Of course, settings with any of the lower context types can also be set at server start time.

sighup

Changes to these settings can be made in `postgresql.conf` without restarting the server. Send a `SIGHUP` signal to the postmaster to cause it to re-read `postgresql.conf` and apply the changes. The postmaster will also forward the `SIGHUP` signal to its child processes so that they all pick up the new value.

superuser-backend

Changes to these settings can be made in `postgresql.conf` without restarting the server. They can also be set for a particular session in the connection request packet (for example, via libpq's `PGOPTIONS` environment variable), but only if the connecting user is a superuser. However, these settings never change in a session after it is started. If you change them in `postgresql.conf`, send a `SIGHUP` signal to the postmaster to cause it to re-read `postgresql.conf`. The new values will only affect subsequently-launched sessions.

backend

Changes to these settings can be made in `postgresql.conf` without restarting the server. They can also be set for a particular session in the connection request packet (for example, via libpq's `PGOPTIONS` environment variable); any user can make such a change for their session. However, these settings never change in a session after it is started. If you change them in `postgresql.conf`, send a `SIGHUP` signal to the postmaster to cause it to re-read `postgresql.conf`. The new values will only affect subsequently-launched sessions.

superuser

These settings can be set from `postgresql.conf`, or within a session via the `SET` command; but only superusers can change them via `SET`. Changes in `postgresql.conf` will affect existing sessions only if no session-local value has been established with `SET`.

user

These settings can be set from `postgresql.conf`, or within a session via the `SET` command. Any user is allowed to change their session-local value. Changes in `postgresql.conf` will affect existing sessions only if no session-local value has been established with `SET`.

See Section 19.1 for more information about the various ways to change these parameters.

The `pg_settings` view cannot be inserted into or deleted from, but it can be updated. An `UPDATE` applied to a row of `pg_settings` is equivalent to executing the `SET` command on that named parameter. The change only affects the value used by the current session. If an `UPDATE` is issued within a transaction that is later aborted, the effects of the `UPDATE` command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another `UPDATE` or `SET`.

51.87. `pg_shadow`

The view `pg_shadow` exists for backwards compatibility: it emulates a catalog that existed in PostgreSQL before version 8.1. It shows properties of all roles that are marked as `rolcanlogin` in `pg_authid`.

The name stems from the fact that this table should not be readable by the public since it contains passwords. `pg_user` is a publicly readable view on `pg_shadow` that blanks out the password field.

Table 51.88. `pg_shadow` Columns

Name	Type	References	Description
<code>username</code>	<code>name</code>	<code>pg_authid.rolname</code>	User name
<code>usesysid</code>	<code>oid</code>	<code>pg_authid.oid</code>	ID of this user

Name	Type	References	Description
usecreatedb	bool		User can create databases
usesuper	bool		User is a superuser
userepl	bool		User can initiate streaming replication and put the system in and out of backup mode.
usebypassrls	bool		User bypasses every row level security policy, see Section 5.8 for more information.
passwd	text		Password (possibly encrypted); null if none. See <code>pg_authid</code> for details of how encrypted passwords are stored.
valuntil	timestampz		Password expiry time (only used for password authentication)
useconfig	text[]		Session defaults for runtime configuration variables

51.88. `pg_stats`

The view `pg_stats` provides access to the information stored in the `pg_statistic` catalog. This view allows access only to rows of `pg_statistic` that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

`pg_stats` is also designed to present the information in a more readable format than the underlying catalog — at the cost that its schema must be extended whenever new slot types are defined for `pg_statistic`.

Table 51.89. `pg_stats` Columns

Name	Type	References	Description
schemaname	name	<code>pg_namespace.nspname</code>	Name of schema containing table
tablename	name	<code>pg_class.relname</code>	Name of table
attname	name	<code>pg_attribute.attname</code>	Name of the column described by this row
inherited	bool		If true, this row includes inheritance child columns, not just the values in the specified table
null_frac	real		Fraction of column entries that are null
avg_width	integer		Average width in bytes of column's entries

Name	Type	References	Description
n_distinct	real		If greater than zero, the estimated number of distinct values in the column. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique column in which the number of distinct values is the same as the number of rows.
most_common_vals	anyarray		A list of the most common values in the column. (Null if no values seem to be more common than any others.)
most_common_frequencies	real[]		A list of the frequencies of the most common values, i.e., number of occurrences of each divided by total number of rows. (Null when most_common_vals is.)
histogram_bounds	anyarray		A list of values that divide the column's values into groups of approximately equal population. The values in most_common_vals, if present, are omitted from this histogram calculation. (This column is null if the column data type does not have a < operator or if the most_common_vals list accounts for the entire population.)
correlation	real		Statistical correlation between physical row

Name	Type	References	Description
			ordering and logical ordering of the column values. This ranges from -1 to +1. When the value is near -1 or +1, an index scan on the column will be estimated to be cheaper than when it is near zero, due to reduction of random access to the disk. (This column is null if the column data type does not have a < operator.)
most_common_elems	anyarray		A list of non-null element values most often appearing within values of the column. (Null for scalar types.)
most_common_elem_freqs	real[]		A list of the frequencies of the most common element values, i.e., the fraction of rows containing at least one instance of the given value. Two or three additional values follow the per-element frequencies; these are the minimum and maximum of the preceding per-element frequencies, and optionally the frequency of null elements. (Null when most_common_elems is.)
elem_count_histogram	real[]		A histogram of the counts of distinct non-null element values within the values of the column, followed by the average number of distinct non-null elements. (Null for scalar types.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the `default_statistics_target` run-time parameter.

51.89. pg_stats_ext

The view `pg_stats_ext` provides access to the information stored in the `pg_statistic_ext` and `pg_statistic_ext_data` catalogs. This view allows access only to rows of `pg_statistic_ext`.

`tic_ext` and `pg_statistic_ext_data` that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

`pg_stats_ext` is also designed to present the information in a more readable format than the underlying catalogs — at the cost that its schema must be extended whenever new types of extended statistics are added to `pg_statistic_ext`.

Table 51.90. `pg_stats_ext` Columns

Name	Type	References	Description
<code>schemaname</code>	<code>name</code>	<code>pg_namespace.nspname</code>	Name of schema containing table
<code>tablename</code>	<code>name</code>	<code>pg_class.relname</code>	Name of table
<code>statistics_schemaname</code>	<code>name</code>	<code>pg_namespace.nspname</code>	Name of schema containing extended statistic
<code>statistics_name</code>	<code>name</code>	<code>pg_statistic_ext.stxname</code>	Name of extended statistics
<code>statistics_owner</code>	<code>oid</code>	<code>pg_authid.oid</code>	Owner of the extended statistics
<code>attnames</code>	<code>name[]</code>	<code>pg_attribute.attname</code>	Names of the columns the extended statistics is defined on
<code>kinds</code>	<code>text[]</code>		Types of extended statistics enabled for this record
<code>n_distinct</code>	<code>pg_ndistinct</code>		N-distinct counts for combinations of column values. If greater than zero, the estimated number of distinct values in the combination. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique combination of columns in which the number of distinct combinations is the same as the number of rows.
<code>dependencies</code>	<code>pg_dependencies</code>		Functional dependency statistics

Name	Type	References	Description
most_common_vals	anyarray		A list of the most common combinations of values in the columns. (Null if no combinations seem to be more common than any others.)
most_common_val_nulls	anyarray		A list of NULL flags for the most common combinations of values. (Null when most_common_vals is.)
most_common_freqs	real[]		A list of the frequencies of the most common combinations, i.e., number of occurrences of each divided by total number of rows. (Null when most_common_vals is.)
most_common_base_freqs	real[]		A list of the base frequencies of the most common combinations, i.e., product of per-value frequencies. (Null when most_common_vals is.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the `default_statistics_target` run-time parameter.

51.90. pg_tables

The view `pg_tables` provides access to useful information about each table in the database.

Table 51.91. pg_tables Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing table
tablename	name	pg_class.relname	Name of table
tableowner	name	pg_authid.rolname	Name of table's owner
tablespace	name	pg_tablespace.spcname	Name of tablespace containing table (null if default for database)
hasindexes	boolean	pg_class.relhasindex	True if table has (or recently had) any indexes
hasrules	boolean	pg_class.relhasrules	True if table has (or once had) rules

Name	Type	References	Description
hastriggers	boolean	pg_class.relhas-triggers	True if table has (or once had) triggers
rowsecurity	boolean	pg_class.rel-rowsecurity	True if row security is enabled on the table

51.91. pg_timezone_abbrevs

The view `pg_timezone_abbrevs` provides a list of time zone abbreviations that are currently recognized by the datetime input routines. The contents of this view change when the `timezone_abbreviations` run-time parameter is modified.

Table 51.92. pg_timezone_abbrevs Columns

Name	Type	Description
abbrev	text	Time zone abbreviation
utc_offset	interval	Offset from UTC (positive means east of Greenwich)
is_dst	boolean	True if this is a daylight-savings abbreviation

While most timezone abbreviations represent fixed offsets from UTC, there are some that have historically varied in value (see Section B.4 for more information). In such cases this view presents their current meaning.

51.92. pg_timezone_names

The view `pg_timezone_names` provides a list of time zone names that are recognized by SET TIMEZONE, along with their associated abbreviations, UTC offsets, and daylight-savings status. (Technically, PostgreSQL does not use UTC because leap seconds are not handled.) Unlike the abbreviations shown in `pg_timezone_abbrevs`, many of these names imply a set of daylight-savings transition date rules. Therefore, the associated information changes across local DST boundaries. The displayed information is computed based on the current value of `CURRENT_TIMESTAMP`.

Table 51.93. pg_timezone_names Columns

Name	Type	Description
name	text	Time zone name
abbrev	text	Time zone abbreviation
utc_offset	interval	Offset from UTC (positive means east of Greenwich)
is_dst	boolean	True if currently observing daylight savings

51.93. pg_user

The view `pg_user` provides access to information about database users. This is simply a publicly readable view of `pg_shadow` that blanks out the password field.

Table 51.94. pg_user Columns

Name	Type	Description
username	name	User name

Name	Type	Description
usesysid	oid	ID of this user
usecreatedb	bool	User can create databases
usesuper	bool	User is a superuser
userepl	bool	User can initiate streaming replication and put the system in and out of backup mode.
usebypassrls	bool	User bypasses every row level security policy, see Section 5.8 for more information.
passwd	text	Not the password (always reads as *****)
valuntil	timestamptz	Password expiry time (only used for password authentication)
useconfig	text[]	Session defaults for run-time configuration variables

51.94. pg_user_mappings

The view `pg_user_mappings` provides access to information about user mappings. This is essentially a publicly readable view of `pg_user_mapping` that leaves out the options field if the user has no rights to use it.

Table 51.95. pg_user_mappings Columns

Name	Type	References	Description
umid	oid	<code>pg_user_mapping.oid</code>	OID of the user mapping
srvid	oid	<code>pg_foreign_server.oid</code>	The OID of the foreign server that contains this mapping
srvname	name	<code>pg_foreign_server.srvname</code>	Name of the foreign server
umuser	oid	<code>pg_authid.oid</code>	OID of the local role being mapped, 0 if the user mapping is public
username	name		Name of the local user to be mapped
umoptions	text[]		User mapping specific options, as “keyword=value” strings

To protect password information stored as a user mapping option, the `umoptions` column will read as null unless one of the following applies:

- current user is the user being mapped, and owns the server or holds `USAGE` privilege on it
- current user is the server owner and mapping is for `PUBLIC`
- current user is a superuser

51.95. pg_views

The view `pg_views` provides access to useful information about each view in the database.

Table 51.96. `pg_views` Columns

Name	Type	References	Description
<code>schemaname</code>	<code>name</code>	<code>pg_namespace.nspname</code>	Name of schema containing view
<code>viewname</code>	<code>name</code>	<code>pg_class.relname</code>	Name of view
<code>viewowner</code>	<code>name</code>	<code>pg_authid.rolname</code>	Name of view's owner
<code>definition</code>	<code>text</code>		View definition (a reconstructed <code>SELECT</code> query)

Chapter 52. Frontend/Backend Protocol

PostgreSQL uses a message-based protocol for communication between frontends and backends (clients and servers). The protocol is supported over TCP/IP and also over Unix-domain sockets. Port number 5432 has been registered with IANA as the customary TCP port number for servers supporting this protocol, but in practice any non-privileged port number can be used.

This document describes version 3.0 of the protocol, implemented in PostgreSQL 7.4 and later. For descriptions of the earlier protocol versions, see previous releases of the PostgreSQL documentation. A single server can support multiple protocol versions. The initial startup-request message tells the server which protocol version the client is attempting to use. If the major version requested by the client is not supported by the server, the connection will be rejected (for example, this would occur if the client requested protocol version 4.0, which does not exist as of this writing). If the minor version requested by the client is not supported by the server (e.g. the client requests version 3.1, but the server supports only 3.0), the server may either reject the connection or may respond with a `NegotiateProtocolVersion` message containing the highest minor protocol version which it supports. The client may then choose either to continue with the connection using the specified protocol version or to abort the connection.

In order to serve multiple clients efficiently, the server launches a new “backend” process for each client. In the current implementation, a new child process is created immediately after an incoming connection is detected. This is transparent to the protocol, however. For purposes of the protocol, the terms “backend” and “server” are interchangeable; likewise “frontend” and “client” are interchangeable.

52.1. Overview

The protocol has separate phases for startup and normal operation. In the startup phase, the frontend opens a connection to the server and authenticates itself to the satisfaction of the server. (This might involve a single message, or multiple messages depending on the authentication method being used.) If all goes well, the server then sends status information to the frontend, and finally enters normal operation. Except for the initial startup-request message, this part of the protocol is driven by the server.

During normal operation, the frontend sends queries and other commands to the backend, and the backend sends back query results and other responses. There are a few cases (such as `NOTIFY`) wherein the backend will send unsolicited messages, but for the most part this portion of a session is driven by frontend requests.

Termination of the session is normally by frontend choice, but can be forced by the backend in certain cases. In any case, when the backend closes the connection, it will roll back any open (incomplete) transaction before exiting.

Within normal operation, SQL commands can be executed through either of two sub-protocols. In the “simple query” protocol, the frontend just sends a textual query string, which is parsed and immediately executed by the backend. In the “extended query” protocol, processing of queries is separated into multiple steps: parsing, binding of parameter values, and execution. This offers flexibility and performance benefits, at the cost of extra complexity.

Normal operation has additional sub-protocols for special operations such as `COPY`.

52.1.1. Messaging Overview

All communication is through a stream of messages. The first byte of a message identifies the message type, and the next four bytes specify the length of the rest of the message (this length count includes itself, but not the message-type byte). The remaining contents of the message are determined by the

message type. For historical reasons, the very first message sent by the client (the startup message) has no initial message-type byte.

To avoid losing synchronization with the message stream, both servers and clients typically read an entire message into a buffer (using the byte count) before attempting to process its contents. This allows easy recovery if an error is detected while processing the contents. In extreme situations (such as not having enough memory to buffer the message), the receiver can use the byte count to determine how much input to skip before it resumes reading messages.

Conversely, both servers and clients must take care never to send an incomplete message. This is commonly done by marshaling the entire message in a buffer before beginning to send it. If a communications failure occurs partway through sending or receiving a message, the only sensible response is to abandon the connection, since there is little hope of recovering message-boundary synchronization.

52.1.2. Extended Query Overview

In the extended-query protocol, execution of SQL commands is divided into multiple steps. The state retained between steps is represented by two types of objects: *prepared statements* and *portals*. A prepared statement represents the result of parsing and semantic analysis of a textual query string. A prepared statement is not in itself ready to execute, because it might lack specific values for *parameters*. A portal represents a ready-to-execute or already-partially-executed statement, with any missing parameter values filled in. (For `SELECT` statements, a portal is equivalent to an open cursor, but we choose to use a different term since cursors don't handle non-`SELECT` statements.)

The overall execution cycle consists of a *parse* step, which creates a prepared statement from a textual query string; a *bind* step, which creates a portal given a prepared statement and values for any needed parameters; and an *execute* step that runs a portal's query. In the case of a query that returns rows (`SELECT`, `SHOW`, etc), the execute step can be told to fetch only a limited number of rows, so that multiple execute steps might be needed to complete the operation.

The backend can keep track of multiple prepared statements and portals (but note that these exist only within a session, and are never shared across sessions). Existing prepared statements and portals are referenced by names assigned when they were created. In addition, an “unnamed” prepared statement and portal exist. Although these behave largely the same as named objects, operations on them are optimized for the case of executing a query only once and then discarding it, whereas operations on named objects are optimized on the expectation of multiple uses.

52.1.3. Formats and Format Codes

Data of a particular data type might be transmitted in any of several different *formats*. As of PostgreSQL 7.4 the only supported formats are “text” and “binary”, but the protocol makes provision for future extensions. The desired format for any value is specified by a *format code*. Clients can specify a format code for each transmitted parameter value and for each column of a query result. Text has format code zero, binary has format code one, and all other format codes are reserved for future definition.

The text representation of values is whatever strings are produced and accepted by the input/output conversion functions for the particular data type. In the transmitted representation, there is no trailing null character; the frontend must add one to received values if it wants to process them as C strings. (The text format does not allow embedded nulls, by the way.)

Binary representations for integers use network byte order (most significant byte first). For other data types consult the documentation or source code to learn about the binary representation. Keep in mind that binary representations for complex data types might change across server versions; the text format is usually the more portable choice.

52.2. Message Flow

This section describes the message flow and the semantics of each message type. (Details of the exact representation of each message appear in Section 52.7.) There are several different sub-protocols de-

pending on the state of the connection: start-up, query, function call, *COPY*, and termination. There are also special provisions for asynchronous operations (including notification responses and command cancellation), which can occur at any time after the start-up phase.

52.2.1. Start-up

To begin a session, a frontend opens a connection to the server and sends a startup message. This message includes the names of the user and of the database the user wants to connect to; it also identifies the particular protocol version to be used. (Optionally, the startup message can include additional settings for run-time parameters.) The server then uses this information and the contents of its configuration files (such as `pg_hba.conf`) to determine whether the connection is provisionally acceptable, and what additional authentication is required (if any).

The server then sends an appropriate authentication request message, to which the frontend must reply with an appropriate authentication response message (such as a password). For all authentication methods except GSSAPI, SSPI and SASL, there is at most one request and one response. In some methods, no response at all is needed from the frontend, and so no authentication request occurs. For GSSAPI, SSPI and SASL, multiple exchanges of packets may be needed to complete the authentication.

The authentication cycle ends with the server either rejecting the connection attempt (`ErrorResponse`), or sending `AuthenticationOk`.

The possible messages from the server in this phase are:

`ErrorResponse`

The connection attempt has been rejected. The server then immediately closes the connection.

`AuthenticationOk`

The authentication exchange is successfully completed.

`AuthenticationKerberosV5`

The frontend must now take part in a Kerberos V5 authentication dialog (not described here, part of the Kerberos specification) with the server. If this is successful, the server responds with an `AuthenticationOk`, otherwise it responds with an `ErrorResponse`. This is no longer supported.

`AuthenticationCleartextPassword`

The frontend must now send a `PasswordMessage` containing the password in clear-text form. If this is the correct password, the server responds with an `AuthenticationOk`, otherwise it responds with an `ErrorResponse`.

`AuthenticationMD5Password`

The frontend must now send a `PasswordMessage` containing the password (with user name) encrypted via MD5, then encrypted again using the 4-byte random salt specified in the `AuthenticationMD5Password` message. If this is the correct password, the server responds with an `AuthenticationOk`, otherwise it responds with an `ErrorResponse`. The actual `PasswordMessage` can be computed in SQL as `concat('md5', md5(concat(md5(concat(password, username)), random-salt)))`. (Keep in mind the `md5()` function returns its result as a hex string.)

`AuthenticationSCMCredential`

This response is only possible for local Unix-domain connections on platforms that support SCM credential messages. The frontend must issue an SCM credential message and then send a sin-

gle data byte. (The contents of the data byte are uninteresting; it's only used to ensure that the server waits long enough to receive the credential message.) If the credential is acceptable, the server responds with an `AuthenticationOk`, otherwise it responds with an `ErrorResponse`. (This message type is only issued by pre-9.1 servers. It may eventually be removed from the protocol specification.)

AuthenticationGSS

The frontend must now initiate a GSSAPI negotiation. The frontend will send a `GSSResponse` message with the first part of the GSSAPI data stream in response to this. If further messages are needed, the server will respond with `AuthenticationGSSContinue`.

AuthenticationSSPI

The frontend must now initiate a SSPI negotiation. The frontend will send a `GSSResponse` with the first part of the SSPI data stream in response to this. If further messages are needed, the server will respond with `AuthenticationGSSContinue`.

AuthenticationGSSContinue

This message contains the response data from the previous step of GSSAPI or SSPI negotiation (`AuthenticationGSS`, `AuthenticationSSPI` or a previous `AuthenticationGSSContinue`). If the GSSAPI or SSPI data in this message indicates more data is needed to complete the authentication, the frontend must send that data as another `GSSResponse` message. If GSSAPI or SSPI authentication is completed by this message, the server will next send `AuthenticationOk` to indicate successful authentication or `ErrorResponse` to indicate failure.

AuthenticationSASL

The frontend must now initiate a SASL negotiation, using one of the SASL mechanisms listed in the message. The frontend will send a `SASLInitialResponse` with the name of the selected mechanism, and the first part of the SASL data stream in response to this. If further messages are needed, the server will respond with `AuthenticationSASLContinue`. See Section 52.3 for details.

AuthenticationSASLContinue

This message contains challenge data from the previous step of SASL negotiation (`AuthenticationSASL`, or a previous `AuthenticationSASLContinue`). The frontend must respond with a `SASLResponse` message.

AuthenticationSASLFinal

SASL authentication has completed with additional mechanism-specific data for the client. The server will next send `AuthenticationOk` to indicate successful authentication, or an `ErrorResponse` to indicate failure. This message is sent only if the SASL mechanism specifies additional data to be sent from server to client at completion.

NegotiateProtocolVersion

The server does not support the minor protocol version requested by the client, but does support an earlier version of the protocol; this message indicates the highest supported minor version. This message will also be sent if the client requested unsupported protocol options (i.e. beginning with `_p_q_.`) in the startup packet. This message will be followed by an `ErrorResponse` or a message indicating the success or failure of authentication.

If the frontend does not support the authentication method requested by the server, then it should immediately close the connection.

After having received `AuthenticationOk`, the frontend must wait for further messages from the server. In this phase a backend process is being started, and the frontend is just an interested bystander. It

is still possible for the startup attempt to fail (`ErrorResponse`) or the server to decline support for the requested minor protocol version (`NegotiateProtocolVersion`), but in the normal case the backend will send some `ParameterStatus` messages, `BackendKeyData`, and finally `ReadyForQuery`.

During this phase the backend will attempt to apply any additional run-time parameter settings that were given in the startup message. If successful, these values become session defaults. An error causes `ErrorResponse` and exit.

The possible messages from the backend in this phase are:

`BackendKeyData`

This message provides secret-key data that the frontend must save if it wants to be able to issue cancel requests later. The frontend should not respond to this message, but should continue listening for a `ReadyForQuery` message.

`ParameterStatus`

This message informs the frontend about the current (initial) setting of backend parameters, such as `client_encoding` or `DateStyle`. The frontend can ignore this message, or record the settings for its future use; see Section 52.2.6 for more details. The frontend should not respond to this message, but should continue listening for a `ReadyForQuery` message.

`ReadyForQuery`

Start-up is completed. The frontend can now issue commands.

`ErrorResponse`

Start-up failed. The connection is closed after sending this message.

`NoticeResponse`

A warning message has been issued. The frontend should display the message but continue listening for `ReadyForQuery` or `ErrorResponse`.

The `ReadyForQuery` message is the same one that the backend will issue after each command cycle. Depending on the coding needs of the frontend, it is reasonable to consider `ReadyForQuery` as starting a command cycle, or to consider `ReadyForQuery` as ending the start-up phase and each subsequent command cycle.

52.2.2. Simple Query

A simple query cycle is initiated by the frontend sending a `Query` message to the backend. The message includes an SQL command (or commands) expressed as a text string. The backend then sends one or more response messages depending on the contents of the query command string, and finally a `ReadyForQuery` response message. `ReadyForQuery` informs the frontend that it can safely send a new command. (It is not actually necessary for the frontend to wait for `ReadyForQuery` before issuing another command, but the frontend must then take responsibility for figuring out what happens if the earlier command fails and already-issued later commands succeed.)

The possible response messages from the backend are:

`CommandComplete`

An SQL command completed normally.

`CopyInResponse`

The backend is ready to copy data from the frontend to a table; see Section 52.2.5.

CopyOutResponse

The backend is ready to copy data from a table to the frontend; see Section 52.2.5.

RowDescription

Indicates that rows are about to be returned in response to a `SELECT`, `FETCH`, etc query. The contents of this message describe the column layout of the rows. This will be followed by a `DataRow` message for each row being returned to the frontend.

DataRow

One of the set of rows returned by a `SELECT`, `FETCH`, etc query.

EmptyQueryResponse

An empty query string was recognized.

ErrorResponse

An error has occurred.

ReadyForQuery

Processing of the query string is complete. A separate message is sent to indicate this because the query string might contain multiple SQL commands. (`CommandComplete` marks the end of processing one SQL command, not the whole string.) `ReadyForQuery` will always be sent, whether processing terminates successfully or with an error.

NoticeResponse

A warning message has been issued in relation to the query. Notices are in addition to other responses, i.e., the backend will continue processing the command.

The response to a `SELECT` query (or other queries that return row sets, such as `EXPLAIN` or `SHOW`) normally consists of `RowDescription`, zero or more `DataRow` messages, and then `CommandComplete`. `COPY` to or from the frontend invokes special protocol as described in Section 52.2.5. All other query types normally produce only a `CommandComplete` message.

Since a query string could contain several queries (separated by semicolons), there might be several such response sequences before the backend finishes processing the query string. `ReadyForQuery` is issued when the entire string has been processed and the backend is ready to accept a new query string.

If a completely empty (no contents other than whitespace) query string is received, the response is `EmptyQueryResponse` followed by `ReadyForQuery`.

In the event of an error, `ErrorResponse` is issued followed by `ReadyForQuery`. All further processing of the query string is aborted by `ErrorResponse` (even if more queries remained in it). Note that this might occur partway through the sequence of messages generated by an individual query.

In simple Query mode, the format of retrieved values is always text, except when the given command is a `FETCH` from a cursor declared with the `BINARY` option. In that case, the retrieved values are in binary format. The format codes given in the `RowDescription` message tell which format is being used.

A frontend must be prepared to accept `ErrorResponse` and `NoticeResponse` messages whenever it is expecting any other type of message. See also Section 52.2.6 concerning messages that the backend might generate due to outside events.

Recommended practice is to code frontends in a state-machine style that will accept any message type at any time that it could make sense, rather than wiring in assumptions about the exact sequence of messages.

52.2.2.1. Multiple Statements in a Simple Query

When a simple Query message contains more than one SQL statement (separated by semicolons), those statements are executed as a single transaction, unless explicit transaction control commands are included to force a different behavior. For example, if the message contains

```
INSERT INTO mytable VALUES(1);
SELECT 1/0;
INSERT INTO mytable VALUES(2);
```

then the divide-by-zero failure in the `SELECT` will force rollback of the first `INSERT`. Furthermore, because execution of the message is abandoned at the first error, the second `INSERT` is never attempted at all.

If instead the message contains

```
BEGIN;
INSERT INTO mytable VALUES(1);
COMMIT;
INSERT INTO mytable VALUES(2);
SELECT 1/0;
```

then the first `INSERT` is committed by the explicit `COMMIT` command. The second `INSERT` and the `SELECT` are still treated as a single transaction, so that the divide-by-zero failure will roll back the second `INSERT`, but not the first one.

This behavior is implemented by running the statements in a multi-statement Query message in an *implicit transaction block* unless there is some explicit transaction block for them to run in. The main difference between an implicit transaction block and a regular one is that an implicit block is closed automatically at the end of the Query message, either by an implicit commit if there was no error, or an implicit rollback if there was an error. This is similar to the implicit commit or rollback that happens for a statement executed by itself (when not in a transaction block).

If the session is already in a transaction block, as a result of a `BEGIN` in some previous message, then the Query message simply continues that transaction block, whether the message contains one statement or several. However, if the Query message contains a `COMMIT` or `ROLLBACK` closing the existing transaction block, then any following statements are executed in an implicit transaction block. Conversely, if a `BEGIN` appears in a multi-statement Query message, then it starts a regular transaction block that will only be terminated by an explicit `COMMIT` or `ROLLBACK`, whether that appears in this Query message or a later one. If the `BEGIN` follows some statements that were executed as an implicit transaction block, those statements are not immediately committed; in effect, they are retroactively included into the new regular transaction block.

A `COMMIT` or `ROLLBACK` appearing in an implicit transaction block is executed as normal, closing the implicit block; however, a warning will be issued since a `COMMIT` or `ROLLBACK` without a previous `BEGIN` might represent a mistake. If more statements follow, a new implicit transaction block will be started for them.

Savepoints are not allowed in an implicit transaction block, since they would conflict with the behavior of automatically closing the block upon any error.

Remember that, regardless of any transaction control commands that may be present, execution of the Query message stops at the first error. Thus for example given

```
BEGIN;
SELECT 1/0;
ROLLBACK;
```

in a single Query message, the session will be left inside a failed regular transaction block, since the `ROLLBACK` is not reached after the divide-by-zero error. Another `ROLLBACK` will be needed to restore the session to a usable state.

Another behavior of note is that initial lexical and syntactic analysis is done on the entire query string before any of it is executed. Thus simple errors (such as a misspelled keyword) in later statements can prevent execution of any of the statements. This is normally invisible to users since the statements would all roll back anyway when done as an implicit transaction block. However, it can be visible when attempting to do multiple transactions within a multi-statement Query. For instance, if a typo turned our previous example into

```
BEGIN;
INSERT INTO mytable VALUES(1);
COMMIT;
INSERT INTO mytable VALUES(2);
SELECT 1/0;
```

then none of the statements would get run, resulting in the visible difference that the first `INSERT` is not committed. Errors detected at semantic analysis or later, such as a misspelled table or column name, do not have this effect.

52.2.3. Extended Query

The extended query protocol breaks down the above-described simple query protocol into multiple steps. The results of preparatory steps can be re-used multiple times for improved efficiency. Furthermore, additional features are available, such as the possibility of supplying data values as separate parameters instead of having to insert them directly into a query string.

In the extended protocol, the frontend first sends a Parse message, which contains a textual query string, optionally some information about data types of parameter placeholders, and the name of a destination prepared-statement object (an empty string selects the unnamed prepared statement). The response is either `ParseComplete` or `ErrorResponse`. Parameter data types can be specified by `OID`; if not given, the parser attempts to infer the data types in the same way as it would do for untyped literal string constants.

Note

A parameter data type can be left unspecified by setting it to zero, or by making the array of parameter type `OID`s shorter than the number of parameter symbols (`$n`) used in the query string. Another special case is that a parameter's type can be specified as `void` (that is, the `OID` of the `void` pseudo-type). This is meant to allow parameter symbols to be used for function parameters that are actually `OUT` parameters. Ordinarily there is no context in which a `void` parameter could be used, but if such a parameter symbol appears in a function's parameter list, it is effectively ignored. For example, a function call such as `foo($1, $2, $3, $4)` could match a function with two `IN` and two `OUT` arguments, if `$3` and `$4` are specified as having type `void`.

Note

The query string contained in a Parse message cannot include more than one SQL statement; else a syntax error is reported. This restriction does not exist in the simple-query protocol, but it does exist in the extended protocol, because allowing prepared statements or portals to contain multiple commands would complicate the protocol unduly.

If successfully created, a named prepared-statement object lasts till the end of the current session, unless explicitly destroyed. An unnamed prepared statement lasts only until the next Parse statement specifying the unnamed statement as destination is issued. (Note that a simple Query message also destroys the unnamed statement.) Named prepared statements must be explicitly closed before they can be redefined by another Parse message, but this is not required for the unnamed statement. Named prepared statements can also be created and accessed at the SQL command level, using `PREPARE` and `EXECUTE`.

Once a prepared statement exists, it can be readied for execution using a Bind message. The Bind message gives the name of the source prepared statement (empty string denotes the unnamed prepared statement), the name of the destination portal (empty string denotes the unnamed portal), and the values to use for any parameter placeholders present in the prepared statement. The supplied parameter set must match those needed by the prepared statement. (If you declared any `void` parameters in the Parse message, pass `NULL` values for them in the Bind message.) Bind also specifies the format to use for any data returned by the query; the format can be specified overall, or per-column. The response is either `BindComplete` or `ErrorResponse`.

Note

The choice between text and binary output is determined by the format codes given in Bind, regardless of the SQL command involved. The `BINARY` attribute in cursor declarations is irrelevant when using extended query protocol.

Query planning typically occurs when the Bind message is processed. If the prepared statement has no parameters, or is executed repeatedly, the server might save the created plan and re-use it during subsequent Bind messages for the same prepared statement. However, it will do so only if it finds that a generic plan can be created that is not much less efficient than a plan that depends on the specific parameter values supplied. This happens transparently so far as the protocol is concerned.

If successfully created, a named portal object lasts till the end of the current transaction, unless explicitly destroyed. An unnamed portal is destroyed at the end of the transaction, or as soon as the next Bind statement specifying the unnamed portal as destination is issued. (Note that a simple Query message also destroys the unnamed portal.) Named portals must be explicitly closed before they can be redefined by another Bind message, but this is not required for the unnamed portal. Named portals can also be created and accessed at the SQL command level, using `DECLARE CURSOR` and `FETCH`.

Once a portal exists, it can be executed using an Execute message. The Execute message specifies the portal name (empty string denotes the unnamed portal) and a maximum result-row count (zero meaning “fetch all rows”). The result-row count is only meaningful for portals containing commands that return row sets; in other cases the command is always executed to completion, and the row count is ignored. The possible responses to Execute are the same as those described above for queries issued via simple query protocol, except that Execute doesn't cause `ReadyForQuery` or `RowDescription` to be issued.

If Execute terminates before completing the execution of a portal (due to reaching a nonzero result-row count), it will send a `PortalSuspended` message; the appearance of this message tells the frontend that another Execute should be issued against the same portal to complete the operation. The `CommandComplete` message indicating completion of the source SQL command is not sent until the portal's execution is completed. Therefore, an Execute phase is always terminated by the appearance of exactly one of these messages: `CommandComplete`, `EmptyQueryResponse` (if the portal was created from an empty query string), `ErrorResponse`, or `PortalSuspended`.

At completion of each series of extended-query messages, the frontend should issue a Sync message. This parameterless message causes the backend to close the current transaction if it's not inside a `BEGIN/COMMIT` transaction block (“close” meaning to commit if no error, or roll back if error). Then a `ReadyForQuery` response is issued. The purpose of Sync is to provide a resynchronization point for error recovery. When an error is detected while processing any extended-query message, the

backend issues `ErrorResponse`, then reads and discards messages until a `Sync` is reached, then issues `ReadyForQuery` and returns to normal message processing. (But note that no skipping occurs if an error is detected *while* processing `Sync` — this ensures that there is one and only one `ReadyForQuery` sent for each `Sync`.)

Note

`Sync` does not cause a transaction block opened with `BEGIN` to be closed. It is possible to detect this situation since the `ReadyForQuery` message includes transaction status information.

In addition to these fundamental, required operations, there are several optional operations that can be used with extended-query protocol.

The `Describe` message (portal variant) specifies the name of an existing portal (or an empty string for the unnamed portal). The response is a `RowDescription` message describing the rows that will be returned by executing the portal; or a `NoData` message if the portal does not contain a query that will return rows; or `ErrorResponse` if there is no such portal.

The `Describe` message (statement variant) specifies the name of an existing prepared statement (or an empty string for the unnamed prepared statement). The response is a `ParameterDescription` message describing the parameters needed by the statement, followed by a `RowDescription` message describing the rows that will be returned when the statement is eventually executed (or a `NoData` message if the statement will not return rows). `ErrorResponse` is issued if there is no such prepared statement. Note that since `Bind` has not yet been issued, the formats to be used for returned columns are not yet known to the backend; the format code fields in the `RowDescription` message will be zeroes in this case.

Tip

In most scenarios the frontend should issue one or the other variant of `Describe` before issuing `Execute`, to ensure that it knows how to interpret the results it will get back.

The `Close` message closes an existing prepared statement or portal and releases resources. It is not an error to issue `Close` against a nonexistent statement or portal name. The response is normally `CloseComplete`, but could be `ErrorResponse` if some difficulty is encountered while releasing resources. Note that closing a prepared statement implicitly closes any open portals that were constructed from that statement.

The `Flush` message does not cause any specific output to be generated, but forces the backend to deliver any data pending in its output buffers. A `Flush` must be sent after any extended-query command except `Sync`, if the frontend wishes to examine the results of that command before issuing more commands. Without `Flush`, messages returned by the backend will be combined into the minimum possible number of packets to minimize network overhead.

Note

The simple `Query` message is approximately equivalent to the series `Parse`, `Bind`, portal `Describe`, `Execute`, `Close`, `Sync`, using the unnamed prepared statement and portal objects and no parameters. One difference is that it will accept multiple SQL statements in the query string, automatically performing the bind/describe/execute sequence for each one in succession. Another difference is that it will not return `ParseComplete`, `BindComplete`, `CloseComplete`, or `NoData` messages.

52.2.4. Function Call

The Function Call sub-protocol allows the client to request a direct call of any function that exists in the database's `pg_proc` system catalog. The client must have execute permission for the function.

Note

The Function Call sub-protocol is a legacy feature that is probably best avoided in new code. Similar results can be accomplished by setting up a prepared statement that does `SELECT function($1, ...)`. The Function Call cycle can then be replaced with Bind/Execute.

A Function Call cycle is initiated by the frontend sending a `FunctionCall` message to the backend. The backend then sends one or more response messages depending on the results of the function call, and finally a `ReadyForQuery` response message. `ReadyForQuery` informs the frontend that it can safely send a new query or function call.

The possible response messages from the backend are:

ErrorResponse

An error has occurred.

FunctionCallResponse

The function call was completed and returned the result given in the message. (Note that the Function Call protocol can only handle a single scalar result, not a row type or set of results.)

ReadyForQuery

Processing of the function call is complete. `ReadyForQuery` will always be sent, whether processing terminates successfully or with an error.

NoticeResponse

A warning message has been issued in relation to the function call. Notices are in addition to other responses, i.e., the backend will continue processing the command.

52.2.5. COPY Operations

The `COPY` command allows high-speed bulk data transfer to or from the server. Copy-in and copy-out operations each switch the connection into a distinct sub-protocol, which lasts until the operation is completed.

Copy-in mode (data transfer to the server) is initiated when the backend executes a `COPY FROM STDIN SQL` statement. The backend sends a `CopyInResponse` message to the frontend. The frontend should then send zero or more `CopyData` messages, forming a stream of input data. (The message boundaries are not required to have anything to do with row boundaries, although that is often a reasonable choice.) The frontend can terminate the copy-in mode by sending either a `CopyDone` message (allowing successful termination) or a `CopyFail` message (which will cause the `COPY SQL` statement to fail with an error). The backend then reverts to the command-processing mode it was in before the `COPY` started, which will be either simple or extended query protocol. It will next send either `CommandComplete` (if successful) or `ErrorResponse` (if not).

In the event of a backend-detected error during copy-in mode (including receipt of a `CopyFail` message), the backend will issue an `ErrorResponse` message. If the `COPY` command was issued via an extended-query message, the backend will now discard frontend messages until a `Sync` message is received, then it will issue `ReadyForQuery` and return to normal processing. If the `COPY` command was

issued in a simple Query message, the rest of that message is discarded and ReadyForQuery is issued. In either case, any subsequent CopyData, CopyDone, or CopyFail messages issued by the frontend will simply be dropped.

The backend will ignore Flush and Sync messages received during copy-in mode. Receipt of any other non-copy message type constitutes an error that will abort the copy-in state as described above. (The exception for Flush and Sync is for the convenience of client libraries that always send Flush or Sync after an Execute message, without checking whether the command to be executed is a `COPY FROM STDIN`.)

Copy-out mode (data transfer from the server) is initiated when the backend executes a `COPY TO STDOUT SQL` statement. The backend sends a CopyOutResponse message to the frontend, followed by zero or more CopyData messages (always one per row), followed by CopyDone. The backend then reverts to the command-processing mode it was in before the `COPY` started, and sends CommandComplete. The frontend cannot abort the transfer (except by closing the connection or issuing a Cancel request), but it can discard unwanted CopyData and CopyDone messages.

In the event of a backend-detected error during copy-out mode, the backend will issue an ErrorResponse message and revert to normal processing. The frontend should treat receipt of ErrorResponse as terminating the copy-out mode.

It is possible for NoticeResponse and ParameterStatus messages to be interspersed between CopyData messages; frontends must handle these cases, and should be prepared for other asynchronous message types as well (see Section 52.2.6). Otherwise, any message type other than CopyData or CopyDone may be treated as terminating copy-out mode.

There is another Copy-related mode called copy-both, which allows high-speed bulk data transfer to *and* from the server. Copy-both mode is initiated when a backend in walsender mode executes a `START_REPLICATION` statement. The backend sends a CopyBothResponse message to the frontend. Both the backend and the frontend may then send CopyData messages until either end sends a CopyDone message. After the client sends a CopyDone message, the connection goes from copy-both mode to copy-out mode, and the client may not send any more CopyData messages. Similarly, when the server sends a CopyDone message, the connection goes into copy-in mode, and the server may not send any more CopyData messages. After both sides have sent a CopyDone message, the copy mode is terminated, and the backend reverts to the command-processing mode. In the event of a backend-detected error during copy-both mode, the backend will issue an ErrorResponse message, discard frontend messages until a Sync message is received, and then issue ReadyForQuery and return to normal processing. The frontend should treat receipt of ErrorResponse as terminating the copy in both directions; no CopyDone should be sent in this case. See Section 52.4 for more information on the subprotocol transmitted over copy-both mode.

The CopyInResponse, CopyOutResponse and CopyBothResponse messages include fields that inform the frontend of the number of columns per row and the format codes being used for each column. (As of the present implementation, all columns in a given `COPY` operation will use the same format, but the message design does not assume this.)

52.2.6. Asynchronous Operations

There are several cases in which the backend will send messages that are not specifically prompted by the frontend's command stream. Frontends must be prepared to deal with these messages at any time, even when not engaged in a query. At minimum, one should check for these cases before beginning to read a query response.

It is possible for NoticeResponse messages to be generated due to outside activity; for example, if the database administrator commands a “fast” database shutdown, the backend will send a NoticeResponse indicating this fact before closing the connection. Accordingly, frontends should always be prepared to accept and display NoticeResponse messages, even when the connection is nominally idle.

ParameterStatus messages will be generated whenever the active value changes for any of the parameters the backend believes the frontend should know about. Most commonly this occurs in response to a

SET SQL command executed by the frontend, and this case is effectively synchronous — but it is also possible for parameter status changes to occur because the administrator changed a configuration file and then sent the SIGHUP signal to the server. Also, if a SET command is rolled back, an appropriate ParameterStatus message will be generated to report the current effective value.

At present there is a hard-wired set of parameters for which ParameterStatus will be generated: they are `server_version`, `server_encoding`, `client_encoding`, `application_name`, `is_superuser`, `session_authorization`, `DateStyle`, `IntervalStyle`, `TimeZone`, `integer_datetimes`, and `standard_conforming_strings`. (`server_encoding`, `TimeZone`, and `integer_datetimes` were not reported by releases before 8.0; `standard_conforming_strings` was not reported by releases before 8.1; `IntervalStyle` was not reported by releases before 8.4; `application_name` was not reported by releases before 9.0.) Note that `server_version`, `server_encoding` and `integer_datetimes` are pseudo-parameters that cannot change after startup. This set might change in the future, or even become configurable. Accordingly, a frontend should simply ignore ParameterStatus for parameters that it does not understand or care about.

If a frontend issues a LISTEN command, then the backend will send a NotificationResponse message (not to be confused with NoticeResponse!) whenever a NOTIFY command is executed for the same channel name.

Note

At present, NotificationResponse can only be sent outside a transaction, and thus it will not occur in the middle of a command-response series, though it might occur just before ReadyForQuery. It is unwise to design frontend logic that assumes that, however. Good practice is to be able to accept NotificationResponse at any point in the protocol.

52.2.7. Canceling Requests in Progress

During the processing of a query, the frontend might request cancellation of the query. The cancel request is not sent directly on the open connection to the backend for reasons of implementation efficiency: we don't want to have the backend constantly checking for new input from the frontend during query processing. Cancel requests should be relatively infrequent, so we make them slightly cumbersome in order to avoid a penalty in the normal case.

To issue a cancel request, the frontend opens a new connection to the server and sends a CancelRequest message, rather than the StartupMessage message that would ordinarily be sent across a new connection. The server will process this request and then close the connection. For security reasons, no direct reply is made to the cancel request message.

A CancelRequest message will be ignored unless it contains the same key data (PID and secret key) passed to the frontend during connection start-up. If the request matches the PID and secret key for a currently executing backend, the processing of the current query is aborted. (In the existing implementation, this is done by sending a special signal to the backend process that is processing the query.)

The cancellation signal might or might not have any effect — for example, if it arrives after the backend has finished processing the query, then it will have no effect. If the cancellation is effective, it results in the current command being terminated early with an error message.

The upshot of all this is that for reasons of both security and efficiency, the frontend has no direct way to tell whether a cancel request has succeeded. It must continue to wait for the backend to respond to the query. Issuing a cancel simply improves the odds that the current query will finish soon, and improves the odds that it will fail with an error message instead of succeeding.

Since the cancel request is sent across a new connection to the server and not across the regular frontend/backend communication link, it is possible for the cancel request to be issued by any process,

not just the frontend whose query is to be canceled. This might provide additional flexibility when building multiple-process applications. It also introduces a security risk, in that unauthorized persons might try to cancel queries. The security risk is addressed by requiring a dynamically generated secret key to be supplied in cancel requests.

52.2.8. Termination

The normal, graceful termination procedure is that the frontend sends a `Terminate` message and immediately closes the connection. On receipt of this message, the backend closes the connection and terminates.

In rare cases (such as an administrator-commanded database shutdown) the backend might disconnect without any frontend request to do so. In such cases the backend will attempt to send an error or notice message giving the reason for the disconnection before it closes the connection.

Other termination scenarios arise from various failure cases, such as core dump at one end or the other, loss of the communications link, loss of message-boundary synchronization, etc. If either frontend or backend sees an unexpected closure of the connection, it should clean up and terminate. The frontend has the option of launching a new backend by recontacting the server if it doesn't want to terminate itself. Closing the connection is also advisable if an unrecognizable message type is received, since this probably indicates loss of message-boundary sync.

For either normal or abnormal termination, any open transaction is rolled back, not committed. One should note however that if a frontend disconnects while a non-`SELECT` query is being processed, the backend will probably finish the query before noticing the disconnection. If the query is outside any transaction block (`BEGIN ... COMMIT` sequence) then its results might be committed before the disconnection is recognized.

52.2.9. SSL Session Encryption

If PostgreSQL was built with SSL support, frontend/backend communications can be encrypted using SSL. This provides communication security in environments where attackers might be able to capture the session traffic. For more information on encrypting PostgreSQL sessions with SSL, see Section 18.9.

To initiate an SSL-encrypted connection, the frontend initially sends an `SSLRequest` message rather than a `StartupMessage`. The server then responds with a single byte containing `S` or `N`, indicating that it is willing or unwilling to perform SSL, respectively. The frontend might close the connection at this point if it is dissatisfied with the response. To continue after `S`, perform an SSL startup handshake (not described here, part of the SSL specification) with the server. If this is successful, continue with sending the usual `StartupMessage`. In this case the `StartupMessage` and all subsequent data will be SSL-encrypted. To continue after `N`, send the usual `StartupMessage` and proceed without encryption.

The frontend should also be prepared to handle an `ErrorMessage` response to `SSLRequest` from the server. This would only occur if the server predates the addition of SSL support to PostgreSQL. (Such servers are now very ancient, and likely do not exist in the wild anymore.) In this case the connection must be closed, but the frontend might choose to open a fresh connection and proceed without requesting SSL.

An initial `SSLRequest` can also be used in a connection that is being opened to send a `CancelRequest` message.

While the protocol itself does not provide a way for the server to force SSL encryption, the administrator can configure the server to reject unencrypted sessions as a byproduct of authentication checking.

52.2.10. GSSAPI Session Encryption

If PostgreSQL was built with GSSAPI support, frontend/backend communications can be encrypted using GSSAPI. This provides communication security in environments where attackers might be able

to capture the session traffic. For more information on encrypting PostgreSQL sessions with GSSAPI, see Section 18.10.

To initiate a GSSAPI-encrypted connection, the frontend initially sends a `GSSENCRequest` message rather than a `StartupMessage`. The server then responds with a single byte containing `G` or `N`, indicating that it is willing or unwilling to perform GSSAPI encryption, respectively. The frontend might close the connection at this point if it is dissatisfied with the response. To continue after `G`, using the GSSAPI C bindings as discussed in RFC2744 or equivalent, perform a GSSAPI initialization by calling `gss_init_sec_context()` in a loop and sending the result to the server, starting with an empty input and then with each result from the server, until it returns no output. When sending the results of `gss_init_sec_context()` to the server, prepend the length of the message as a four byte integer in network byte order. If this is successful, then use `gss_wrap()` to encrypt the usual `StartupMessage` and all subsequent data, prepending the length of the result from `gss_wrap()` as a four byte integer in network byte order to the actual encrypted payload. Note that the server will only accept encrypted packets from the client which are less than 16kB; `gss_wrap_size_limit()` should be used by the client to determine the size of the unencrypted message which will fit within this limit and larger messages should be broken up into multiple `gss_wrap()` calls. Typical segments are 8kB of unencrypted data, resulting in encrypted packets of slightly larger than 8kB but well within the 16kB maximum. The server can be expected to not send encrypted packets of larger than 16kB to the client. To continue after `N`, send the usual `StartupMessage` and proceed without encryption.

The frontend should also be prepared to handle an `ErrorMessage` response to `GSSENCRequest` from the server. This would only occur if the server predates the addition of GSSAPI encryption support to PostgreSQL. In this case the connection must be closed, but the frontend might choose to open a fresh connection and proceed without requesting GSSAPI encryption. Given the length limits specified above, the `ErrorMessage` can not be confused with a proper response from the server with an appropriate length.

An initial `GSSENCRequest` can also be used in a connection that is being opened to send a `CancelRequest` message.

While the protocol itself does not provide a way for the server to force GSSAPI encryption, the administrator can configure the server to reject unencrypted sessions as a byproduct of authentication checking.

52.3. SASL Authentication

SASL is a framework for authentication in connection-oriented protocols. At the moment, PostgreSQL implements two SASL authentication mechanisms, SCRAM-SHA-256 and SCRAM-SHA-256-PLUS. More might be added in the future. The below steps illustrate how SASL authentication is performed in general, while the next subsection gives more details on SCRAM-SHA-256 and SCRAM-SHA-256-PLUS.

SASL Authentication Message Flow

1. To begin a SASL authentication exchange, the server sends an `AuthenticationSASL` message. It includes a list of SASL authentication mechanisms that the server can accept, in the server's preferred order.
2. The client selects one of the supported mechanisms from the list, and sends a `SASLInitialResponse` message to the server. The message includes the name of the selected mechanism, and an optional `Initial Client Response`, if the selected mechanism uses that.
3. One or more server-challenge and client-response message will follow. Each server-challenge is sent in an `AuthenticationSASLContinue` message, followed by a response from client in an `SASLResponse` message. The particulars of the messages are mechanism specific.
4. Finally, when the authentication exchange is completed successfully, the server sends an `AuthenticationSASLFinal` message, followed immediately by an `AuthenticationOk` message. The

AuthenticationSASLFinal contains additional server-to-client data, whose content is particular to the selected authentication mechanism. If the authentication mechanism doesn't use additional data that's sent at completion, the AuthenticationSASLFinal message is not sent.

On error, the server can abort the authentication at any stage, and send an ErrorMessage.

52.3.1. SCRAM-SHA-256 Authentication

The implemented SASL mechanisms at the moment are SCRAM-SHA-256 and its variant with channel binding SCRAM-SHA-256-PLUS. They are described in detail in RFC 7677 and RFC 5802.

When SCRAM-SHA-256 is used in PostgreSQL, the server will ignore the user name that the client sends in the `client-first-message`. The user name that was already sent in the startup message is used instead. PostgreSQL supports multiple character encodings, while SCRAM dictates UTF-8 to be used for the user name, so it might be impossible to represent the PostgreSQL user name in UTF-8.

The SCRAM specification dictates that the password is also in UTF-8, and is processed with the SASLprep algorithm. PostgreSQL, however, does not require UTF-8 to be used for the password. When a user's password is set, it is processed with SASLprep as if it was in UTF-8, regardless of the actual encoding used. However, if it is not a legal UTF-8 byte sequence, or it contains UTF-8 byte sequences that are prohibited by the SASLprep algorithm, the raw password will be used without SASLprep processing, instead of throwing an error. This allows the password to be normalized when it is in UTF-8, but still allows a non-UTF-8 password to be used, and doesn't require the system to know which encoding the password is in.

Channel binding is supported in PostgreSQL builds with SSL support. The SASL mechanism name for SCRAM with channel binding is SCRAM-SHA-256-PLUS. The channel binding type used by PostgreSQL is `tls-server-end-point`.

In SCRAM without channel binding, the server chooses a random number that is transmitted to the client to be mixed with the user-supplied password in the transmitted password hash. While this prevents the password hash from being successfully retransmitted in a later session, it does not prevent a fake server between the real server and client from passing through the server's random value and successfully authenticating.

SCRAM with channel binding prevents such man-in-the-middle attacks by mixing the signature of the server's certificate into the transmitted password hash. While a fake server can retransmit the real server's certificate, it doesn't have access to the private key matching that certificate, and therefore cannot prove it is the owner, causing SSL connection failure.

Example

1. The server sends an AuthenticationSASL message. It includes a list of SASL authentication mechanisms that the server can accept. This will be SCRAM-SHA-256-PLUS and SCRAM-SHA-256 if the server is built with SSL support, or else just the latter.
2. The client responds by sending a SASLInitialResponse message, which indicates the chosen mechanism, SCRAM-SHA-256 or SCRAM-SHA-256-PLUS. (A client is free to choose either mechanism, but for better security it should choose the channel-binding variant if it can support it.) In the Initial Client response field, the message contains the SCRAM `client-first-message`. The `client-first-message` also contains the channel binding type chosen by the client.
3. Server sends an AuthenticationSASLContinue message, with a SCRAM `server-first-message` as the content.
4. Client sends a SASLResponse message, with SCRAM `client-final-message` as the content.

5. Server sends an `AuthenticationSASLFinal` message, with the `SCRAM server-final-message`, followed immediately by an `AuthenticationOk` message.

52.4. Streaming Replication Protocol

To initiate streaming replication, the frontend sends the `replication` parameter in the startup message. A Boolean value of `true` (or `on`, `yes`, `1`) tells the backend to go into physical replication `walsender` mode, wherein a small set of replication commands, shown below, can be issued instead of SQL statements.

Passing `database` as the value for the `replication` parameter instructs the backend to go into logical replication `walsender` mode, connecting to the database specified in the `dbname` parameter. In logical replication `walsender` mode, the replication commands shown below as well as normal SQL commands can be issued.

In either physical replication or logical replication `walsender` mode, only the simple query protocol can be used.

For the purpose of testing replication commands, you can make a replication connection via `psql` or any other `libpq`-using tool with a connection string including the `replication` option, e.g.:

```
psql "dbname=postgres replication=database" -c "IDENTIFY_SYSTEM;"
```

However, it is often more useful to use `pg_receivewal` (for physical replication) or `pg_recvlogical` (for logical replication).

Replication commands are logged in the server log when `log_replication_commands` is enabled.

The commands accepted in replication mode are:

`IDENTIFY_SYSTEM`

Requests the server to identify itself. Server replies with a result set of a single row, containing four fields:

`systemid` (text)

The unique system identifier identifying the cluster. This can be used to check that the base backup used to initialize the standby came from the same cluster.

`timeline` (int4)

Current timeline ID. Also useful to check that the standby is consistent with the master.

`xlogpos` (text)

Current WAL flush location. Useful to get a known location in the write-ahead log where streaming can start.

`dbname` (text)

Database connected to or null.

`SHOW name`

Requests the server to send the current setting of a run-time parameter. This is similar to the SQL command `SHOW`.

name

The name of a run-time parameter. Available parameters are documented in Chapter 19.

`TIMELINE_HISTORY tli`

Requests the server to send over the timeline history file for timeline *tli*. Server replies with a result set of a single row, containing two fields:

`filename (text)`

File name of the timeline history file, e.g., `00000002.history`.

`content (bytea)`

Contents of the timeline history file.

```
CREATE_REPLICATION_SLOT slot_name [ TEMPORARY ] { PHYSICAL [ RESERVE_WAL ] |  
LOGICAL output_plugin [ EXPORT_SNAPSHOT | NOEXPORT_SNAPSHOT | USE_SNAPSHOT  
] }
```

Create a physical or logical replication slot. See Section 26.2.6 for more about replication slots.

`slot_name`

The name of the slot to create. Must be a valid replication slot name (see Section 26.2.6.1).

`output_plugin`

The name of the output plugin used for logical decoding (see Section 48.6).

`TEMPORARY`

Specify that this replication slot is a temporary one. Temporary slots are not saved to disk and are automatically dropped on error or when the session has finished.

`RESERVE_WAL`

Specify that this physical replication slot reserves WAL immediately. Otherwise, WAL is only reserved upon connection from a streaming replication client.

`EXPORT_SNAPSHOT`

`NOEXPORT_SNAPSHOT`

`USE_SNAPSHOT`

Decides what to do with the snapshot created during logical slot initialization. `EXPORT_SNAPSHOT`, which is the default, will export the snapshot for use in other sessions. This option can't be used inside a transaction. `USE_SNAPSHOT` will use the snapshot for the current transaction executing the command. This option must be used in a transaction, and `CREATE_REPLICATION_SLOT` must be the first command run in that transaction. Finally, `NOEXPORT_SNAPSHOT` will just use the snapshot for logical decoding as normal but won't do anything else with it.

In response to this command, the server will send a one-row result set containing the following fields:

`slot_name (text)`

The name of the newly-created replication slot.

`consistent_point (text)`

The WAL location at which the slot became consistent. This is the earliest location from which streaming can start on this replication slot.

snapshot_name (text)

The identifier of the snapshot exported by the command. The snapshot is valid until a new command is executed on this connection or the replication connection is closed. Null if the created slot is physical.

output_plugin (text)

The name of the output plugin used by the newly-created replication slot. Null if the created slot is physical.

START_REPLICATION [SLOT *slot_name*] [PHYSICAL] XXX/XXX [TIMELINE *tli*]

Instructs server to start streaming WAL, starting at WAL location XXX/XXX. If TIMELINE option is specified, streaming starts on timeline *tli*; otherwise, the server's current timeline is selected. The server can reply with an error, for example if the requested section of WAL has already been recycled. On success, server responds with a CopyBothResponse message, and then starts to stream WAL to the frontend.

If a slot's name is provided via *slot_name*, it will be updated as replication progresses so that the server knows which WAL segments, and if *hot_standby_feedback* is on which transactions, are still needed by the standby.

If the client requests a timeline that's not the latest but is part of the history of the server, the server will stream all the WAL on that timeline starting from the requested start point up to the point where the server switched to another timeline. If the client requests streaming at exactly the end of an old timeline, the server responds immediately with CommandComplete without entering COPY mode.

After streaming all the WAL on a timeline that is not the latest one, the server will end streaming by exiting the COPY mode. When the client acknowledges this by also exiting COPY mode, the server sends a result set with one row and two columns, indicating the next timeline in this server's history. The first column is the next timeline's ID (type `int8`), and the second column is the WAL location where the switch happened (type `text`). Usually, the switch position is the end of the WAL that was streamed, but there are corner cases where the server can send some WAL from the old timeline that it has not itself replayed before promoting. Finally, the server sends CommandComplete message, and is ready to accept a new command.

WAL data is sent as a series of CopyData messages. (This allows other information to be intermixed; in particular the server can send an ErrorResponse message if it encounters a failure after beginning to stream.) The payload of each CopyData message from server to the client contains a message of one of the following formats:

XLogData (B)

Byte1('w')

Identifies the message as WAL data.

Int64

The starting point of the WAL data in this message.

Int64

The current end of WAL on the server.

Int64

The server's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byten

A section of the WAL data stream.

A single WAL record is never split across two XLogData messages. When a WAL record crosses a WAL page boundary, and is therefore already split using continuation records, it can be split at the page boundary. In other words, the first main WAL record and its continuation records can be sent in different XLogData messages.

Primary keepalive message (B)

Byte1('k')

Identifies the message as a sender keepalive.

Int64

The current end of WAL on the server.

Int64

The server's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte1

1 means that the client should reply to this message as soon as possible, to avoid a timeout disconnect. 0 otherwise.

The receiving process can send replies back to the sender at any time, using one of the following message formats (also in the payload of a CopyData message):

Standby status update (F)

Byte1('r')

Identifies the message as a receiver status update.

Int64

The location of the last WAL byte + 1 received and written to disk in the standby.

Int64

The location of the last WAL byte + 1 flushed to disk in the standby.

Int64

The location of the last WAL byte + 1 applied in the standby.

Int64

The client's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte1

If 1, the client requests the server to reply to this message immediately. This can be used to ping the server, to test if the connection is still healthy.

Hot Standby feedback message (F)

Byte1('h')

Identifies the message as a Hot Standby feedback message.

Int64

The client's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Int32

The standby's current global xmin, excluding the catalog_xmin from any replication slots. If both this value and the following catalog_xmin are 0 this is treated as a notification that Hot Standby feedback will no longer be sent on this connection. Later non-zero messages may reinitiate the feedback mechanism.

Int32

The epoch of the global xmin xid on the standby.

Int32

The lowest catalog_xmin of any replication slots on the standby. Set to 0 if no catalog_xmin exists on the standby or if hot standby feedback is being disabled.

Int32

The epoch of the catalog_xmin xid on the standby.

```
START_REPLICATION SLOT slot_name LOGICAL XXX/XXX [ ( option_name [ option_value ] [, ...] ) ]
```

Instructs server to start streaming WAL for logical replication, starting at WAL location XXX/XXX. The server can reply with an error, for example if the requested section of WAL has already been recycled. On success, server responds with a CopyBothResponse message, and then starts to stream WAL to the frontend.

The messages inside the CopyBothResponse messages are of the same format documented for START_REPLICATION ... PHYSICAL.

The output plugin associated with the selected slot is used to process the output for streaming.

SLOT *slot_name*

The name of the slot to stream changes from. This parameter is required, and must correspond to an existing logical replication slot created with CREATE_REPLICATION_SLOT in LOGICAL mode.

XXX/XXX

The WAL location to begin streaming at.

option_name

The name of an option passed to the slot's logical decoding plugin.

option_value

Optional value, in the form of a string constant, associated with the specified option.

```
DROP_REPLICATION_SLOT slot_name [ WAIT ]
```

Drops a replication slot, freeing any reserved server-side resources. If the slot is a logical slot that was created in a database other than the database the walsender is connected to, this command fails.

slot_name

The name of the slot to drop.

WAIT

This option causes the command to wait if the slot is active until it becomes inactive, instead of the default behavior of raising an error.

```
BASE_BACKUP [ LABEL 'label' ] [ PROGRESS ] [ FAST ] [ WAL ] [ NOWAIT ] [ MAX_RATE  
rate ] [ TABLESPACE_MAP ] [ NOVERIFY_CHECKSUMS ]
```

Instructs the server to start streaming a base backup. The system will automatically be put in backup mode before the backup is started, and taken out of it when the backup is complete. The following options are accepted:

LABEL 'label'

Sets the label of the backup. If none is specified, a backup label of `base backup` will be used. The quoting rules for the label are the same as a standard SQL string with `standard_conforming_strings` turned on.

PROGRESS

Request information required to generate a progress report. This will send back an approximate size in the header of each tablespace, which can be used to calculate how far along the stream is done. This is calculated by enumerating all the file sizes once before the transfer is even started, and might as such have a negative impact on the performance. In particular, it might take longer before the first data is streamed. Since the database files can change during the backup, the size is only approximate and might both grow and shrink between the time of approximation and the sending of the actual files.

FAST

Request a fast checkpoint.

WAL

Include the necessary WAL segments in the backup. This will include all the files between start and stop backup in the `pg_wal` directory of the base directory tar file.

NOWAIT

By default, the backup will wait until the last required WAL segment has been archived, or emit a warning if log archiving is not enabled. Specifying `NOWAIT` disables both the waiting and the warning, leaving the client responsible for ensuring the required log is available.

MAX_RATE rate

Limit (throttle) the maximum amount of data transferred from server to client per unit of time. The expected unit is kilobytes per second. If this option is specified, the value must either be equal to zero or it must fall within the range from 32 kB through 1 GB (inclusive). If zero is passed or the option is not specified, no restriction is imposed on the transfer.

TABLESPACE_MAP

Include information about symbolic links present in the directory `pg_tblspc` in a file named `tablespace_map`. The tablespace map file includes each symbolic link name as it exists in the directory `pg_tblspc/` and the full path of that symbolic link.

NOVERIFY_CHECKSUMS

By default, checksums are verified during a base backup if they are enabled. Specifying `NOVERIFY_CHECKSUMS` disables this verification.

When the backup is started, the server will first send two ordinary result sets, followed by one or more CopyResponse results.

The first ordinary result set contains the starting position of the backup, in a single row with two columns. The first column contains the start position given in XLogRecPtr format, and the second column contains the corresponding timeline ID.

The second ordinary result set has one row for each tablespace. The fields in this row are:

`spcoid (oid)`

The OID of the tablespace, or null if it's the base directory.

`spcllocation (text)`

The full path of the tablespace directory, or null if it's the base directory.

`size (int8)`

The approximate size of the tablespace, if progress report has been requested; otherwise it's null.

After the second regular result set, one or more CopyResponse results will be sent, one for the main data directory and one for each additional tablespace other than `pg_default` and `pg_global`. The data in the CopyResponse results will be a tar format (following the “ustar interchange format” specified in the POSIX 1003.1-2008 standard) dump of the tablespace contents, except that the two trailing blocks of zeroes specified in the standard are omitted. After the tar data is complete, a final ordinary result set will be sent, containing the WAL end position of the backup, in the same format as the start position.

The tar archive for the data directory and each tablespace will contain all files in the directories, regardless of whether they are PostgreSQL files or other files added to the same directory. The only excluded files are:

- `postmaster.pid`
- `postmaster.opts`
- `pg_internal.init` (found in multiple directories)
- Various temporary files and directories created during the operation of the PostgreSQL server, such as any file or directory beginning with `pgsql_tmp` and temporary relations.
- Unlogged relations, except for the init fork which is required to recreate the (empty) unlogged relation on recovery.
- `pg_wal`, including subdirectories. If the backup is run with WAL files included, a synthesized version of `pg_wal` will be included, but it will only contain the files necessary for the backup to work, not the rest of the contents.
- `pg_dynshmem`, `pg_notify`, `pg_replslot`, `pg_serial`, `pg_snapshots`, `pg_stat_tmp`, and `pg_subtrans` are copied as empty directories (even if they are symbolic links).
- Files other than regular files and directories, such as symbolic links (other than for the directories listed above) and special device files, are skipped. (Symbolic links in `pg_tblspc` are maintained.)

Owner, group, and file mode are set if the underlying file system on the server supports it.

52.5. Logical Streaming Replication Protocol

This section describes the logical replication protocol, which is the message flow started by the `START_REPLICATION SLOT slot_name LOGICAL` replication command.

The logical streaming replication protocol builds on the primitives of the physical streaming replication protocol.

52.5.1. Logical Streaming Replication Parameters

The logical replication `START_REPLICATION` command accepts following parameters:

`proto_version`

Protocol version. Currently only version 1 is supported.

`publication_names`

Comma separated list of publication names for which to subscribe (receive changes). The individual publication names are treated as standard objects names and can be quoted the same as needed.

52.5.2. Logical Replication Protocol Messages

The individual protocol messages are discussed in the following subsections. Individual messages are described in Section 52.9.

All top-level protocol messages begin with a message type byte. While represented in code as a character, this is a signed byte with no associated encoding.

Since the streaming replication protocol supplies a message length there is no need for top-level protocol messages to embed a length in their header.

52.5.3. Logical Replication Protocol Message Flow

With the exception of the `START_REPLICATION` command and the replay progress messages, all information flows only from the backend to the frontend.

The logical replication protocol sends individual transactions one by one. This means that all messages between a pair of Begin and Commit messages belong to the same transaction.

Every sent transaction contains zero or more DML messages (Insert, Update, Delete). In case of a cascaded setup it can also contain Origin messages. The origin message indicated that the transaction originated on different replication node. Since a replication node in the scope of logical replication protocol can be pretty much anything, the only identifier is the origin name. It's downstream's responsibility to handle this as needed (if needed). The Origin message is always sent before any DML messages in the transaction.

Every DML message contains an arbitrary relation ID, which can be mapped to an ID in the Relation messages. The Relation messages describe the schema of the given relation. The Relation message is sent for a given relation either because it is the first time we send a DML message for given relation in the current session or because the relation definition has changed since the last Relation message was sent for it. The protocol assumes that the client is capable of caching the metadata for as many relations as needed.

52.6. Message Data Types

This section describes the base data types used in messages.

`Intn(i)`

An n -bit integer in network byte order (most significant byte first). If i is specified it is the exact value that will appear, otherwise the value is variable. Eg. `Int16`, `Int32(42)`.

`Intn[k]`

An array of k n -bit integers, each in network byte order. The array length k is always determined by an earlier field in the message. Eg. `Int16[M]`.

String(*s*)

A null-terminated string (C-style string). There is no specific length limitation on strings. If *s* is specified it is the exact value that will appear, otherwise the value is variable. Eg. String, String("user").

Note

There is no predefined limit on the length of a string that can be returned by the backend. Good coding strategy for a frontend is to use an expandable buffer so that anything that fits in memory can be accepted. If that's not feasible, read the full string and discard trailing characters that don't fit into your fixed-size buffer.

Byte(*n*)

Exactly *n* bytes. If the field width *n* is not a constant, it is always determinable from an earlier field in the message. If *c* is specified it is the exact value. Eg. Byte2, Byte1('\n').

52.7. Message Formats

This section describes the detailed format of each message. Each is marked to indicate that it can be sent by a frontend (F), a backend (B), or both (F & B). Notice that although each message includes a byte count at the beginning, the message format is defined so that the message end can be found without reference to the byte count. This aids validity checking. (The CopyData message is an exception, because it forms part of a data stream; the contents of any individual CopyData message cannot be interpretable on their own.)

AuthenticationOk (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(0)

Specifies that the authentication was successful.

AuthenticationKerberosV5 (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(2)

Specifies that Kerberos V5 authentication is required.

AuthenticationCleartextPassword (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(3)

Specifies that a clear-text password is required.

AuthenticationMD5Password (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(12)

Length of message contents in bytes, including self.

Int32(5)

Specifies that an MD5-encrypted password is required.

Byte4

The salt to use when encrypting the password.

AuthenticationSCMCredential (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(6)

Specifies that an SCM credentials message is required.

AuthenticationGSS (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(7)

Specifies that GSSAPI authentication is required.

AuthenticationSSPI (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(9)

Specifies that SSPI authentication is required.

AuthenticationGSSContinue (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(8)

Specifies that this message contains GSSAPI or SSPI data.

Byten

GSSAPI or SSPI authentication data.

AuthenticationSASL (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(10)

Specifies that SASL authentication is required.

The message body is a list of SASL authentication mechanisms, in the server's order of preference. A zero byte is required as terminator after the last authentication mechanism name. For each mechanism, there is the following:

String

Name of a SASL authentication mechanism.

AuthenticationSASLContinue (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(11)

Specifies that this message contains a SASL challenge.

Byten

SASL data, specific to the SASL mechanism being used.

AuthenticationSASLFinal (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(12)

Specifies that SASL authentication has completed.

Byten

SASL outcome "additional data", specific to the SASL mechanism being used.

BackendKeyData (B)

Byte1('K')

Identifies the message as cancellation key data. The frontend must save these values if it wishes to be able to issue CancelRequest messages later.

Int32(12)

Length of message contents in bytes, including self.

Int32

The process ID of this backend.

Int32

The secret key of this backend.

Bind (F)

Byte1('B')

Identifies the message as a Bind command.

Int32

Length of message contents in bytes, including self.

String

The name of the destination portal (an empty string selects the unnamed portal).

String

The name of the source prepared statement (an empty string selects the unnamed prepared statement).

Int16

The number of parameter format codes that follow (denoted *C* below). This can be zero to indicate that there are no parameters or that the parameters all use the default format (*text*); or one, in which case the specified format code is applied to all parameters; or it can equal the actual number of parameters.

Int16[C]

The parameter format codes. Each must presently be zero (text) or one (binary).

Int16

The number of parameter values that follow (possibly zero). This must match the number of parameters needed by the query.

Next, the following pair of fields appear for each parameter:

Int32

The length of the parameter value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL parameter value. No value bytes follow in the NULL case.

Byten

The value of the parameter, in the format indicated by the associated format code. *n* is the above length.

After the last parameter, the following fields appear:

Int16

The number of result-column format codes that follow (denoted *R* below). This can be zero to indicate that there are no result columns or that the result columns should all use the default format (text); or one, in which case the specified format code is applied to all result columns (if any); or it can equal the actual number of result columns of the query.

Int16[R]

The result-column format codes. Each must presently be zero (text) or one (binary).

BindComplete (B)

Byte1('2')

Identifies the message as a Bind-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CancelRequest (F)

Int32(16)

Length of message contents in bytes, including self.

Int32(80877102)

The cancel request code. The value is chosen to contain 1234 in the most significant 16 bits, and 5678 in the least significant 16 bits. (To avoid confusion, this code must not be the same as any protocol version number.)

Int32

The process ID of the target backend.

Int32

The secret key for the target backend.

Close (F)

Byte1('C')

Identifies the message as a Close command.

Int32

Length of message contents in bytes, including self.

Byte1

'S' to close a prepared statement; or 'P' to close a portal.

String

The name of the prepared statement or portal to close (an empty string selects the unnamed prepared statement or portal).

CloseComplete (B)

Byte1('3')

Identifies the message as a Close-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CommandComplete (B)

Byte1('C')

Identifies the message as a command-completed response.

Int32

Length of message contents in bytes, including self.

String

The command tag. This is usually a single word that identifies which SQL command was completed.

For an INSERT command, the tag is INSERT *oid rows*, where *rows* is the number of rows inserted. *oid* used to be the object ID of the inserted row if *rows* was 1 and the target table had OIDs, but OIDs system columns are not supported anymore; therefore *oid* is always 0.

For a DELETE command, the tag is DELETE *rows* where *rows* is the number of rows deleted.

For an UPDATE command, the tag is UPDATE *rows* where *rows* is the number of rows updated.

For a SELECT or CREATE TABLE AS command, the tag is SELECT *rows* where *rows* is the number of rows retrieved.

For a MOVE command, the tag is MOVE *rows* where *rows* is the number of rows the cursor's position has been changed by.

For a FETCH command, the tag is FETCH *rows* where *rows* is the number of rows that have been retrieved from the cursor.

For a COPY command, the tag is COPY *rows* where *rows* is the number of rows copied. (Note: the row count appears only in PostgreSQL 8.2 and later.)

CopyData (F & B)

Byte1('d')

Identifies the message as COPY data.

Int32

Length of message contents in bytes, including self.

Byten

Data that forms part of a COPY data stream. Messages sent from the backend will always correspond to single data rows, but messages sent by frontends might divide the data stream arbitrarily.

CopyDone (F & B)

Byte1('c')

Identifies the message as a COPY-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CopyFail (F)

Byte1('f')

Identifies the message as a COPY-failure indicator.

Int32

Length of message contents in bytes, including self.

String

An error message to report as the cause of failure.

CopyInResponse (B)

Byte1('G')

Identifies the message as a Start Copy In response. The frontend must now send copy-in data (if not prepared to do so, send a CopyFail message).

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

CopyOutResponse (B)

Byte1('H')

Identifies the message as a Start Copy Out response. This message will be followed by copy-out data.

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

CopyBothResponse (B)

Byte1('W')

Identifies the message as a Start Copy Both response. This message is used only for Streaming Replication.

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

DataRow (B)

Byte1('D')

Identifies the message as a data row.

Int32

Length of message contents in bytes, including self.

Int16

The number of column values that follow (possibly zero).

Next, the following pair of fields appear for each column:

Int32

The length of the column value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL column value. No value bytes follow in the NULL case.

Byte n

The value of the column, in the format indicated by the associated format code. n is the above length.

Describe (F)

Byte1('D')

Identifies the message as a Describe command.

Int32

Length of message contents in bytes, including self.

Byte1

'S' to describe a prepared statement; or 'P' to describe a portal.

String

The name of the prepared statement or portal to describe (an empty string selects the unnamed prepared statement or portal).

EmptyQueryResponse (B)

Byte1('I')

Identifies the message as a response to an empty query string. (This substitutes for CommandComplete.)

Int32(4)

Length of message contents in bytes, including self.

ErrorResponse (B)

Byte1('E')

Identifies the message as an error.

Int32

Length of message contents in bytes, including self.

The message body consists of one or more identified fields, followed by a zero byte as a terminator. Fields can appear in any order. For each field there is the following:

Byte1

A code identifying the field type; if zero, this is the message terminator and no string follows. The presently defined field types are listed in Section 52.8. Since more field types might be added in future, frontends should silently ignore fields of unrecognized type.

String

The field value.

Execute (F)

Byte1('E')

Identifies the message as an Execute command.

Int32

Length of message contents in bytes, including self.

String

The name of the portal to execute (an empty string selects the unnamed portal).

Int32

Maximum number of rows to return, if portal contains a query that returns rows (ignored otherwise). Zero denotes “no limit”.

Flush (F)

Byte1('H')

Identifies the message as a Flush command.

Int32(4)

Length of message contents in bytes, including self.

FunctionCall (F)

Byte1('F')

Identifies the message as a function call.

Int32

Length of message contents in bytes, including self.

Int32

Specifies the object ID of the function to call.

Int16

The number of argument format codes that follow (denoted *C* below). This can be zero to indicate that there are no arguments or that the arguments all use the default format (text); or one, in which case the specified format code is applied to all arguments; or it can equal the actual number of arguments.

Int16[*C*]

The argument format codes. Each must presently be zero (text) or one (binary).

Int16

Specifies the number of arguments being supplied to the function.

Next, the following pair of fields appear for each argument:

Int32

The length of the argument value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL argument value. No value bytes follow in the NULL case.

Byten

The value of the argument, in the format indicated by the associated format code. *n* is the above length.

After the last argument, the following field appears:

Int16

The format code for the function result. Must presently be zero (text) or one (binary).

FunctionCallResponse (B)

Byte1('V')

Identifies the message as a function call result.

Int32

Length of message contents in bytes, including self.

Int32

The length of the function result value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL function result. No value bytes follow in the NULL case.

Byten

The value of the function result, in the format indicated by the associated format code. *n* is the above length.

GSSResponse (F)

Byte1('p')

Identifies the message as a GSSAPI or SSPI response. Note that this is also used for SASL and password response messages. The exact message type can be deduced from the context.

Int32

Length of message contents in bytes, including self.

Byten

GSSAPI/SSPI specific message data.

NegotiateProtocolVersion (B)

Byte1('v')

Identifies the message as a protocol version negotiation message.

Int32

Length of message contents in bytes, including self.

Int32

Newest minor protocol version supported by the server for the major protocol version requested by the client.

Int32

Number of protocol options not recognized by the server.

Then, for protocol option not recognized by the server, there is the following:

String

The option name.

NoData (B)

Byte1('n')

Identifies the message as a no-data indicator.

Int32(4)

Length of message contents in bytes, including self.

NoticeResponse (B)

Byte1('N')

Identifies the message as a notice.

Int32

Length of message contents in bytes, including self.

The message body consists of one or more identified fields, followed by a zero byte as a terminator. Fields can appear in any order. For each field there is the following:

Byte1

A code identifying the field type; if zero, this is the message terminator and no string follows. The presently defined field types are listed in Section 52.8. Since more field types might be added in future, frontends should silently ignore fields of unrecognized type.

String

The field value.

NotificationResponse (B)

Byte1('A')

Identifies the message as a notification response.

Int32

Length of message contents in bytes, including self.

Int32

The process ID of the notifying backend process.

String

The name of the channel that the notify has been raised on.

String

The “payload” string passed from the notifying process.

ParameterDescription (B)

Byte1('t')

Identifies the message as a parameter description.

Int32

Length of message contents in bytes, including self.

Int16

The number of parameters used by the statement (can be zero).

Then, for each parameter, there is the following:

Int32

Specifies the object ID of the parameter data type.

ParameterStatus (B)

Byte1('S')

Identifies the message as a run-time parameter status report.

Int32

Length of message contents in bytes, including self.

String

The name of the run-time parameter being reported.

String

The current value of the parameter.

Parse (F)

Byte1('P')

Identifies the message as a Parse command.

Int32

Length of message contents in bytes, including self.

String

The name of the destination prepared statement (an empty string selects the unnamed prepared statement).

String

The query string to be parsed.

Int16

The number of parameter data types specified (can be zero). Note that this is not an indication of the number of parameters that might appear in the query string, only the number that the frontend wants to prespecify types for.

Then, for each parameter, there is the following:

Int32

Specifies the object ID of the parameter data type. Placing a zero here is equivalent to leaving the type unspecified.

ParseComplete (B)

Byte1('1')

Identifies the message as a Parse-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

PasswordMessage (F)

Byte1('p')

Identifies the message as a password response. Note that this is also used for GSSAPI, SSPI and SASL response messages. The exact message type can be deduced from the context.

Int32

Length of message contents in bytes, including self.

String

The password (encrypted, if requested).

PortalSuspended (B)

Byte1('s')

Identifies the message as a portal-suspended indicator. Note this only appears if an Execute message's row-count limit was reached.

Int32(4)

Length of message contents in bytes, including self.

Query (F)

Byte1('Q')

Identifies the message as a simple query.

Int32

Length of message contents in bytes, including self.

String

The query string itself.

ReadyForQuery (B)

Byte1('Z')

Identifies the message type. ReadyForQuery is sent whenever the backend is ready for a new query cycle.

Int32(5)

Length of message contents in bytes, including self.

Byte1

Current backend transaction status indicator. Possible values are 'I' if idle (not in a transaction block); 'T' if in a transaction block; or 'E' if in a failed transaction block (queries will be rejected until block is ended).

RowDescription (B)

Byte1('T')

Identifies the message as a row description.

Int32

Length of message contents in bytes, including self.

Int16

Specifies the number of fields in a row (can be zero).

Then, for each field, there is the following:

String

The field name.

Int32

If the field can be identified as a column of a specific table, the object ID of the table; otherwise zero.

Int16

If the field can be identified as a column of a specific table, the attribute number of the column; otherwise zero.

Int32

The object ID of the field's data type.

Int16

The data type size (see `pg_type.typelen`). Note that negative values denote variable-width types.

Int32

The type modifier (see `pg_attribute.atttypmod`). The meaning of the modifier is type-specific.

Int16

The format code being used for the field. Currently will be zero (text) or one (binary). In a RowDescription returned from the statement variant of Describe, the format code is not yet known and will always be zero.

SASLInitialResponse (F)

Byte1('p')

Identifies the message as an initial SASL response. Note that this is also used for GSSAPI, SSPI and password response messages. The exact message type is deduced from the context.

Int32

Length of message contents in bytes, including self.

String

Name of the SASL authentication mechanism that the client selected.

Int32

Length of SASL mechanism specific "Initial Client Response" that follows, or -1 if there is no Initial Response.

Byten

SASL mechanism specific "Initial Response".

SASLResponse (F)

Byte1('p')

Identifies the message as a SASL response. Note that this is also used for GSSAPI, SSPI and password response messages. The exact message type can be deduced from the context.

Int32

Length of message contents in bytes, including self.

Byten

SASL mechanism specific message data.

SSLRequest (F)

Int32(8)

Length of message contents in bytes, including self.

Int32(80877103)

The SSL request code. The value is chosen to contain 1234 in the most significant 16 bits, and 5679 in the least significant 16 bits. (To avoid confusion, this code must not be the same as any protocol version number.)

GSSENCRequest (F)

Int32(8)

Length of message contents in bytes, including self.

Int32(80877104)

The GSSAPI Encryption request code. The value is chosen to contain 1234 in the most significant 16 bits, and 5680 in the least significant 16 bits. (To avoid confusion, this code must not be the same as any protocol version number.)

StartupMessage (F)

Int32

Length of message contents in bytes, including self.

Int32(196608)

The protocol version number. The most significant 16 bits are the major version number (3 for the protocol described here). The least significant 16 bits are the minor version number (0 for the protocol described here).

The protocol version number is followed by one or more pairs of parameter name and value strings. A zero byte is required as a terminator after the last name/value pair. Parameters can appear in any order. `user` is required, others are optional. Each parameter is specified as:

String

The parameter name. Currently recognized names are:

`user`

The database user name to connect as. Required; there is no default.

`database`

The database to connect to. Defaults to the user name.

`options`

Command-line arguments for the backend. (This is deprecated in favor of setting individual run-time parameters.) Spaces within this string are considered to separate arguments, unless escaped with a backslash (`\`); write `\\` to represent a literal backslash.

`replication`

Used to connect in streaming replication mode, where a small set of replication commands can be issued instead of SQL statements. Value can be `true`, `false`, or `database`, and the default is `false`. See Section 52.4 for details.

In addition to the above, other parameters may be listed. Parameter names beginning with `_pq_` are reserved for use as protocol extensions, while others are treated as run-time parameters to be set at backend start time. Such settings will be applied during backend start (after parsing the command-line arguments if any) and will act as session defaults.

String

The parameter value.

Sync (F)

Byte1('S')

Identifies the message as a Sync command.

Int32(4)

Length of message contents in bytes, including self.

Terminate (F)

Byte1('X')

Identifies the message as a termination.

Int32(4)

Length of message contents in bytes, including self.

52.8. Error and Notice Message Fields

This section describes the fields that can appear in `ErrorResponse` and `NoticeResponse` messages. Each field type has a single-byte identification token. Note that any given field type should appear at most once per message.

S

Severity: the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message), or a localized translation of one of these. Always present.

V

Severity: the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message). This is identical to the S field except that the contents are never localized. This is present only in messages generated by PostgreSQL versions 9.6 and later.

C

Code: the `SQLSTATE` code for the error (see Appendix A). Not localizable. Always present.

M

Message: the primary human-readable error message. This should be accurate but terse (typically one line). Always present.

D

Detail: an optional secondary error message carrying more detail about the problem. Might run to multiple lines.

H

Hint: an optional suggestion what to do about the problem. This is intended to differ from Detail in that it offers advice (potentially inappropriate) rather than hard facts. Might run to multiple lines.

P

Position: the field value is a decimal ASCII integer, indicating an error cursor position as an index into the original query string. The first character has index 1, and positions are measured in characters not bytes.

P

Internal position: this is defined the same as the P field, but it is used when the cursor position refers to an internally generated command rather than the one submitted by the client. The `q` field will always appear when this field appears.

q

Internal query: the text of a failed internally-generated command. This could be, for example, a SQL query issued by a PL/pgSQL function.

W

Where: an indication of the context in which the error occurred. Presently this includes a call stack traceback of active procedural language functions and internally-generated queries. The trace is one entry per line, most recent first.

s

Schema name: if the error was associated with a specific database object, the name of the schema containing that object, if any.

t

Table name: if the error was associated with a specific table, the name of the table. (Refer to the schema name field for the name of the table's schema.)

c

Column name: if the error was associated with a specific table column, the name of the column. (Refer to the schema and table name fields to identify the table.)

d

Data type name: if the error was associated with a specific data type, the name of the data type. (Refer to the schema name field for the name of the data type's schema.)

n

Constraint name: if the error was associated with a specific constraint, the name of the constraint. Refer to fields listed above for the associated table or domain. (For this purpose, indexes are treated as constraints, even if they weren't created with constraint syntax.)

F

File: the file name of the source-code location where the error was reported.

L

Line: the line number of the source-code location where the error was reported.

R

Routine: the name of the source-code routine reporting the error.

Note

The fields for schema name, table name, column name, data type name, and constraint name are supplied only for a limited number of error types; see Appendix A. Frontends should not assume that the presence of any of these fields guarantees the presence of another field. Core error sources observe the interrelationships noted above, but user-defined functions may use these fields in other ways. In the same vein, clients should not assume that these fields denote contemporary objects in the current database.

The client is responsible for formatting displayed information to meet its needs; in particular it should break long lines as needed. Newline characters appearing in the error message fields should be treated as paragraph breaks, not line breaks.

52.9. Logical Replication Message Formats

This section describes the detailed format of each logical replication message. These messages are returned either by the replication slot SQL interface or are sent by a walsender. In case of a walsender they are encapsulated inside the replication protocol WAL messages as described in Section 52.4 and generally obey same message flow as physical replication.

Begin

Byte1('B')

Identifies the message as a begin message.

Int64

The final LSN of the transaction.

Int64

Commit timestamp of the transaction. The value is in number of microseconds since PostgreSQL epoch (2000-01-01).

Int32

Xid of the transaction.

Commit

Byte1('C')

Identifies the message as a commit message.

Int8

Flags; currently unused (must be 0).

Int64

The LSN of the commit.

Int64

The end LSN of the transaction.

Int64

Commit timestamp of the transaction. The value is in number of microseconds since PostgreSQL epoch (2000-01-01).

Origin

Byte1('O')

Identifies the message as an origin message.

Int64

The LSN of the commit on the origin server.

String

Name of the origin.

Note that there can be multiple Origin messages inside a single transaction.

Relation

Byte1('R')

Identifies the message as a relation message.

Int32

ID of the relation.

String

Namespace (empty string for `pg_catalog`).

String

Relation name.

Int8

Replica identity setting for the relation (same as `relreplident` in `pg_class`).

Int16

Number of columns.

Next, the following message part appears for each column (except generated columns):

Int8

Flags for the column. Currently can be either 0 for no flags or 1 which marks the column as part of the key.

String

Name of the column.

Int32

ID of the column's data type.

Int32

Type modifier of the column (`atttypmod`).

Type

Byte1('Y')

Identifies the message as a type message.

Int32

ID of the data type.

String

Namespace (empty string for `pg_catalog`).

String

Name of the data type.

Insert

Byte1('I')

Identifies the message as an insert message.

Int32

ID of the relation corresponding to the ID in the relation message.

Byte1('N')

Identifies the following TupleData message as a new tuple.

TupleData

TupleData message part representing the contents of new tuple.

Update

Byte1('U')

Identifies the message as an update message.

Int32

ID of the relation corresponding to the ID in the relation message.

Byte1('K')

Identifies the following TupleData submessage as a key. This field is optional and is only present if the update changed data in any of the column(s) that are part of the REPLICATION IDENTITY index.

Byte1('O')

Identifies the following TupleData submessage as an old tuple. This field is optional and is only present if table in which the update happened has REPLICATION IDENTITY set to FULL.

TupleData

TupleData message part representing the contents of the old tuple or primary key. Only present if the previous 'O' or 'K' part is present.

Byte1('N')

Identifies the following TupleData message as a new tuple.

TupleData

TupleData message part representing the contents of a new tuple.

The Update message may contain either a 'K' message part or an 'O' message part or neither of them, but never both of them.

Delete

Byte1('D')

Identifies the message as a delete message.

Int32

ID of the relation corresponding to the ID in the relation message.

Byte1('K')

Identifies the following TupleData submessage as a key. This field is present if the table in which the delete has happened uses an index as REPLICATION IDENTITY.

Byte1('O')

Identifies the following TupleData message as a old tuple. This field is present if the table in which the delete has happened has REPLICATION IDENTITY set to FULL.

TupleData

TupleData message part representing the contents of the old tuple or primary key, depending on the previous field.

The Delete message may contain either a 'K' message part or an 'O' message part, but never both of them.

Truncate

Byte1('T')

Identifies the message as a truncate message.

Int32

Number of relations

Int8

Option bits for TRUNCATE: 1 for CASCADE, 2 for RESTART IDENTITY

Int32

ID of the relation corresponding to the ID in the relation message. This field is repeated for each relation.

The following message parts are shared by the above messages.

TupleData

Int16

Number of columns.

Next, one of the following submessages appears for each column (except generated columns):

Byte1('n')

Identifies the data as NULL value.

Or

Byte1('u')

Identifies unchanged TOASTed value (the actual value is not sent).

Or

Byte1('t')

Identifies the data as text formatted value.

Int32

Length of the column value.

Byten

The value of the column, in text format. (A future release might support additional formats.)
n is the above length.

52.10. Summary of Changes since Protocol 2.0

This section provides a quick checklist of changes, for the benefit of developers trying to update existing client libraries to protocol 3.0.

The initial startup packet uses a flexible list-of-strings format instead of a fixed format. Notice that session default values for run-time parameters can now be specified directly in the startup packet. (Actually, you could do that before using the `options` field, but given the limited width of `options` and the lack of any way to quote whitespace in the values, it wasn't a very safe technique.)

All messages now have a length count immediately following the message type byte (except for startup packets, which have no type byte). Also note that `PasswordMessage` now has a type byte.

`ErrorResponse` and `NoticeResponse` ('E' and 'N') messages now contain multiple fields, from which the client code can assemble an error message of the desired level of verbosity. Note that individual fields will typically not end with a newline, whereas the single string sent in the older protocol always did.

The `ReadyForQuery` ('Z') message includes a transaction status indicator.

The distinction between `BinaryRow` and `DataRow` message types is gone; the single `DataRow` message type serves for returning data in all formats. Note that the layout of `DataRow` has changed to make it easier to parse. Also, the representation of binary values has changed: it is no longer directly tied to the server's internal representation.

There is a new “extended query” sub-protocol, which adds the frontend message types `Parse`, `Bind`, `Execute`, `Describe`, `Close`, `Flush`, and `Sync`, and the backend message types `ParseComplete`, `BindComplete`, `PortalSuspended`, `ParameterDescription`, `NoData`, and `CloseComplete`. Existing clients do not have to concern themselves with this sub-protocol, but making use of it might allow improvements in performance or functionality.

`COPY` data is now encapsulated into `CopyData` and `CopyDone` messages. There is a well-defined way to recover from errors during `COPY`. The special “\.” last line is not needed anymore, and is not sent during `COPY OUT`. (It is still recognized as a terminator during `COPY IN`, but its use is deprecated and will eventually be removed.) Binary `COPY` is supported. The `CopyInResponse` and `CopyOutResponse` messages include fields indicating the number of columns and the format of each column.

The layout of `FunctionCall` and `FunctionCallResponse` messages has changed. `FunctionCall` can now support passing `NULL` arguments to functions. It also can handle passing parameters and retrieving results in either text or binary format. There is no longer any reason to consider `FunctionCall` a potential security hole, since it does not offer direct access to internal server data representations.

The backend sends `ParameterStatus` ('S') messages during connection startup for all parameters it considers interesting to the client library. Subsequently, a `ParameterStatus` message is sent whenever the active value changes for any of these parameters.

The `RowDescription` ('T') message carries new table OID and column number fields for each column of the described row. It also shows the format code for each column.

The `CursorResponse` ('P') message is no longer generated by the backend.

The NotificationResponse ('A') message has an additional string field, which can carry a “payload” string passed from the NOTIFY event sender.

The EmptyQueryResponse ('I') message used to include an empty string parameter; this has been removed.

Chapter 53. PostgreSQL Coding Conventions

53.1. Formatting

Source code formatting uses 4 column tab spacing, with tabs preserved (i.e., tabs are not expanded to spaces). Each logical indentation level is one additional tab stop.

Layout rules (brace positioning, etc) follow BSD conventions. In particular, curly braces for the controlled blocks of `if`, `while`, `switch`, etc go on their own lines.

Limit line lengths so that the code is readable in an 80-column window. (This doesn't mean that you must never go past 80 columns. For instance, breaking a long error message string in arbitrary places just to keep the code within 80 columns is probably not a net gain in readability.)

To maintain a consistent coding style, do not use C++ style comments (`//` comments). `pgindent` will replace them with `/* ... */`.

The preferred style for multi-line comment blocks is

```
/*
 * comment text begins here
 * and continues here
 */
```

Note that comment blocks that begin in column 1 will be preserved as-is by `pgindent`, but it will reflow indented comment blocks as though they were plain text. If you want to preserve the line breaks in an indented block, add dashes like this:

```
/*-----
 * comment text begins here
 * and continues here
 *-----
 */
```

While submitted patches do not absolutely have to follow these formatting rules, it's a good idea to do so. Your code will get run through `pgindent` before the next release, so there's no point in making it look nice under some other set of formatting conventions. A good rule of thumb for patches is "make the new code look like the existing code around it".

The `src/tools` directory contains sample settings files that can be used with the `emacs`, `xemacs` or `vim` editors to help ensure that they format code according to these conventions.

The text browsing tools `more` and `less` can be invoked as:

```
more -x4
less -x4
```

to make them show tabs appropriately.

53.2. Reporting Errors Within the Server

Error, warning, and log messages generated within the server code should be created using `ereport`, or its older cousin `eelog`. The use of this function is complex enough to require some explanation.

There are two required elements for every message: a severity level (ranging from `DEBUG` to `PANIC`) and a primary message text. In addition there are optional elements, the most common of which is an error identifier code that follows the SQL spec's `SQLSTATE` conventions. `ereport` itself is just a shell function, that exists mainly for the syntactic convenience of making message generation look like a function call in the C source code. The only parameter accepted directly by `ereport` is the severity level. The primary message text and any optional message elements are generated by calling auxiliary functions, such as `errmsg`, within the `ereport` call.

A typical call to `ereport` might look like this:

```
ereport (ERROR,
        (errcode(ERRCODE_DIVISION_BY_ZERO),
         errmsg("division by zero")));
```

This specifies error severity level `ERROR` (a run-of-the-mill error). The `errcode` call specifies the `SQLSTATE` error code using a macro defined in `src/include/utils/errcodes.h`. The `errmsg` call provides the primary message text. Notice the extra set of parentheses surrounding the auxiliary function calls — these are annoying but syntactically necessary.

Here is a more complex example:

```
ereport (ERROR,
        (errcode(ERRCODE_AMBIGUOUS_FUNCTION),
         errmsg("function %s is not unique",
              func_signature_string(funcname, nargs,
                                   NIL, actual_arg_types)),
         errhint("Unable to choose a best candidate function. "
                "You might need to add explicit typecasts.")));
```

This illustrates the use of format codes to embed run-time values into a message text. Also, an optional “hint” message is provided.

If the severity level is `ERROR` or higher, `ereport` aborts the execution of the user-defined function and does not return to the caller. If the severity level is lower than `ERROR`, `ereport` returns normally.

The available auxiliary routines for `ereport` are:

- `errcode(sqlerrcode)` specifies the `SQLSTATE` error identifier code for the condition. If this routine is not called, the error identifier defaults to `ERRCODE_INTERNAL_ERROR` when the error severity level is `ERROR` or higher, `ERRCODE_WARNING` when the error level is `WARNING`, otherwise (for `NOTICE` and below) `ERRCODE_SUCCESSFUL_COMPLETION`. While these defaults are often convenient, always think whether they are appropriate before omitting the `errcode()` call.
- `errmsg(const char *msg, ...)` specifies the primary error message text, and possibly run-time values to insert into it. Insertions are specified by `sprintf`-style format codes. In addition to the standard format codes accepted by `sprintf`, the format code `%m` can be used to insert the error message returned by `strerror` for the current value of `errno`.¹ `%m` does not require any corresponding entry in the parameter list for `errmsg`. Note that the message string will be run through `gettext` for possible localization before format codes are processed.
- `errmsg_internal(const char *msg, ...)` is the same as `errmsg`, except that the message string will not be translated nor included in the internationalization message dictionary.

¹ That is, the value that was current when the `ereport` call was reached; changes of `errno` within the auxiliary reporting routines will not affect it. That would not be true if you were to write `strerror(errno)` explicitly in `errmsg`'s parameter list; accordingly, do not do so.

This should be used for “cannot happen” cases that are probably not worth expending translation effort on.

- `errmsg_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errmsg`, but with support for various plural forms of the message. *fmt_singular* is the English singular format, *fmt_plural* is the English plural format, *n* is the integer value that determines which plural form is needed, and the remaining arguments are formatted according to the selected format string. For more information see Section 54.2.2.
- `errdetail(const char *msg, ...)` supplies an optional “detail” message; this is to be used when there is additional information that seems inappropriate to put in the primary message. The message string is processed in just the same way as for `errmsg`.
- `errdetail_internal(const char *msg, ...)` is the same as `errdetail`, except that the message string will not be translated nor included in the internationalization message dictionary. This should be used for detail messages that are not worth expending translation effort on, for instance because they are too technical to be useful to most users.
- `errdetail_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errdetail`, but with support for various plural forms of the message. For more information see Section 54.2.2.
- `errdetail_log(const char *msg, ...)` is the same as `errdetail` except that this string goes only to the server log, never to the client. If both `errdetail` (or one of its equivalents above) and `errdetail_log` are used then one string goes to the client and the other to the log. This is useful for error details that are too security-sensitive or too bulky to include in the report sent to the client.
- `errdetail_log_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errdetail_log`, but with support for various plural forms of the message. For more information see Section 54.2.2.
- `errhint(const char *msg, ...)` supplies an optional “hint” message; this is to be used when offering suggestions about how to fix the problem, as opposed to factual details about what went wrong. The message string is processed in just the same way as for `errmsg`.
- `errcontext(const char *msg, ...)` is not normally called directly from an `ereport` message site; rather it is used in `error_context_stack` callback functions to provide information about the context in which an error occurred, such as the current location in a PL function. The message string is processed in just the same way as for `errmsg`. Unlike the other auxiliary functions, this can be called more than once per `ereport` call; the successive strings thus supplied are concatenated with separating newlines.
- `errposition(int cursorpos)` specifies the textual location of an error within a query string. Currently it is only useful for errors detected in the lexical and syntactic analysis phases of query processing.
- `errtable(Relation rel)` specifies a relation whose name and schema name should be included as auxiliary fields in the error report.
- `errtablecol(Relation rel, int attnum)` specifies a column whose name, table name, and schema name should be included as auxiliary fields in the error report.
- `errtableconstraint(Relation rel, const char *conname)` specifies a table constraint whose name, table name, and schema name should be included as auxiliary fields in the error report. Indexes should be considered to be constraints for this purpose, whether or not they have an associated `pg_constraint` entry. Be careful to pass the underlying heap relation, not the index itself, as `rel`.
- `errdatatype(Oid datatypeOid)` specifies a data type whose name and schema name should be included as auxiliary fields in the error report.

- `errdomainconstraint(Oid datatypeOid, const char *conname)` specifies a domain constraint whose name, domain name, and schema name should be included as auxiliary fields in the error report.
- `errcode_for_file_access()` is a convenience function that selects an appropriate `SQLSTATE` error identifier for a failure in a file-access-related system call. It uses the saved `errno` to determine which error code to generate. Usually this should be used in combination with `%m` in the primary error message text.
- `errcode_for_socket_access()` is a convenience function that selects an appropriate `SQLSTATE` error identifier for a failure in a socket-related system call.
- `errhidestmt(bool hide_stmt)` can be called to specify suppression of the `STATEMENT:` portion of a message in the postmaster log. Generally this is appropriate if the message text includes the current statement already.
- `errhidecontext(bool hide_ctx)` can be called to specify suppression of the `CONTEXT:` portion of a message in the postmaster log. This should only be used for verbose debugging messages where the repeated inclusion of context would bloat the log volume too much.

Note

At most one of the functions `errtable`, `errtablecol`, `errtableconstraint`, `errdatatype`, or `errdomainconstraint` should be used in an `ereport` call. These functions exist to allow applications to extract the name of a database object associated with the error condition without having to examine the potentially-localized error message text. These functions should be used in error reports for which it's likely that applications would wish to have automatic error handling. As of PostgreSQL 9.3, complete coverage exists only for errors in `SQLSTATE` class 23 (integrity constraint violation), but this is likely to be expanded in future.

There is an older function `elog` that is still heavily used. An `elog` call:

```
elog(level, "format string", ...);
```

is exactly equivalent to:

```
ereport(level, (errmsg_internal("format string", ...)));
```

Notice that the `SQLSTATE` error code is always defaulted, and the message string is not subject to translation. Therefore, `elog` should be used only for internal errors and low-level debug logging. Any message that is likely to be of interest to ordinary users should go through `ereport`. Nonetheless, there are enough internal “cannot happen” error checks in the system that `elog` is still widely used; it is preferred for those messages for its notational simplicity.

Advice about writing good error messages can be found in Section 53.3.

53.3. Error Message Style Guide

This style guide is offered in the hope of maintaining a consistent, user-friendly style throughout all the messages generated by PostgreSQL.

What Goes Where

The primary message should be short, factual, and avoid reference to implementation details such as specific function names. “Short” means “should fit on one line under normal conditions”. Use a detail

message if needed to keep the primary message short, or if you feel a need to mention implementation details such as the particular system call that failed. Both primary and detail messages should be factual. Use a hint message for suggestions about what to do to fix the problem, especially if the suggestion might not always be applicable.

For example, instead of:

```
IpMemoryCreate: shmget(key=%d, size=%u, 0%o) failed: %m  
(plus a long addendum that is basically a hint)
```

write:

```
Primary:    could not create shared memory segment: %m  
Detail:    Failed syscall was shmget(key=%d, size=%u, 0%o).  
Hint:      the addendum
```

Rationale: keeping the primary message short helps keep it to the point, and lets clients lay out screen space on the assumption that one line is enough for error messages. Detail and hint messages can be relegated to a verbose mode, or perhaps a pop-up error-details window. Also, details and hints would normally be suppressed from the server log to save space. Reference to implementation details is best avoided since users aren't expected to know the details.

Formatting

Don't put any specific assumptions about formatting into the message texts. Expect clients and the server log to wrap lines to fit their own needs. In long messages, newline characters (`\n`) can be used to indicate suggested paragraph breaks. Don't end a message with a newline. Don't use tabs or other formatting characters. (In error context displays, newlines are automatically added to separate levels of context such as function calls.)

Rationale: Messages are not necessarily displayed on terminal-type displays. In GUI displays or browsers these formatting instructions are at best ignored.

Quotation Marks

English text should use double quotes when quoting is appropriate. Text in other languages should consistently use one kind of quotes that is consistent with publishing customs and computer output of other programs.

Rationale: The choice of double quotes over single quotes is somewhat arbitrary, but tends to be the preferred use. Some have suggested choosing the kind of quotes depending on the type of object according to SQL conventions (namely, strings single quoted, identifiers double quoted). But this is a language-internal technical issue that many users aren't even familiar with, it won't scale to other kinds of quoted terms, it doesn't translate to other languages, and it's pretty pointless, too.

Use of Quotes

Use quotes always to delimit file names, user-supplied identifiers, and other variables that might contain words. Do not use them to mark up variables that will not contain words (for example, operator names).

There are functions in the backend that will double-quote their own output at need (for example, `format_type_be()`). Do not put additional quotes around the output of such functions.

Rationale: Objects can have names that create ambiguity when embedded in a message. Be consistent about denoting where a plugged-in name starts and ends. But don't clutter messages with unnecessary or duplicate quote marks.

Grammar and Punctuation

The rules are different for primary error messages and for detail/hint messages:

Primary error messages: Do not capitalize the first letter. Do not end a message with a period. Do not even think about ending a message with an exclamation point.

Detail and hint messages: Use complete sentences, and end each with a period. Capitalize the first word of sentences. Put two spaces after the period if another sentence follows (for English text; might be inappropriate in other languages).

Error context strings: Do not capitalize the first letter and do not end the string with a period. Context strings should normally not be complete sentences.

Rationale: Avoiding punctuation makes it easier for client applications to embed the message into a variety of grammatical contexts. Often, primary messages are not grammatically complete sentences anyway. (And if they're long enough to be more than one sentence, they should be split into primary and detail parts.) However, detail and hint messages are longer and might need to include multiple sentences. For consistency, they should follow complete-sentence style even when there's only one sentence.

Upper Case vs. Lower Case

Use lower case for message wording, including the first letter of a primary error message. Use upper case for SQL commands and key words if they appear in the message.

Rationale: It's easier to make everything look more consistent this way, since some messages are complete sentences and some not.

Avoid Passive Voice

Use the active voice. Use complete sentences when there is an acting subject (“A could not do B”). Use telegram style without subject if the subject would be the program itself; do not use “I” for the program.

Rationale: The program is not human. Don't pretend otherwise.

Present vs. Past Tense

Use past tense if an attempt to do something failed, but could perhaps succeed next time (perhaps after fixing some problem). Use present tense if the failure is certainly permanent.

There is a nontrivial semantic difference between sentences of the form:

```
could not open file "%s": %m
```

and:

```
cannot open file "%s"
```

The first one means that the attempt to open the file failed. The message should give a reason, such as “disk full” or “file doesn't exist”. The past tense is appropriate because next time the disk might not be full anymore or the file in question might exist.

The second form indicates that the functionality of opening the named file does not exist at all in the program, or that it's conceptually impossible. The present tense is appropriate because the condition will persist indefinitely.

Rationale: Granted, the average user will not be able to draw great conclusions merely from the tense of the message, but since the language provides us with a grammar we should use it correctly.

Type of the Object

When citing the name of an object, state what kind of object it is.

Rationale: Otherwise no one will know what “foo.bar.baz” refers to.

Brackets

Square brackets are only to be used (1) in command synopses to denote optional arguments, or (2) to denote an array subscript.

Rationale: Anything else does not correspond to widely-known customary usage and will confuse people.

Assembling Error Messages

When a message includes text that is generated elsewhere, embed it in this style:

```
could not open file %s: %m
```

Rationale: It would be difficult to account for all possible error codes to paste this into a single smooth sentence, so some sort of punctuation is needed. Putting the embedded text in parentheses has also been suggested, but it's unnatural if the embedded text is likely to be the most important part of the message, as is often the case.

Reasons for Errors

Messages should always state the reason why an error occurred. For example:

```
BAD:    could not open file %s
BETTER: could not open file %s (I/O failure)
```

If no reason is known you better fix the code.

Function Names

Don't include the name of the reporting routine in the error text. We have other mechanisms for finding that out when needed, and for most users it's not helpful information. If the error text doesn't make as much sense without the function name, reword it.

```
BAD:    pg_strtoint32: error in "z": cannot parse "z"
BETTER: invalid input syntax for type integer: "z"
```

Avoid mentioning called function names, either; instead say what the code was trying to do:

```
BAD:    open() failed: %m
BETTER: could not open file %s: %m
```

If it really seems necessary, mention the system call in the detail message. (In some cases, providing the actual values passed to the system call might be appropriate information for the detail message.)

Rationale: Users don't know what all those functions do.

Tricky Words to Avoid

Unable. “Unable” is nearly the passive voice. Better use “cannot” or “could not”, as appropriate.

Bad. Error messages like “bad result” are really hard to interpret intelligently. It's better to write why the result is “bad”, e.g., “invalid format”.

Illegal. “Illegal” stands for a violation of the law, the rest is “invalid”. Better yet, say why it's invalid.

Unknown. Try to avoid “unknown”. Consider “error: unknown response”. If you don't know what the response is, how do you know it's erroneous? “Unrecognized” is often a better choice. Also, be sure to include the value being complained of.

```
BAD:      unknown node type
BETTER:  unrecognized node type: 42
```

Find vs. Exists. If the program uses a nontrivial algorithm to locate a resource (e.g., a path search) and that algorithm fails, it is fair to say that the program couldn't “find” the resource. If, on the other hand, the expected location of the resource is known but the program cannot access it there then say that the resource doesn't “exist”. Using “find” in this case sounds weak and confuses the issue.

May vs. Can vs. Might. “May” suggests permission (e.g., “You may borrow my rake.”), and has little use in documentation or error messages. “Can” suggests ability (e.g., “I can lift that log.”), and “might” suggests possibility (e.g., “It might rain today.”). Using the proper word clarifies meaning and assists translation.

Contractions. Avoid contractions, like “can't”; use “cannot” instead.

Proper Spelling

Spell out words in full. For instance, avoid:

- spec
- stats
- parens
- auth
- xact

Rationale: This will improve consistency.

Localization

Keep in mind that error message texts need to be translated into other languages. Follow the guidelines in Section 54.2.2 to avoid making life difficult for translators.

53.4. Miscellaneous Coding Conventions

C Standard

Code in PostgreSQL should only rely on language features available in the C99 standard. That means a conforming C99 compiler has to be able to compile postgres, at least aside from a few platform dependent pieces.

A few features included in the C99 standard are, at this time, not permitted to be used in core PostgreSQL code. This currently includes variable length arrays, intermingled declarations and code, // comments, universal character names. Reasons for that include portability and historical practices.

Features from later revision of the C standard or compiler specific features can be used, if a fallback is provided.

For example `_Static_assert()` and `__builtin_constant_p` are currently used, even though they are from newer revisions of the C standard and a GCC extension respectively. If not available we respectively fall back to using a C99 compatible replacement that performs the same checks, but emits rather cryptic messages and do not use `__builtin_constant_p`.

Function-Like Macros and Inline Functions

Both, macros with arguments and `static inline` functions, may be used. The latter are preferable if there are multiple-evaluation hazards when written as a macro, as e.g. the case with

```
#define Max(x, y)      ((x) > (y) ? (x) : (y))
```

or when the macro would be very long. In other cases it's only possible to use macros, or at least easier. For example because expressions of various types need to be passed to the macro.

When the definition of an inline function references symbols (i.e. variables, functions) that are only available as part of the backend, the function may not be visible when included from frontend code.

```
#ifndef FRONTEND
static inline MemoryContext
MemoryContextSwitchTo(MemoryContext context)
{
    MemoryContext old = CurrentMemoryContext;

    CurrentMemoryContext = context;
    return old;
}
#endif /* FRONTEND */
```

In this example `CurrentMemoryContext`, which is only available in the backend, is referenced and the function thus hidden with a `#ifndef FRONTEND`. This rule exists because some compilers emit references to symbols contained in inline functions even if the function is not used.

Writing Signal Handlers

To be suitable to run inside a signal handler code has to be written very carefully. The fundamental problem is that, unless blocked, a signal handler can interrupt code at any time. If code inside the signal handler uses the same state as code outside chaos may ensue. As an example consider what happens if a signal handler tries to acquire a lock that's already held in the interrupted code.

Barring special arrangements code in signal handlers may only call async-signal safe functions (as defined in POSIX) and access variables of type `volatile sig_atomic_t`. A few functions in `postgres` are also deemed signal safe, importantly `SetLatch()`.

In most cases signal handlers should do nothing more than note that a signal has arrived, and wake up code running outside of the handler using a latch. An example of such a handler is the following:

```
static void
handle_sighup(SIGNAL_ARGS)
```

```
{
    int          save_errno = errno;

    got_SIGHUP = true;
    SetLatch(MyLatch);

    errno = save_errno;
}
```

`errno` is saved and restored because `SetLatch()` might change it. If that were not done interrupted code that's currently inspecting `errno` might see the wrong value.

Calling Function Pointers

For clarity, it is preferred to explicitly dereference a function pointer when calling the pointed-to function if the pointer is a simple variable, for example:

```
(*emit_log_hook) (edata);
```

(even though `emit_log_hook(edata)` would also work). When the function pointer is part of a structure, then the extra punctuation can and usually should be omitted, for example:

```
paramInfo->paramFetch(paramInfo, paramId);
```

Chapter 54. Native Language Support

54.1. For the Translator

PostgreSQL programs (server and client) can issue their messages in your favorite language — if the messages have been translated. Creating and maintaining translated message sets needs the help of people who speak their own language well and want to contribute to the PostgreSQL effort. You do not have to be a programmer at all to do this. This section explains how to help.

54.1.1. Requirements

We won't judge your language skills — this section is about software tools. Theoretically, you only need a text editor. But this is only in the unlikely event that you do not want to try out your translated messages. When you configure your source tree, be sure to use the `--enable-nls` option. This will also check for the `libintl` library and the `msgfmt` program, which all end users will need anyway. To try out your work, follow the applicable portions of the installation instructions.

If you want to start a new translation effort or want to do a message catalog merge (described later), you will need the programs `xgettext` and `msgmerge`, respectively, in a GNU-compatible implementation. Later, we will try to arrange it so that if you use a packaged source distribution, you won't need `xgettext`. (If working from Git, you will still need it.) GNU Gettext 0.10.36 or later is currently recommended.

Your local `gettext` implementation should come with its own documentation. Some of that is probably duplicated in what follows, but for additional details you should look there.

54.1.2. Concepts

The pairs of original (English) messages and their (possibly) translated equivalents are kept in *message catalogs*, one for each program (although related programs can share a message catalog) and for each target language. There are two file formats for message catalogs: The first is the “PO” file (for Portable Object), which is a plain text file with special syntax that translators edit. The second is the “MO” file (for Machine Object), which is a binary file generated from the respective PO file and is used while the internationalized program is run. Translators do not deal with MO files; in fact hardly anyone does.

The extension of the message catalog file is to no surprise either `.po` or `.mo`. The base name is either the name of the program it accompanies, or the language the file is for, depending on the situation. This is a bit confusing. Examples are `psql.po` (PO file for `psql`) or `fr.mo` (MO file in French).

The file format of the PO files is illustrated here:

```
# comment

msgid "original string"
msgstr "translated string"

msgid "more original"
msgstr "another translated"
"string can be broken up like this"

...
```

The `msgid`'s are extracted from the program source. (They need not be, but this is the most common way.) The `msgstr` lines are initially empty and are filled in with useful strings by the translator. The strings can contain C-style escape characters and can be continued across lines as illustrated. (The next line must start at the beginning of the line.)

The # character introduces a comment. If whitespace immediately follows the # character, then this is a comment maintained by the translator. There can also be automatic comments, which have a non-whitespace character immediately following the #. These are maintained by the various tools that operate on the PO files and are intended to aid the translator.

```
#. automatic comment
#: filename.c:1023
#, flags, flags
```

The #. style comments are extracted from the source file where the message is used. Possibly the programmer has inserted information for the translator, such as about expected alignment. The #: comment indicates the exact location(s) where the message is used in the source. The translator need not look at the program source, but can if there is doubt about the correct translation. The #, comments contain flags that describe the message in some way. There are currently two flags: `fuzzy` is set if the message has possibly been outdated because of changes in the program source. The translator can then verify this and possibly remove the fuzzy flag. Note that fuzzy messages are not made available to the end user. The other flag is `c-format`, which indicates that the message is a `printf`-style format template. This means that the translation should also be a format string with the same number and type of placeholders. There are tools that can verify this, which key off the `c-format` flag.

54.1.3. Creating and Maintaining Message Catalogs

OK, so how does one create a “blank” message catalog? First, go into the directory that contains the program whose messages you want to translate. If there is a file `nls.mk`, then this program has been prepared for translation.

If there are already some `.po` files, then someone has already done some translation work. The files are named `language.po`, where `language` is the ISO 639-1 two-letter language code (in lower case)¹, e.g., `fr.po` for French. If there is really a need for more than one translation effort per language then the files can also be named `language_region.po` where `region` is the ISO 3166-1 two-letter country code (in upper case)², e.g., `pt_BR.po` for Portuguese in Brazil. If you find the language you wanted you can just start working on that file.

If you need to start a new translation effort, then first run the command:

```
make init-po
```

This will create a file `prognamename.pot`. (`.pot` to distinguish it from PO files that are “in production”. The T stands for “template”.) Copy this file to `language.po` and edit it. To make it known that the new language is available, also edit the file `nls.mk` and add the language (or language and country) code to the line that looks like:

```
AVAIL_LANGUAGES := de fr
```

(Other languages can appear, of course.)

As the underlying program or library changes, messages might be changed or added by the programmers. In this case you do not need to start from scratch. Instead, run the command:

```
make update-po
```

which will create a new blank message catalog file (the `pot` file you started with) and will merge it with the existing PO files. If the merge algorithm is not sure about a particular message it marks it “fuzzy” as explained above. The new PO file is saved with a `.po.new` extension.

¹ http://www.loc.gov/standards/iso639-2/php/English_list.php

² <https://www.iso.org/iso-3166-country-codes.html>

54.1.4. Editing the PO Files

The PO files can be edited with a regular text editor. The translator should only change the area between the quotes after the `msgstr` directive, add comments, and alter the fuzzy flag. There is (unsurprisingly) a PO mode for Emacs, which I find quite useful.

The PO files need not be completely filled in. The software will automatically fall back to the original string if no translation (or an empty translation) is available. It is no problem to submit incomplete translations for inclusions in the source tree; that gives room for other people to pick up your work. However, you are encouraged to give priority to removing fuzzy entries after doing a merge. Remember that fuzzy entries will not be installed; they only serve as reference for what might be the right translation.

Here are some things to keep in mind while editing the translations:

- Make sure that if the original ends with a newline, the translation does, too. Similarly for tabs, etc.
- If the original is a `printf` format string, the translation also needs to be. The translation also needs to have the same format specifiers in the same order. Sometimes the natural rules of the language make this impossible or at least awkward. In that case you can modify the format specifiers like this:

```
msgstr "Die Datei %2$s hat %1$u Zeichen."
```

Then the first placeholder will actually use the second argument from the list. The `digits$` needs to follow the `%` immediately, before any other format manipulators. (This feature really exists in the `printf` family of functions. You might not have heard of it before because there is little use for it outside of message internationalization.)

- If the original string contains a linguistic mistake, report that (or fix it yourself in the program source) and translate normally. The corrected string can be merged in when the program sources have been updated. If the original string contains a factual mistake, report that (or fix it yourself) and do not translate it. Instead, you can mark the string with a comment in the PO file.
- Maintain the style and tone of the original string. Specifically, messages that are not sentences (`cannot open file %s`) should probably not start with a capital letter (if your language distinguishes letter case) or end with a period (if your language uses punctuation marks). It might help to read Section 53.3.
- If you don't know what a message means, or if it is ambiguous, ask on the developers' mailing list. Chances are that English speaking end users might also not understand it or find it ambiguous, so it's best to improve the message.

54.2. For the Programmer

54.2.1. Mechanics

This section describes how to implement native language support in a program or library that is part of the PostgreSQL distribution. Currently, it only applies to C programs.

Adding NLS Support to a Program

1. Insert this code into the start-up sequence of the program:

```
#ifdef ENABLE_NLS
#include <locale.h>
#endif
```

...

```
#ifdef ENABLE-NLS
setlocale(LC_ALL, "");
bindtextdomain("progname", LOCALEDIR);
textdomain("progname");
#endif
```

(The *progname* can actually be chosen freely.)

2. Wherever a message that is a candidate for translation is found, a call to `gettext()` needs to be inserted. E.g.:

```
fprintf(stderr, "panic level %d\n", lvl);
```

would be changed to:

```
fprintf(stderr, gettext("panic level %d\n"), lvl);
```

(`gettext` is defined as a no-op if NLS support is not configured.)

This tends to add a lot of clutter. One common shortcut is to use:

```
#define _(x) gettext(x)
```

Another solution is feasible if the program does much of its communication through one or a few functions, such as `ereport()` in the backend. Then you make this function call `gettext` internally on all input strings.

3. Add a file `nls.mk` in the directory with the program sources. This file will be read as a makefile. The following variable assignments need to be made here:

CATALOG_NAME

The program name, as provided in the `textdomain()` call.

AVAIL_LANGUAGES

List of provided translations — initially empty.

GETTEXT_FILES

List of files that contain translatable strings, i.e., those marked with `gettext` or an alternative solution. Eventually, this will include nearly all source files of the program. If this list gets too long you can make the first “file” be a + and the second word be a file that contains one file name per line.

GETTEXT_TRIGGERS

The tools that generate message catalogs for the translators to work on need to know what function calls contain translatable strings. By default, only `gettext()` calls are known. If you used `_` or other identifiers you need to list them here. If the translatable string is not the first argument, the item needs to be of the form `func:2` (for the second argument). If you have a function that supports pluralized messages, the item should look like `func:1,2` (identifying the singular and plural message arguments).

The build system will automatically take care of building and installing the message catalogs.

54.2.2. Message-Writing Guidelines

Here are some guidelines for writing messages that are easily translatable.

- Do not construct sentences at run-time, like:

```
printf("Files were %s.\n", flag ? "copied" : "removed");
```

The word order within the sentence might be different in other languages. Also, even if you remember to call `gettext()` on each fragment, the fragments might not translate well separately. It's better to duplicate a little code so that each message to be translated is a coherent whole. Only numbers, file names, and such-like run-time variables should be inserted at run time into a message text.

- For similar reasons, this won't work:

```
printf("copied %d file%s", n, n!=1 ? "s" : "");
```

because it assumes how the plural is formed. If you figured you could solve it like this:

```
if (n==1)
    printf("copied 1 file");
else
    printf("copied %d files", n);
```

then be disappointed. Some languages have more than two forms, with some peculiar rules. It's often best to design the message to avoid the issue altogether, for instance like this:

```
printf("number of copied files: %d", n);
```

If you really want to construct a properly pluralized message, there is support for this, but it's a bit awkward. When generating a primary or detail error message in `ereport()`, you can write something like this:

```
errmsg_plural("copied %d file",
              "copied %d files",
              n,
              n)
```

The first argument is the format string appropriate for English singular form, the second is the format string appropriate for English plural form, and the third is the integer control value that determines which plural form to use. Subsequent arguments are formatted per the format string as usual. (Normally, the pluralization control value will also be one of the values to be formatted, so it has to be written twice.) In English it only matters whether `n` is 1 or not 1, but in other languages there can be many different plural forms. The translator sees the two English forms as a group and has the opportunity to supply multiple substitute strings, with the appropriate one being selected based on the run-time value of `n`.

If you need to pluralize a message that isn't going directly to an `errmsg` or `errdetail` report, you have to use the underlying function `ngettext`. See the `gettext` documentation.

- If you want to communicate something to the translator, such as about how a message is intended to line up with other output, precede the occurrence of the string with a comment that starts with `translator`, e.g.:

`/* translator: This message is not what it seems to be. */`

These comments are copied to the message catalog files so that the translators can see them.

Chapter 55. Writing a Procedural Language Handler

All calls to functions that are written in a language other than the current “version 1” interface for compiled languages (this includes functions in user-defined procedural languages and functions written in SQL) go through a *call handler* function for the specific language. It is the responsibility of the call handler to execute the function in a meaningful way, such as by interpreting the supplied source text. This chapter outlines how a new procedural language's call handler can be written.

The call handler for a procedural language is a “normal” function that must be written in a compiled language such as C, using the version-1 interface, and registered with PostgreSQL as taking no arguments and returning the type `language_handler`. This special pseudo-type identifies the function as a call handler and prevents it from being called directly in SQL commands. For more details on C language calling conventions and dynamic loading, see Section 37.10.

The call handler is called in the same way as any other function: It receives a pointer to a `FunctionCallInfoBaseData` struct containing argument values and information about the called function, and it is expected to return a `Datum` result (and possibly set the `isnull` field of the `FunctionCallInfoBaseData` structure, if it wishes to return an SQL null result). The difference between a call handler and an ordinary callee function is that the `flinfo->fn_oid` field of the `FunctionCallInfoBaseData` structure will contain the OID of the actual function to be called, not of the call handler itself. The call handler must use this field to determine which function to execute. Also, the passed argument list has been set up according to the declaration of the target function, not of the call handler.

It's up to the call handler to fetch the entry of the function from the `pg_proc` system catalog and to analyze the argument and return types of the called function. The `AS` clause from the `CREATE FUNCTION` command for the function will be found in the `prosrc` column of the `pg_proc` row. This is commonly source text in the procedural language, but in theory it could be something else, such as a path name to a file, or anything else that tells the call handler what to do in detail.

Often, the same function is called many times per SQL statement. A call handler can avoid repeated lookups of information about the called function by using the `flinfo->fn_extra` field. This will initially be `NULL`, but can be set by the call handler to point at information about the called function. On subsequent calls, if `flinfo->fn_extra` is already non-`NULL` then it can be used and the information lookup step skipped. The call handler must make sure that `flinfo->fn_extra` is made to point at memory that will live at least until the end of the current query, since an `FmgrInfo` data structure could be kept that long. One way to do this is to allocate the extra data in the memory context specified by `flinfo->fn_mcxt`; such data will normally have the same lifespan as the `FmgrInfo` itself. But the handler could also choose to use a longer-lived memory context so that it can cache function definition information across queries.

When a procedural-language function is invoked as a trigger, no arguments are passed in the usual way, but the `FunctionCallInfoBaseData`'s `context` field points at a `TriggerData` structure, rather than being `NULL` as it is in a plain function call. A language handler should provide mechanisms for procedural-language functions to get at the trigger information.

This is a template for a procedural-language handler written in C:

```
#include "postgres.h"
#include "executor/spi.h"
#include "commands/trigger.h"
#include "fmgr.h"
#include "access/heapam.h"
#include "utils/syscache.h"
#include "catalog/pg_proc.h"
```

```

#include "catalog/pg_type.h"

PG_MODULE_MAGIC;

PG_FUNCTION_INFO_V1(plsample_call_handler);

Datum
plsample_call_handler(PG_FUNCTION_ARGS)
{
    Datum          retval;

    if (CALLED_AS_TRIGGER(fcinfo))
    {
        /*
         * Called as a trigger function
         */
        TriggerData *trigdata = (TriggerData *) fcinfo->context;

        retval = ...
    }
    else
    {
        /*
         * Called as a function
         */

        retval = ...
    }

    return retval;
}

```

Only a few thousand lines of code have to be added instead of the dots to complete the call handler.

After having compiled the handler function into a loadable module (see Section 37.10.5), the following commands then register the sample procedural language:

```

CREATE FUNCTION plsample_call_handler() RETURNS language_handler
AS 'filename'
LANGUAGE C;
CREATE LANGUAGE plsample
HANDLER plsample_call_handler;

```

Although providing a call handler is sufficient to create a minimal procedural language, there are two other functions that can optionally be provided to make the language more convenient to use. These are a *validator* and an *inline handler*. A validator can be provided to allow language-specific checking to be done during CREATE FUNCTION. An inline handler can be provided to allow the language to support anonymous code blocks executed via the DO command.

If a validator is provided by a procedural language, it must be declared as a function taking a single parameter of type `oid`. The validator's result is ignored, so it is customarily declared to return `void`. The validator will be called at the end of a CREATE FUNCTION command that has created or updated a function written in the procedural language. The passed-in OID is the OID of the function's `pg_proc` row. The validator must fetch this row in the usual way, and do whatever checking is appropriate. First, call `CheckFunctionValidatorAccess()` to diagnose explicit calls to the validator that the user could not achieve through CREATE FUNCTION. Typical checks then include verifying that the function's argument and result types are supported by the language, and that the function's body is syntactically correct in the language. If the validator finds the function to be okay, it should just

return. If it finds an error, it should report that via the normal `ereport()` error reporting mechanism. Throwing an error will force a transaction rollback and thus prevent the incorrect function definition from being committed.

Validator functions should typically honor the `check_function_bodies` parameter: if it is turned off then any expensive or context-sensitive checking should be skipped. If the language provides for code execution at compilation time, the validator must suppress checks that would induce such execution. In particular, this parameter is turned off by `pg_dump` so that it can load procedural language functions without worrying about side effects or dependencies of the function bodies on other database objects. (Because of this requirement, the call handler should avoid assuming that the validator has fully checked the function. The point of having a validator is not to let the call handler omit checks, but to notify the user immediately if there are obvious errors in a `CREATE FUNCTION` command.) While the choice of exactly what to check is mostly left to the discretion of the validator function, note that the core `CREATE FUNCTION` code only executes `SET` clauses attached to a function when `check_function_bodies` is on. Therefore, checks whose results might be affected by GUC parameters definitely should be skipped when `check_function_bodies` is off, to avoid false failures when reloading a dump.

If an inline handler is provided by a procedural language, it must be declared as a function taking a single parameter of type `internal`. The inline handler's result is ignored, so it is customarily declared to return `void`. The inline handler will be called when a `DO` statement is executed specifying the procedural language. The parameter actually passed is a pointer to an `InlineCodeBlock` struct, which contains information about the `DO` statement's parameters, in particular the text of the anonymous code block to be executed. The inline handler should execute this code and return.

It's recommended that you wrap all these function declarations, as well as the `CREATE LANGUAGE` command itself, into an *extension* so that a simple `CREATE EXTENSION` command is sufficient to install the language. See Section 37.17 for information about writing extensions.

The procedural languages included in the standard distribution are good references when trying to write your own language handler. Look into the `src/pl` subdirectory of the source tree. The `CREATE LANGUAGE` reference page also has some useful details.

Chapter 56. Writing a Foreign Data Wrapper

All operations on a foreign table are handled through its foreign data wrapper, which consists of a set of functions that the core server calls. The foreign data wrapper is responsible for fetching data from the remote data source and returning it to the PostgreSQL executor. If updating foreign tables is to be supported, the wrapper must handle that, too. This chapter outlines how to write a new foreign data wrapper.

The foreign data wrappers included in the standard distribution are good references when trying to write your own. Look into the `contrib` subdirectory of the source tree. The `CREATE FOREIGN DATA WRAPPER` reference page also has some useful details.

Note

The SQL standard specifies an interface for writing foreign data wrappers. However, PostgreSQL does not implement that API, because the effort to accommodate it into PostgreSQL would be large, and the standard API hasn't gained wide adoption anyway.

56.1. Foreign Data Wrapper Functions

The FDW author needs to implement a handler function, and optionally a validator function. Both functions must be written in a compiled language such as C, using the version-1 interface. For details on C language calling conventions and dynamic loading, see Section 37.10.

The handler function simply returns a struct of function pointers to callback functions that will be called by the planner, executor, and various maintenance commands. Most of the effort in writing an FDW is in implementing these callback functions. The handler function must be registered with PostgreSQL as taking no arguments and returning the special pseudo-type `fdw_handler`. The callback functions are plain C functions and are not visible or callable at the SQL level. The callback functions are described in Section 56.2.

The validator function is responsible for validating options given in `CREATE` and `ALTER` commands for its foreign data wrapper, as well as foreign servers, user mappings, and foreign tables using the wrapper. The validator function must be registered as taking two arguments, a text array containing the options to be validated, and an OID representing the type of object the options are associated with (in the form of the OID of the system catalog the object would be stored in, either `ForeignDataWrapperRelationId`, `ForeignServerRelationId`, `UserMappingRelationId`, or `ForeignTableRelationId`). If no validator function is supplied, options are not checked at object creation time or object alteration time.

56.2. Foreign Data Wrapper Callback Routines

The FDW handler function returns a palloc'd `FdwRoutine` struct containing pointers to the callback functions described below. The scan-related functions are required, the rest are optional.

The `FdwRoutine` struct type is declared in `src/include/foreign/fdwapi.h`, which see for additional details.

56.2.1. FDW Routines for Scanning Foreign Tables

```
void
GetForeignRelSize(PlannerInfo *root,
                  RelOptInfo *baserel,
                  Oid foreigntableid);
```

Obtain relation size estimates for a foreign table. This is called at the beginning of planning for a query that scans a foreign table. `root` is the planner's global information about the query; `baserel` is the planner's information about this table; and `foreigntableid` is the `pg_class` OID of the foreign table. (`foreigntableid` could be obtained from the planner data structures, but it's passed explicitly to save effort.)

This function should update `baserel->rows` to be the expected number of rows returned by the table scan, after accounting for the filtering done by the restriction quals. The initial value of `baserel->rows` is just a constant default estimate, which should be replaced if at all possible. The function may also choose to update `baserel->width` if it can compute a better estimate of the average result row width.

See Section 56.4 for additional information.

```
void
GetForeignPaths(PlannerInfo *root,
                RelOptInfo *baserel,
                Oid foreigntableid);
```

Create possible access paths for a scan on a foreign table. This is called during query planning. The parameters are the same as for `GetForeignRelSize`, which has already been called.

This function must generate at least one access path (`ForeignPath` node) for a scan on the foreign table and must call `add_path` to add each such path to `baserel->pathlist`. It's recommended to use `create_foreignscan_path` to build the `ForeignPath` nodes. The function can generate multiple access paths, e.g., a path which has valid `pathkeys` to represent a pre-sorted result. Each access path must contain cost estimates, and can contain any FDW-private information that is needed to identify the specific scan method intended.

See Section 56.4 for additional information.

```
ForeignScan *
GetForeignPlan(PlannerInfo *root,
               RelOptInfo *baserel,
               Oid foreigntableid,
               ForeignPath *best_path,
               List *tlist,
               List *scan_clauses,
               Plan *outer_plan);
```

Create a `ForeignScan` plan node from the selected foreign access path. This is called at the end of query planning. The parameters are as for `GetForeignRelSize`, plus the selected `ForeignPath` (previously produced by `GetForeignPaths`, `GetForeignJoinPaths`, or `GetForeignUpperPaths`), the target list to be emitted by the plan node, the restriction clauses to be enforced by the plan node, and the outer subplan of the `ForeignScan`, which is used for rechecks performed by `RecheckForeignScan`. (If the path is for a join rather than a base relation, `foreigntableid` is `InvalidOid`.)

This function must create and return a `ForeignScan` plan node; it's recommended to use `make_foreignscan` to build the `ForeignScan` node.

See Section 56.4 for additional information.

```
void
BeginForeignScan(ForeignScanState *node,
                int eflags);
```

Begin executing a foreign scan. This is called during executor startup. It should perform any initialization needed before the scan can start, but not start executing the actual scan (that should be done upon the first call to `IterateForeignScan`). The `ForeignScanState` node has already been created, but its `fdw_state` field is still `NULL`. Information about the table to scan is accessible through the `ForeignScanState` node (in particular, from the underlying `ForeignScan` plan node, which contains any FDW-private information provided by `GetForeignPlan`). `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainForeignScan` and `EndForeignScan`.

```
TupleTableSlot *
IterateForeignScan(ForeignScanState *node);
```

Fetch one row from the foreign source, returning it in a tuple table slot (the node's `ScanTupleSlot` should be used for this purpose). Return `NULL` if no more rows are available. The tuple table slot infrastructure allows either a physical or virtual tuple to be returned; in most cases the latter choice is preferable from a performance standpoint. Note that this is called in a short-lived memory context that will be reset between invocations. Create a memory context in `BeginForeignScan` if you need longer-lived storage, or use the `es_query_cxt` of the node's `EState`.

The rows returned must match the `fdw_scan_tlist` target list if one was supplied, otherwise they must match the row type of the foreign table being scanned. If you choose to optimize away fetching columns that are not needed, you should insert nulls in those column positions, or else generate a `fdw_scan_tlist` list with those columns omitted.

Note that PostgreSQL's executor doesn't care whether the rows returned violate any constraints that were defined on the foreign table — but the planner does care, and may optimize queries incorrectly if there are rows visible in the foreign table that do not satisfy a declared constraint. If a constraint is violated when the user has declared that the constraint should hold true, it may be appropriate to raise an error (just as you would need to do in the case of a data type mismatch).

```
void
ReScanForeignScan(ForeignScanState *node);
```

Restart the scan from the beginning. Note that any parameters the scan depends on may have changed value, so the new scan does not necessarily return exactly the same rows.

```
void
EndForeignScan(ForeignScanState *node);
```

End the scan and release resources. It is normally not important to release `palloc'd` memory, but for example open files and connections to remote servers should be cleaned up.

56.2.2. FDW Routines for Scanning Foreign Joins

If an FDW supports performing foreign joins remotely (rather than by fetching both tables' data and doing the join locally), it should provide this callback function:

```
void
GetForeignJoinPaths(PlannerInfo *root,
```

```

RelOptInfo *joinrel,
RelOptInfo *outerrel,
RelOptInfo *innerrel,
JoinType jointype,
JoinPathExtraData *extra);

```

Create possible access paths for a join of two (or more) foreign tables that all belong to the same foreign server. This optional function is called during query planning. As with `GetForeignPaths`, this function should generate `ForeignPath` path(s) for the supplied `joinrel` (use `create_foreign_join_path` to build them), and call `add_path` to add these paths to the set of paths considered for the join. But unlike `GetForeignPaths`, it is not necessary that this function succeed in creating at least one path, since paths involving local joining are always possible.

Note that this function will be invoked repeatedly for the same join relation, with different combinations of inner and outer relations; it is the responsibility of the FDW to minimize duplicated work.

If a `ForeignPath` path is chosen for the join, it will represent the entire join process; paths generated for the component tables and subsidiary joins will not be used. Subsequent processing of the join path proceeds much as it does for a path scanning a single foreign table. One difference is that the `scanrelid` of the resulting `ForeignScan` plan node should be set to zero, since there is no single relation that it represents; instead, the `fs_relids` field of the `ForeignScan` node represents the set of relations that were joined. (The latter field is set up automatically by the core planner code, and need not be filled by the FDW.) Another difference is that, because the column list for a remote join cannot be found from the system catalogs, the FDW must fill `fdw_scan_tlist` with an appropriate list of `TargetEntry` nodes, representing the set of columns it will supply at run time in the tuples it returns.

See Section 56.4 for additional information.

56.2.3. FDW Routines for Planning Post-Scan/Join Processing

If an FDW supports performing remote post-scan/join processing, such as remote aggregation, it should provide this callback function:

```

void
GetForeignUpperPaths(PlannerInfo *root,
                    UpperRelationKind stage,
                    RelOptInfo *input_rel,
                    RelOptInfo *output_rel,
                    void *extra);

```

Create possible access paths for *upper relation* processing, which is the planner's term for all post-scan/join query processing, such as aggregation, window functions, sorting, and table updates. This optional function is called during query planning. Currently, it is called only if all base relation(s) involved in the query belong to the same FDW. This function should generate `ForeignPath` path(s) for any post-scan/join processing that the FDW knows how to perform remotely (use `create_foreign_upper_path` to build them), and call `add_path` to add these paths to the indicated upper relation. As with `GetForeignJoinPaths`, it is not necessary that this function succeed in creating any paths, since paths involving local processing are always possible.

The `stage` parameter identifies which post-scan/join step is currently being considered. `output_rel` is the upper relation that should receive paths representing computation of this step, and `input_rel` is the relation representing the input to this step. The `extra` parameter provides additional details, currently, it is set only for `UPPERREL_PARTIAL_GROUP_AGG` or `UPPERREL_GROUP_AGG`, in which case it points to a `GroupPathExtraData` structure; or for `UPPERREL_FINAL`, in which case it points to a `FinalPathExtraData` structure. (Note that `Foreign-`

Path paths added to `output_rel` would typically not have any direct dependency on paths of the `input_rel`, since their processing is expected to be done externally. However, examining paths previously generated for the previous processing step can be useful to avoid redundant planning work.)

See Section 56.4 for additional information.

56.2.4. FDW Routines for Updating Foreign Tables

If an FDW supports writable foreign tables, it should provide some or all of the following callback functions depending on the needs and capabilities of the FDW:

```
void
AddForeignUpdateTargets(Query *parsetree,
                       RangeTblEntry *target_rte,
                       Relation target_relation);
```

UPDATE and DELETE operations are performed against rows previously fetched by the table-scanning functions. The FDW may need extra information, such as a row ID or the values of primary-key columns, to ensure that it can identify the exact row to update or delete. To support that, this function can add extra hidden, or “junk”, target columns to the list of columns that are to be retrieved from the foreign table during an UPDATE or DELETE.

To do that, add `TargetEntry` items to `parsetree->targetList`, containing expressions for the extra values to be fetched. Each such entry must be marked `resjunk = true`, and must have a distinct `resname` that will identify it at execution time. Avoid using names matching `ctidN`, `wholerow`, or `wholerowN`, as the core system can generate junk columns of these names. If the extra expressions are more complex than simple Vars, they must be run through `eval_const_expressions` before adding them to the `targetlist`.

Although this function is called during planning, the information provided is a bit different from that available to other planning routines. `parsetree` is the parse tree for the UPDATE or DELETE command, while `target_rte` and `target_relation` describe the target foreign table.

If the `AddForeignUpdateTargets` pointer is set to NULL, no extra target expressions are added. (This will make it impossible to implement DELETE operations, though UPDATE may still be feasible if the FDW relies on an unchanging primary key to identify rows.)

```
List *
PlanForeignModify(PlannerInfo *root,
                 ModifyTable *plan,
                 Index resultRelation,
                 int subplan_index);
```

Perform any additional planning actions needed for an insert, update, or delete on a foreign table. This function generates the FDW-private information that will be attached to the `ModifyTable` plan node that performs the update action. This private information must have the form of a `List`, and will be delivered to `BeginForeignModify` during the execution stage.

`root` is the planner's global information about the query. `plan` is the `ModifyTable` plan node, which is complete except for the `fdwPrivLists` field. `resultRelation` identifies the target foreign table by its range table index. `subplan_index` identifies which target of the `ModifyTable` plan node this is, counting from zero; use this if you want to index into `plan->plans` or other substructure of the `plan` node.

See Section 56.4 for additional information.

If the `PlanForeignModify` pointer is set to NULL, no additional plan-time actions are taken, and the `fdw_private` list delivered to `BeginForeignModify` will be NIL.

```

void
BeginForeignModify(ModifyTableState *mtstate,
                  ResultRelInfo *rinfo,
                  List *fdw_private,
                  int subplan_index,
                  int eflags);

```

Begin executing a foreign table modification operation. This routine is called during executor startup. It should perform any initialization needed prior to the actual table modifications. Subsequently, `ExecForeignInsert`, `ExecForeignUpdate` or `ExecForeignDelete` will be called for each tuple to be inserted, updated, or deleted.

`mtstate` is the overall state of the `ModifyTable` plan node being executed; global data about the plan and execution state is available via this structure. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. (The `ri_FdwState` field of `ResultRelInfo` is available for the FDW to store any private state it needs for this operation.) `fdw_private` contains the private data generated by `PlanForeignModify`, if any. `subplan_index` identifies which target of the `ModifyTable` plan node this is. `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when (`eflags & EXEC_FLAG_EXPLAIN_ONLY`) is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainForeignModify` and `EndForeignModify`.

If the `BeginForeignModify` pointer is set to `NULL`, no action is taken during executor startup.

```

TupleTableSlot *
ExecForeignInsert(EState *estate,
                 ResultRelInfo *rinfo,
                 TupleTableSlot *slot,
                 TupleTableSlot *planSlot);

```

Insert one tuple into the foreign table. `estate` is global execution state for the query. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. `slot` contains the tuple to be inserted; it will match the row-type definition of the foreign table. `planSlot` contains the tuple that was generated by the `ModifyTable` plan node's subplan; it differs from `slot` in possibly containing additional "junk" columns. (The `planSlot` is typically of little interest for `INSERT` cases, but is provided for completeness.)

The return value is either a slot containing the data that was actually inserted (this might differ from the data supplied, for example as a result of trigger actions), or `NULL` if no row was actually inserted (again, typically as a result of triggers). The passed-in `slot` can be re-used for this purpose.

The data in the returned slot is used only if the `INSERT` statement has a `RETURNING` clause or involves a view `WITH CHECK OPTION`; or if the foreign table has an `AFTER ROW` trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the `RETURNING` clause or `WITH CHECK OPTION` constraints. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the `ExecForeignInsert` pointer is set to `NULL`, attempts to insert into the foreign table will fail with an error message.

Note that this function is also called when inserting routed tuples into a foreign-table partition or executing `COPY FROM` on a foreign table, in which case it is called in a different way than it is in the `INSERT` case. See the callback functions described below that allow the FDW to support that.

```
TupleTableSlot *
ExecForeignUpdate(EState *estate,
                 ResultRelInfo *rinfo,
                 TupleTableSlot *slot,
                 TupleTableSlot *planSlot);
```

Update one tuple in the foreign table. `estate` is global execution state for the query. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. `slot` contains the new data for the tuple; it will match the row-type definition of the foreign table. `planSlot` contains the tuple that was generated by the `ModifyTable` plan node's subplan; it differs from `slot` in possibly containing additional "junk" columns. In particular, any junk columns that were requested by `AddForeignUpdateTargets` will be available from this slot.

The return value is either a slot containing the row as it was actually updated (this might differ from the data supplied, for example as a result of trigger actions), or `NULL` if no row was actually updated (again, typically as a result of triggers). The passed-in `slot` can be re-used for this purpose.

The data in the returned slot is used only if the `UPDATE` statement has a `RETURNING` clause or involves a view `WITH CHECK OPTION`; or if the foreign table has an `AFTER ROW` trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the `RETURNING` clause or `WITH CHECK OPTION` constraints. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the `ExecForeignUpdate` pointer is set to `NULL`, attempts to update the foreign table will fail with an error message.

```
TupleTableSlot *
ExecForeignDelete(EState *estate,
                 ResultRelInfo *rinfo,
                 TupleTableSlot *slot,
                 TupleTableSlot *planSlot);
```

Delete one tuple from the foreign table. `estate` is global execution state for the query. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. `slot` contains nothing useful upon call, but can be used to hold the returned tuple. `planSlot` contains the tuple that was generated by the `ModifyTable` plan node's subplan; in particular, it will carry any junk columns that were requested by `AddForeignUpdateTargets`. The junk column(s) must be used to identify the tuple to be deleted.

The return value is either a slot containing the row that was deleted, or `NULL` if no row was deleted (typically as a result of triggers). The passed-in `slot` can be used to hold the tuple to be returned.

The data in the returned slot is used only if the `DELETE` query has a `RETURNING` clause or the foreign table has an `AFTER ROW` trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the `RETURNING` clause. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the `ExecForeignDelete` pointer is set to `NULL`, attempts to delete from the foreign table will fail with an error message.

```
void
EndForeignModify(EState *estate,
                ResultRelInfo *rinfo);
```

End the table update and release resources. It is normally not important to release palloc'd memory, but for example open files and connections to remote servers should be cleaned up.

If the `EndForeignModify` pointer is set to `NULL`, no action is taken during executor shutdown.

Tuples inserted into a partitioned table by `INSERT` or `COPY FROM` are routed to partitions. If an FDW supports routable foreign-table partitions, it should also provide the following callback functions. These functions are also called when `COPY FROM` is executed on a foreign table.

```
void  
BeginForeignInsert(ModifyTableState *mtstate,  
                  ResultRelInfo *rinfo);
```

Begin executing an insert operation on a foreign table. This routine is called right before the first tuple is inserted into the foreign table in both cases when it is the partition chosen for tuple routing and the target specified in a `COPY FROM` command. It should perform any initialization needed prior to the actual insertion. Subsequently, `ExecForeignInsert` will be called for each tuple to be inserted into the foreign table.

`mtstate` is the overall state of the `ModifyTable` plan node being executed; global data about the plan and execution state is available via this structure. `rinfo` is the `ResultRelInfo` struct describing the target foreign table. (The `ri_FdwState` field of `ResultRelInfo` is available for the FDW to store any private state it needs for this operation.)

When this is called by a `COPY FROM` command, the plan-related global data in `mtstate` is not provided and the `planSlot` parameter of `ExecForeignInsert` subsequently called for each inserted tuple is `NULL`, whether the foreign table is the partition chosen for tuple routing or the target specified in the command.

If the `BeginForeignInsert` pointer is set to `NULL`, no action is taken for the initialization.

Note that if the FDW does not support routable foreign-table partitions and/or executing `COPY FROM` on foreign tables, this function or `ExecForeignInsert` subsequently called must throw error as needed.

```
void  
EndForeignInsert(ESTate *estate,  
                ResultRelInfo *rinfo);
```

End the insert operation and release resources. It is normally not important to release `malloc'd` memory, but for example open files and connections to remote servers should be cleaned up.

If the `EndForeignInsert` pointer is set to `NULL`, no action is taken for the termination.

```
int  
IsForeignRelUpdatable(Relation rel);
```

Report which update operations the specified foreign table supports. The return value should be a bit mask of rule event numbers indicating which operations are supported by the foreign table, using the `CmdType` enumeration; that is, $(1 \ll \text{CMD_UPDATE}) = 4$ for `UPDATE`, $(1 \ll \text{CMD_INSERT}) = 8$ for `INSERT`, and $(1 \ll \text{CMD_DELETE}) = 16$ for `DELETE`.

If the `IsForeignRelUpdatable` pointer is set to `NULL`, foreign tables are assumed to be insertable, updatable, or deletable if the FDW provides `ExecForeignInsert`, `ExecForeignUpdate`, or `ExecForeignDelete` respectively. This function is only needed if the FDW supports some tables that are updatable and some that are not. (Even then, it's permissible to throw an error in the execution routine instead of checking in this function. However, this function is used to determine updatability for display in the `information_schema` views.)

Some inserts, updates, and deletes to foreign tables can be optimized by implementing an alternative set of interfaces. The ordinary interfaces for inserts, updates, and deletes fetch rows from the remote server and then modify those rows one at a time. In some cases, this row-by-row approach is necessary, but it can be inefficient. If it is possible for the foreign server to determine which rows should be

modified without actually retrieving them, and if there are no local structures which would affect the operation (row-level local triggers, stored generated columns, or `WITH CHECK OPTION` constraints from parent views), then it is possible to arrange things so that the entire operation is performed on the remote server. The interfaces described below make this possible.

```
bool
PlanDirectModify(PlannerInfo *root,
                 ModifyTable *plan,
                 Index resultRelation,
                 int subplan_index);
```

Decide whether it is safe to execute a direct modification on the remote server. If so, return `true` after performing planning actions needed for that. Otherwise, return `false`. This optional function is called during query planning. If this function succeeds, `BeginDirectModify`, `IterateDirectModify` and `EndDirectModify` will be called at the execution stage, instead. Otherwise, the table modification will be executed using the table-updating functions described above. The parameters are the same as for `PlanForeignModify`.

To execute the direct modification on the remote server, this function must rewrite the target subplan with a `ForeignScan` plan node that executes the direct modification on the remote server. The operation field of the `ForeignScan` must be set to the `CmdType` enumeration appropriately; that is, `CMD_UPDATE` for `UPDATE`, `CMD_INSERT` for `INSERT`, and `CMD_DELETE` for `DELETE`.

See Section 56.4 for additional information.

If the `PlanDirectModify` pointer is set to `NULL`, no attempts to execute a direct modification on the remote server are taken.

```
void
BeginDirectModify(ForeignScanState *node,
                  int eflags);
```

Prepare to execute a direct modification on the remote server. This is called during executor startup. It should perform any initialization needed prior to the direct modification (that should be done upon the first call to `IterateDirectModify`). The `ForeignScanState` node has already been created, but its `fdw_state` field is still `NULL`. Information about the table to modify is accessible through the `ForeignScanState` node (in particular, from the underlying `ForeignScan` plan node, which contains any FDW-private information provided by `PlanDirectModify`). `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainDirectModify` and `EndDirectModify`.

If the `BeginDirectModify` pointer is set to `NULL`, no attempts to execute a direct modification on the remote server are taken.

```
TupleTableSlot *
IterateDirectModify(ForeignScanState *node);
```

When the `INSERT`, `UPDATE` or `DELETE` query doesn't have a `RETURNING` clause, just return `NULL` after a direct modification on the remote server. When the query has the clause, fetch one result containing the data needed for the `RETURNING` calculation, returning it in a tuple table slot (the node's `ScanTupleSlot` should be used for this purpose). The data that was actually inserted, updated or deleted must be stored in the `es_result_relation_info->ri_projectReturning->pi_exprContext->ecxt_scantuple` of the node's `EState`. Return `NULL` if no more rows are available. Note that this is called in a short-lived memory context that will be reset between invocations.

Create a memory context in `BeginDirectModify` if you need longer-lived storage, or use the `es_query_cxt` of the node's `EState`.

The rows returned must match the `fdw_scan_tlist` target list if one was supplied, otherwise they must match the row type of the foreign table being updated. If you choose to optimize away fetching columns that are not needed for the `RETURNING` calculation, you should insert nulls in those column positions, or else generate a `fdw_scan_tlist` list with those columns omitted.

Whether the query has the clause or not, the query's reported row count must be incremented by the FDW itself. When the query doesn't have the clause, the FDW must also increment the row count for the `ForeignScanState` node in the `EXPLAIN ANALYZE` case.

If the `IteratedDirectModify` pointer is set to `NULL`, no attempts to execute a direct modification on the remote server are taken.

```
void
EndDirectModify(ForeignScanState *node);
```

Clean up following a direct modification on the remote server. It is normally not important to release `palloc'd` memory, but for example open files and connections to the remote server should be cleaned up.

If the `EndDirectModify` pointer is set to `NULL`, no attempts to execute a direct modification on the remote server are taken.

56.2.5. FDW Routines for Row Locking

If an FDW wishes to support *late row locking* (as described in Section 56.5), it must provide the following callback functions:

```
RowMarkType
GetForeignRowMarkType(RangeTblEntry *rte,
                      LockClauseStrength strength);
```

Report which row-marking option to use for a foreign table. `rte` is the `RangeTblEntry` node for the table and `strength` describes the lock strength requested by the relevant `FOR UPDATE/SHARE` clause, if any. The result must be a member of the `RowMarkType` enum type.

This function is called during query planning for each foreign table that appears in an `UPDATE`, `DELETE`, or `SELECT FOR UPDATE/SHARE` query and is not the target of `UPDATE` or `DELETE`.

If the `GetForeignRowMarkType` pointer is set to `NULL`, the `ROW_MARK_COPY` option is always used. (This implies that `RefetchForeignRow` will never be called, so it need not be provided either.)

See Section 56.5 for more information.

```
void
RefetchForeignRow(EState *estate,
                  ExecRowMark *erm,
                  Datum rowid,
                  TupleTableSlot *slot,
                  bool *updated);
```

Re-fetch one tuple slot from the foreign table, after locking it if required. `estate` is global execution state for the query. `erm` is the `ExecRowMark` struct describing the target foreign table and the row lock type (if any) to acquire. `rowid` identifies the tuple to be fetched. `slot` contains nothing useful upon call, but can be used to hold the returned tuple. `updated` is an output parameter.

This function should store the tuple into the provided slot, or clear it if the row lock couldn't be obtained. The row lock type to acquire is defined by `erm->markType`, which is the value previously returned by `GetForeignRowMarkType`. (`ROW_MARK_REFERENCE` means to just re-fetch the tuple without acquiring any lock, and `ROW_MARK_COPY` will never be seen by this routine.)

In addition, `*updated` should be set to `true` if what was fetched was an updated version of the tuple rather than the same version previously obtained. (If the FDW cannot be sure about this, always returning `true` is recommended.)

Note that by default, failure to acquire a row lock should result in raising an error; returning with an empty slot is only appropriate if the `SKIP_LOCKED` option is specified by `erm->waitPolicy`.

The `rowid` is the `ctid` value previously read for the row to be re-fetched. Although the `rowid` value is passed as a `Datum`, it can currently only be a `tid`. The function API is chosen in hopes that it may be possible to allow other data types for row IDs in future.

If the `RefetchForeignRow` pointer is set to `NULL`, attempts to re-fetch rows will fail with an error message.

See Section 56.5 for more information.

```
bool
RecheckForeignScan(ForeignScanState *node,
                   TupleTableSlot *slot);
```

Recheck that a previously-returned tuple still matches the relevant scan and join qualifiers, and possibly provide a modified version of the tuple. For foreign data wrappers which do not perform join pushdown, it will typically be more convenient to set this to `NULL` and instead set `fdw_recheck_qual` appropriately. When outer joins are pushed down, however, it isn't sufficient to reapply the checks relevant to all the base tables to the result tuple, even if all needed attributes are present, because failure to match some qualifier might result in some attributes going to `NULL`, rather than in no tuple being returned. `RecheckForeignScan` can recheck qualifiers and return `true` if they are still satisfied and `false` otherwise, but it can also store a replacement tuple into the supplied slot.

To implement join pushdown, a foreign data wrapper will typically construct an alternative local join plan which is used only for rechecks; this will become the outer subplan of the `ForeignScan`. When a recheck is required, this subplan can be executed and the resulting tuple can be stored in the slot. This plan need not be efficient since no base table will return more than one row; for example, it may implement all joins as nested loops. The function `GetExistingLocalJoinPath` may be used to search existing paths for a suitable local join path, which can be used as the alternative local join plan. `GetExistingLocalJoinPath` searches for an unparameterized path in the path list of the specified join relation. (If it does not find such a path, it returns `NULL`, in which case a foreign data wrapper may build the local path by itself or may choose not to create access paths for that join.)

56.2.6. FDW Routines for EXPLAIN

```
void
ExplainForeignScan(ForeignScanState *node,
                   ExplainState *es);
```

Print additional `EXPLAIN` output for a foreign table scan. This function can call `ExplainPropertyText` and related functions to add fields to the `EXPLAIN` output. The flag fields in `es` can be used to determine what to print, and the state of the `ForeignScanState` node can be inspected to provide run-time statistics in the `EXPLAIN ANALYZE` case.

If the `ExplainForeignScan` pointer is set to `NULL`, no additional information is printed during `EXPLAIN`.

```
void
ExplainForeignModify(ModifyTableState *mtstate,
                    ResultRelInfo *rinfo,
                    List *fdw_private,
                    int subplan_index,
                    struct ExplainState *es);
```

Print additional EXPLAIN output for a foreign table update. This function can call `ExplainPropertyText` and related functions to add fields to the EXPLAIN output. The flag fields in `es` can be used to determine what to print, and the state of the `ModifyTableState` node can be inspected to provide run-time statistics in the EXPLAIN ANALYZE case. The first four arguments are the same as for `BeginForeignModify`.

If the `ExplainForeignModify` pointer is set to `NULL`, no additional information is printed during EXPLAIN.

```
void
ExplainDirectModify(ForeignScanState *node,
                  ExplainState *es);
```

Print additional EXPLAIN output for a direct modification on the remote server. This function can call `ExplainPropertyText` and related functions to add fields to the EXPLAIN output. The flag fields in `es` can be used to determine what to print, and the state of the `ForeignScanState` node can be inspected to provide run-time statistics in the EXPLAIN ANALYZE case.

If the `ExplainDirectModify` pointer is set to `NULL`, no additional information is printed during EXPLAIN.

56.2.7. FDW Routines for ANALYZE

```
bool
AnalyzeForeignTable(Relation relation,
                  AcquireSampleRowsFunc *func,
                  BlockNumber *totalpages);
```

This function is called when ANALYZE is executed on a foreign table. If the FDW can collect statistics for this foreign table, it should return `true`, and provide a pointer to a function that will collect sample rows from the table in `func`, plus the estimated size of the table in pages in `totalpages`. Otherwise, return `false`.

If the FDW does not support collecting statistics for any tables, the `AnalyzeForeignTable` pointer can be set to `NULL`.

If provided, the sample collection function must have the signature

```
int
AcquireSampleRowsFunc(Relation relation,
                    int elevel,
                    HeapTuple *rows,
                    int targrows,
                    double *totalrows,
                    double *totaldeadrows);
```

A random sample of up to `targrows` rows should be collected from the table and stored into the caller-provided `rows` array. The actual number of rows collected must be returned. In addition, store estimates of the total numbers of live and dead rows in the table into the output parameters `total-`

rows and *totaldeadrows*. (Set *totaldeadrows* to zero if the FDW does not have any concept of dead rows.)

56.2.8. FDW Routines for IMPORT FOREIGN SCHEMA

```
List *
ImportForeignSchema(ImportForeignSchemaStmt *stmt, Oid serverOid);
```

Obtain a list of foreign table creation commands. This function is called when executing IMPORT FOREIGN SCHEMA, and is passed the parse tree for that statement, as well as the OID of the foreign server to use. It should return a list of C strings, each of which must contain a CREATE FOREIGN TABLE command. These strings will be parsed and executed by the core server.

Within the `ImportForeignSchemaStmt` struct, `remote_schema` is the name of the remote schema from which tables are to be imported. `list_type` identifies how to filter table names: `FDW_IMPORT_SCHEMA_ALL` means that all tables in the remote schema should be imported (in this case `table_list` is empty), `FDW_IMPORT_SCHEMA_LIMIT_TO` means to include only tables listed in `table_list`, and `FDW_IMPORT_SCHEMA_EXCEPT` means to exclude the tables listed in `table_list`. `options` is a list of options used for the import process. The meanings of the options are up to the FDW. For example, an FDW could use an option to define whether the NOT NULL attributes of columns should be imported. These options need not have anything to do with those supported by the FDW as database object options.

The FDW may ignore the `local_schema` field of the `ImportForeignSchemaStmt`, because the core server will automatically insert that name into the parsed CREATE FOREIGN TABLE commands.

The FDW does not have to concern itself with implementing the filtering specified by `list_type` and `table_list`, either, as the core server will automatically skip any returned commands for tables excluded according to those options. However, it's often useful to avoid the work of creating commands for excluded tables in the first place. The function `IsImportableForeignTable()` may be useful to test whether a given foreign-table name will pass the filter.

If the FDW does not support importing table definitions, the `ImportForeignSchema` pointer can be set to NULL.

56.2.9. FDW Routines for Parallel Execution

A `ForeignScan` node can, optionally, support parallel execution. A parallel `ForeignScan` will be executed in multiple processes and must return each row exactly once across all cooperating processes. To do this, processes can coordinate through fixed-size chunks of dynamic shared memory. This shared memory is not guaranteed to be mapped at the same address in every process, so it must not contain pointers. The following functions are all optional, but most are required if parallel execution is to be supported.

```
bool
IsForeignScanParallelSafe(PlannerInfo *root, RelOptInfo *rel,
                          RangeTblEntry *rte);
```

Test whether a scan can be performed within a parallel worker. This function will only be called when the planner believes that a parallel plan might be possible, and should return true if it is safe for that scan to run within a parallel worker. This will generally not be the case if the remote data source has transaction semantics, unless the worker's connection to the data can somehow be made to share the same transaction context as the leader.

If this function is not defined, it is assumed that the scan must take place within the parallel leader. Note that returning true does not mean that the scan itself can be done in parallel, only that the scan

can be performed within a parallel worker. Therefore, it can be useful to define this method even when parallel execution is not supported.

```
Size
EstimateDSMForeignScan(ForeignScanState *node, ParallelContext
    *pcxt);
```

Estimate the amount of dynamic shared memory that will be required for parallel operation. This may be higher than the amount that will actually be used, but it must not be lower. The return value is in bytes. This function is optional, and can be omitted if not needed; but if it is omitted, the next three functions must be omitted as well, because no shared memory will be allocated for the FDW's use.

```
void
InitializeDSMForeignScan(ForeignScanState *node, ParallelContext
    *pcxt,
                        void *coordinate);
```

Initialize the dynamic shared memory that will be required for parallel operation. `coordinate` points to a shared memory area of size equal to the return value of `EstimateDSMForeignScan`. This function is optional, and can be omitted if not needed.

```
void
ReInitializeDSMForeignScan(ForeignScanState *node, ParallelContext
    *pcxt,
                        void *coordinate);
```

Re-initialize the dynamic shared memory required for parallel operation when the foreign-scan plan node is about to be re-scanned. This function is optional, and can be omitted if not needed. Recommended practice is that this function reset only shared state, while the `ReScanForeignScan` function resets only local state. Currently, this function will be called before `ReScanForeignScan`, but it's best not to rely on that ordering.

```
void
InitializeWorkerForeignScan(ForeignScanState *node, shm_toc *toc,
    void *coordinate);
```

Initialize a parallel worker's local state based on the shared state set up by the leader during `InitializeDSMForeignScan`. This function is optional, and can be omitted if not needed.

```
void
ShutdownForeignScan(ForeignScanState *node);
```

Release resources when it is anticipated the node will not be executed to completion. This is not called in all cases; sometimes, `EndForeignScan` may be called without this function having been called first. Since the DSM segment used by parallel query is destroyed just after this callback is invoked, foreign data wrappers that wish to take some action before the DSM segment goes away should implement this method.

56.2.10. FDW Routines for Reparameterization of Paths

```
List *
ReparameterizeForeignPathByChild(PlannerInfo *root, List
    *fdw_private,
```

```
RelOptInfo *child_rel);
```

This function is called while converting a path parameterized by the top-most parent of the given child relation `child_rel` to be parameterized by the child relation. The function is used to reparameterize any paths or translate any expression nodes saved in the given `fdw_private` member of a `ForeignPath`. The callback may use `reparameterize_path_by_child`, `adjust_appendrel_attrs` or `adjust_appendrel_attrs_multilevel` as required.

56.3. Foreign Data Wrapper Helper Functions

Several helper functions are exported from the core server so that authors of foreign data wrappers can get easy access to attributes of FDW-related objects, such as FDW options. To use any of these functions, you need to include the header file `foreign/foreign.h` in your source file. That header also defines the struct types that are returned by these functions.

```
ForeignDataWrapper *  
GetForeignDataWrapperExtended(Oid fdwid, bits16 flags);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given OID. A `ForeignDataWrapper` object contains properties of the FDW (see `foreign/foreign.h` for details). `flags` is a bitwise-or'd bit mask indicating an extra set of options. It can take the value `FDW_MISSING_OK`, in which case a NULL result is returned to the caller instead of an error for an undefined object.

```
ForeignDataWrapper *  
GetForeignDataWrapper(Oid fdwid);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given OID. A `ForeignDataWrapper` object contains properties of the FDW (see `foreign/foreign.h` for details).

```
ForeignServer *  
GetForeignServerExtended(Oid serverid, bits16 flags);
```

This function returns a `ForeignServer` object for the foreign server with the given OID. A `ForeignServer` object contains properties of the server (see `foreign/foreign.h` for details). `flags` is a bitwise-or'd bit mask indicating an extra set of options. It can take the value `FSV_MISSING_OK`, in which case a NULL result is returned to the caller instead of an error for an undefined object.

```
ForeignServer *  
GetForeignServer(Oid serverid);
```

This function returns a `ForeignServer` object for the foreign server with the given OID. A `ForeignServer` object contains properties of the server (see `foreign/foreign.h` for details).

```
UserMapping *  
GetUserMapping(Oid userid, Oid serverid);
```

This function returns a `UserMapping` object for the user mapping of the given role on the given server. (If there is no mapping for the specific user, it will return the mapping for `PUBLIC`, or throw error if there is none.) A `UserMapping` object contains properties of the user mapping (see `foreign/foreign.h` for details).

```
ForeignTable *  
GetForeignTable(Oid relid);
```

This function returns a `ForeignTable` object for the foreign table with the given OID. A `ForeignTable` object contains properties of the foreign table (see `foreign/foreign.h` for details).

```
List *  
GetForeignColumnOptions(Oid relid, AttrNumber attnum);
```

This function returns the per-column FDW options for the column with the given foreign table OID and attribute number, in the form of a list of `DefElem`. `NIL` is returned if the column has no options.

Some object types have name-based lookup functions in addition to the OID-based ones:

```
ForeignDataWrapper *  
GetForeignDataWrapperByName(const char *name, bool missing_ok);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given name. If the wrapper is not found, return `NULL` if `missing_ok` is true, otherwise raise an error.

```
ForeignServer *  
GetForeignServerByName(const char *name, bool missing_ok);
```

This function returns a `ForeignServer` object for the foreign server with the given name. If the server is not found, return `NULL` if `missing_ok` is true, otherwise raise an error.

56.4. Foreign Data Wrapper Query Planning

The FDW callback functions `GetForeignRelSize`, `GetForeignPaths`, `GetForeignPlan`, `PlanForeignModify`, `GetForeignJoinPaths`, `GetForeignUpperPaths`, and `PlanDirectModify` must fit into the workings of the PostgreSQL planner. Here are some notes about what they must do.

The information in `root` and `baserel` can be used to reduce the amount of information that has to be fetched from the foreign table (and therefore reduce the cost). `baserel->baserestrictinfo` is particularly interesting, as it contains restriction quals (`WHERE` clauses) that should be used to filter the rows to be fetched. (The FDW itself is not required to enforce these quals, as the core executor can check them instead.) `baserel->reltarget->exprs` can be used to determine which columns need to be fetched; but note that it only lists columns that have to be emitted by the `ForeignScan` plan node, not columns that are used in qual evaluation but not output by the query.

Various private fields are available for the FDW planning functions to keep information in. Generally, whatever you store in FDW private fields should be `palloc'd`, so that it will be reclaimed at the end of planning.

`baserel->fdw_private` is a void pointer that is available for FDW planning functions to store information relevant to the particular foreign table. The core planner does not touch it except to initialize it to `NULL` when the `RelOptInfo` node is created. It is useful for passing information forward from `GetForeignRelSize` to `GetForeignPaths` and/or `GetForeignPaths` to `GetForeignPlan`, thereby avoiding recalculation.

`GetForeignPaths` can identify the meaning of different access paths by storing private information in the `fdw_private` field of `ForeignPath` nodes. `fdw_private` is declared as a `List` pointer, but could actually contain anything since the core planner does not touch it. However, best practice is to use a representation that's dumpable by `nodeToString`, for use with debugging support available in the backend.

`GetForeignPlan` can examine the `fdw_private` field of the selected `ForeignPath` node, and can generate `fdw_exprs` and `fdw_private` lists to be placed in the `ForeignScan` plan node, where they will be available at execution time. Both of these lists must be represented in a form that `copyObject` knows how to copy. The `fdw_private` list has no other restrictions and is not interpreted by the core backend in any way. The `fdw_exprs` list, if not `NIL`, is expected to contain expression trees that are intended to be executed at run time. These trees will undergo post-processing by the planner to make them fully executable.

In `GetForeignPlan`, generally the passed-in target list can be copied into the plan node as-is. The passed `scan_clauses` list contains the same clauses as `basere1->baserestrictinfo`, but may be re-ordered for better execution efficiency. In simple cases the FDW can just strip `RestrictInfo` nodes from the `scan_clauses` list (using `extract_actual_clauses`) and put all the clauses into the plan node's qual list, which means that all the clauses will be checked by the executor at run time. More complex FDWs may be able to check some of the clauses internally, in which case those clauses can be removed from the plan node's qual list so that the executor doesn't waste time rechecking them.

As an example, the FDW might identify some restriction clauses of the form `foreign_variable = sub_expression`, which it determines can be executed on the remote server given the locally-evaluated value of the `sub_expression`. The actual identification of such a clause should happen during `GetForeignPaths`, since it would affect the cost estimate for the path. The path's `fdw_private` field would probably include a pointer to the identified clause's `RestrictInfo` node. Then `GetForeignPlan` would remove that clause from `scan_clauses`, but add the `sub_expression` to `fdw_exprs` to ensure that it gets massaged into executable form. It would probably also put control information into the plan node's `fdw_private` field to tell the execution functions what to do at run time. The query transmitted to the remote server would involve something like `WHERE foreign_variable = $1`, with the parameter value obtained at run time from evaluation of the `fdw_exprs` expression tree.

Any clauses removed from the plan node's qual list must instead be added to `fdw_recheck_qual`s or rechecked by `RecheckForeignScan` in order to ensure correct behavior at the `READ COMMITTED` isolation level. When a concurrent update occurs for some other table involved in the query, the executor may need to verify that all of the original quals are still satisfied for the tuple, possibly against a different set of parameter values. Using `fdw_recheck_qual`s is typically easier than implementing checks inside `RecheckForeignScan`, but this method will be insufficient when outer joins have been pushed down, since the join tuples in that case might have some fields go to `NULL` without rejecting the tuple entirely.

Another `ForeignScan` field that can be filled by FDWs is `fdw_scan_tlist`, which describes the tuples returned by the FDW for this plan node. For simple foreign table scans this can be set to `NIL`, implying that the returned tuples have the row type declared for the foreign table. A non-`NIL` value must be a target list (list of `TargetEntries`) containing `Vars` and/or expressions representing the returned columns. This might be used, for example, to show that the FDW has omitted some columns that it noticed won't be needed for the query. Also, if the FDW can compute expressions used by the query more cheaply than can be done locally, it could add those expressions to `fdw_scan_tlist`. Note that join plans (created from paths made by `GetForeignJoinPaths`) must always supply `fdw_scan_tlist` to describe the set of columns they will return.

The FDW should always construct at least one path that depends only on the table's restriction clauses. In join queries, it might also choose to construct path(s) that depend on join clauses, for example `foreign_variable = local_variable`. Such clauses will not be found in `basere1->baserestrictinfo` but must be sought in the relation's join lists. A path using such a clause is called a "parameterized path". It must identify the other relations used in the selected join clause(s) with a suitable value of `param_info`; use `get_basere1_parampathinfo` to compute that value. In `GetForeignPlan`, the `local_variable` portion of the join clause would be added to `fdw_exprs`, and then at run time the case works the same as for an ordinary restriction clause.

If an FDW supports remote joins, `GetForeignJoinPaths` should produce `ForeignPaths` for potential remote joins in much the same way as `GetForeignPaths` works for base tables. Informa-

tion about the intended join can be passed forward to `GetForeignPlan` in the same ways described above. However, `baserestrictinfo` is not relevant for join relations; instead, the relevant join clauses for a particular join are passed to `GetForeignJoinPaths` as a separate parameter (`extra->restrictlist`).

An FDW might additionally support direct execution of some plan actions that are above the level of scans and joins, such as grouping or aggregation. To offer such options, the FDW should generate paths and insert them into the appropriate *upper relation*. For example, a path representing remote aggregation should be inserted into the `UPPERREL_GROUP_AGG` relation, using `add_path`. This path will be compared on a cost basis with local aggregation performed by reading a simple scan path for the foreign relation (note that such a path must also be supplied, else there will be an error at plan time). If the remote-aggregation path wins, which it usually would, it will be converted into a plan in the usual way, by calling `GetForeignPlan`. The recommended place to generate such paths is in the `GetForeignUpperPaths` callback function, which is called for each upper relation (i.e., each post-scan/join processing step), if all the base relations of the query come from the same FDW.

`PlanForeignModify` and the other callbacks described in Section 56.2.4 are designed around the assumption that the foreign relation will be scanned in the usual way and then individual row updates will be driven by a local `ModifyTable` plan node. This approach is necessary for the general case where an update requires reading local tables as well as foreign tables. However, if the operation could be executed entirely by the foreign server, the FDW could generate a path representing that and insert it into the `UPPERREL_FINAL` upper relation, where it would compete against the `ModifyTable` approach. This approach could also be used to implement remote `SELECT FOR UPDATE`, rather than using the row locking callbacks described in Section 56.2.5. Keep in mind that a path inserted into `UPPERREL_FINAL` is responsible for implementing *all* behavior of the query.

When planning an `UPDATE` or `DELETE`, `PlanForeignModify` and `PlanDirectModify` can look up the `RelOptInfo` struct for the foreign table and make use of the `baserel->fdw_private` data previously created by the scan-planning functions. However, in `INSERT` the target table is not scanned so there is no `RelOptInfo` for it. The `List` returned by `PlanForeignModify` has the same restrictions as the `fdw_private` list of a `ForeignScan` plan node, that is it must contain only structures that `copyObject` knows how to copy.

`INSERT` with an `ON CONFLICT` clause does not support specifying the conflict target, as unique constraints or exclusion constraints on remote tables are not locally known. This in turn implies that `ON CONFLICT DO UPDATE` is not supported, since the specification is mandatory there.

56.5. Row Locking in Foreign Data Wrappers

If an FDW's underlying storage mechanism has a concept of locking individual rows to prevent concurrent updates of those rows, it is usually worthwhile for the FDW to perform row-level locking with as close an approximation as practical to the semantics used in ordinary PostgreSQL tables. There are multiple considerations involved in this.

One key decision to be made is whether to perform *early locking* or *late locking*. In early locking, a row is locked when it is first retrieved from the underlying store, while in late locking, the row is locked only when it is known that it needs to be locked. (The difference arises because some rows may be discarded by locally-checked restriction or join conditions.) Early locking is much simpler and avoids extra round trips to a remote store, but it can cause locking of rows that need not have been locked, resulting in reduced concurrency or even unexpected deadlocks. Also, late locking is only possible if the row to be locked can be uniquely re-identified later. Preferably the row identifier should identify a specific version of the row, as PostgreSQL TIDs do.

By default, PostgreSQL ignores locking considerations when interfacing to FDWs, but an FDW can perform early locking without any explicit support from the core code. The API functions described in Section 56.2.5, which were added in PostgreSQL 9.5, allow an FDW to use late locking if it wishes.

An additional consideration is that in `READ COMMITTED` isolation mode, PostgreSQL may need to re-check restriction and join conditions against an updated version of some target tuple. Rechecking

join conditions requires re-obtaining copies of the non-target rows that were previously joined to the target tuple. When working with standard PostgreSQL tables, this is done by including the TIDs of the non-target tables in the column list projected through the join, and then re-fetching non-target rows when required. This approach keeps the join data set compact, but it requires inexpensive re-fetch capability, as well as a TID that can uniquely identify the row version to be re-fetched. By default, therefore, the approach used with foreign tables is to include a copy of the entire row fetched from a foreign table in the column list projected through the join. This puts no special demands on the FDW but can result in reduced performance of merge and hash joins. An FDW that is capable of meeting the re-fetch requirements can choose to do it the first way.

For an UPDATE or DELETE on a foreign table, it is recommended that the ForeignScan operation on the target table perform early locking on the rows that it fetches, perhaps via the equivalent of SELECT FOR UPDATE. An FDW can detect whether a table is an UPDATE/DELETE target at plan time by comparing its relid to root->parse->resultRelation, or at execution time by using ExecRelationIsTargetRelation(). An alternative possibility is to perform late locking within the ExecForeignUpdate or ExecForeignDelete callback, but no special support is provided for this.

For foreign tables that are specified to be locked by a SELECT FOR UPDATE/SHARE command, the ForeignScan operation can again perform early locking by fetching tuples with the equivalent of SELECT FOR UPDATE/SHARE. To perform late locking instead, provide the callback functions defined in Section 56.2.5. In GetForeignRowMarkType, select rowmark option ROW_MARK_EXCLUSIVE, ROW_MARK_NOKEYEXCLUSIVE, ROW_MARK_SHARE, or ROW_MARK_KEYSHARE depending on the requested lock strength. (The core code will act the same regardless of which of these four options you choose.) Elsewhere, you can detect whether a foreign table was specified to be locked by this type of command by using get_plan_rowmark at plan time, or ExecFindRowMark at execution time; you must check not only whether a non-null rowmark struct is returned, but that its strength field is not LCS_NONE.

Lastly, for foreign tables that are used in an UPDATE, DELETE or SELECT FOR UPDATE/SHARE command but are not specified to be row-locked, you can override the default choice to copy entire rows by having GetForeignRowMarkType select option ROW_MARK_REFERENCE when it sees lock strength LCS_NONE. This will cause RefetchForeignRow to be called with that value for markType; it should then re-fetch the row without acquiring any new lock. (If you have a GetForeignRowMarkType function but don't wish to re-fetch unlocked rows, select option ROW_MARK_COPY for LCS_NONE.)

See src/include/nodes/lockoptions.h, the comments for RowMarkType and PlanRowMark in src/include/nodes/plannodes.h, and the comments for ExecRowMark in src/include/nodes/execnodes.h for additional information.

Chapter 57. Writing a Table Sampling Method

PostgreSQL's implementation of the `TABLESAMPLE` clause supports custom table sampling methods, in addition to the `BERNOULLI` and `SYSTEM` methods that are required by the SQL standard. The sampling method determines which rows of the table will be selected when the `TABLESAMPLE` clause is used.

At the SQL level, a table sampling method is represented by a single SQL function, typically implemented in C, having the signature

```
method_name(internal) RETURNS tsm_handler
```

The name of the function is the same method name appearing in the `TABLESAMPLE` clause. The `internal` argument is a dummy (always having value zero) that simply serves to prevent this function from being called directly from a SQL command. The result of the function must be a palloc'd struct of type `TsmRoutine`, which contains pointers to support functions for the sampling method. These support functions are plain C functions and are not visible or callable at the SQL level. The support functions are described in Section 57.1.

In addition to function pointers, the `TsmRoutine` struct must provide these additional fields:

```
List *parameterTypes
```

This is an OID list containing the data type OIDs of the parameter(s) that will be accepted by the `TABLESAMPLE` clause when this sampling method is used. For example, for the built-in methods, this list contains a single item with value `FLOAT4OID`, which represents the sampling percentage. Custom sampling methods can have more or different parameters.

```
bool repeatable_across_queries
```

If `true`, the sampling method can deliver identical samples across successive queries, if the same parameters and `REPEATABLE` seed value are supplied each time and the table contents have not changed. When this is `false`, the `REPEATABLE` clause is not accepted for use with the sampling method.

```
bool repeatable_across_scans
```

If `true`, the sampling method can deliver identical samples across successive scans in the same query (assuming unchanging parameters, seed value, and snapshot). When this is `false`, the planner will not select plans that would require scanning the sampled table more than once, since that might result in inconsistent query output.

The `TsmRoutine` struct type is declared in `src/include/access/tsmapi.h`, which see for additional details.

The table sampling methods included in the standard distribution are good references when trying to write your own. Look into the `src/backend/access/tablesample` subdirectory of the source tree for the built-in sampling methods, and into the `contrib` subdirectory for add-on methods.

57.1. Sampling Method Support Functions

The TSM handler function returns a palloc'd `TsmRoutine` struct containing pointers to the support functions described below. Most of the functions are required, but some are optional, and those pointers can be `NULL`.

```
void
SampleScanGetSampleSize (PlannerInfo *root,
                        RelOptInfo *baserel,
                        List *paramexprs,
                        BlockNumber *pages,
                        double *tuples);
```

This function is called during planning. It must estimate the number of relation pages that will be read during a sample scan, and the number of tuples that will be selected by the scan. (For example, these might be determined by estimating the sampling fraction, and then multiplying the `baserel->pages` and `baserel->tuples` numbers by that, being sure to round the results to integral values.) The `paramexprs` list holds the expression(s) that are parameters to the `TABLESAMPLE` clause. It is recommended to use `estimate_expression_value()` to try to reduce these expressions to constants, if their values are needed for estimation purposes; but the function must provide size estimates even if they cannot be reduced, and it should not fail even if the values appear invalid (remember that they're only estimates of what the run-time values will be). The `pages` and `tuples` parameters are outputs.

```
void
InitSampleScan (SampleScanState *node,
               int eflags);
```

Initialize for execution of a `SampleScan` plan node. This is called during executor startup. It should perform any initialization needed before processing can start. The `SampleScanState` node has already been created, but its `tsm_state` field is `NULL`. The `InitSampleScan` function can `malloc` whatever internal state data is needed by the sampling method, and store a pointer to it in `node->tsm_state`. Information about the table to scan is accessible through other fields of the `SampleScanState` node (but note that the `node->ss.ss_currentScanDesc` scan descriptor is not set up yet). `eflags` contains flag bits describing the executor's operating mode for this plan node.

When `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, the scan will not actually be performed, so this function should only do the minimum required to make the node state valid for `EXPLAIN` and `EndSampleScan`.

This function can be omitted (set the pointer to `NULL`), in which case `BeginSampleScan` must perform all initialization needed by the sampling method.

```
void
BeginSampleScan (SampleScanState *node,
                Datum *params,
                int nparams,
                uint32 seed);
```

Begin execution of a sampling scan. This is called just before the first attempt to fetch a tuple, and may be called again if the scan needs to be restarted. Information about the table to scan is accessible through fields of the `SampleScanState` node (but note that the `node->ss.ss_currentScanDesc` scan descriptor is not set up yet). The `params` array, of length `nparams`, contains the values of the parameters supplied in the `TABLESAMPLE` clause. These will have the number and types specified in the sampling method's `parameterTypes` list, and have been checked to not be null. `seed` contains a seed to use for any random numbers generated within the sampling method; it is either a hash derived from the `REPEATABLE` value if one was given, or the result of `random()` if not.

This function may adjust the fields `node->use_bulkread` and `node->use_pagemode`. If `node->use_bulkread` is true, which it is by default, the scan will use a buffer access strategy that encourages recycling buffers after use. It might be reasonable to set this to false if the scan will visit only a small fraction of the table's pages. If `node->use_pagemode` is true, which it is by

default, the scan will perform visibility checking in a single pass for all tuples on each visited page. It might be reasonable to set this to `false` if the scan will select only a small fraction of the tuples on each visited page. That will result in fewer tuple visibility checks being performed, though each one will be more expensive because it will require more locking.

If the sampling method is marked `repeatable_across_scans`, it must be able to select the same set of tuples during a rescan as it did originally, that is a fresh call of `BeginSampleScan` must lead to selecting the same tuples as before (if the `TABLESAMPLE` parameters and seed don't change).

```
BlockNumber
NextSampleBlock (SampleScanState *node, BlockNumber nblocks);
```

Returns the block number of the next page to be scanned, or `InvalidBlockNumber` if no pages remain to be scanned.

This function can be omitted (set the pointer to `NULL`), in which case the core code will perform a sequential scan of the entire relation. Such a scan can use synchronized scanning, so that the sampling method cannot assume that the relation pages are visited in the same order on each scan.

```
OffsetNumber
NextSampleTuple (SampleScanState *node,
                BlockNumber blockno,
                OffsetNumber maxoffset);
```

Returns the offset number of the next tuple to be sampled on the specified page, or `InvalidOffsetNumber` if no tuples remain to be sampled. `maxoffset` is the largest offset number in use on the page.

Note

`NextSampleTuple` is not explicitly told which of the offset numbers in the range `1 .. maxoffset` actually contain valid tuples. This is not normally a problem since the core code ignores requests to sample missing or invisible tuples; that should not result in any bias in the sample. However, if necessary, the function can use `node->donetuples` to examine how many of the tuples it returned were valid and visible.

Note

`NextSampleTuple` must *not* assume that `blockno` is the same page number returned by the most recent `NextSampleBlock` call. It was returned by some previous `NextSampleBlock` call, but the core code is allowed to call `NextSampleBlock` in advance of actually scanning pages, so as to support prefetching. It is OK to assume that once sampling of a given page begins, successive `NextSampleTuple` calls all refer to the same page until `InvalidOffsetNumber` is returned.

```
void
EndSampleScan (SampleScanState *node);
```

End the scan and release resources. It is normally not important to release `palloc'd` memory, but any externally-visible resources should be cleaned up. This function can be omitted (set the pointer to `NULL`) in the common case where no such resources exist.

Chapter 58. Writing a Custom Scan Provider

PostgreSQL supports a set of experimental facilities which are intended to allow extension modules to add new scan types to the system. Unlike a foreign data wrapper, which is only responsible for knowing how to scan its own foreign tables, a custom scan provider can provide an alternative method of scanning any relation in the system. Typically, the motivation for writing a custom scan provider will be to allow the use of some optimization not supported by the core system, such as caching or some form of hardware acceleration. This chapter outlines how to write a new custom scan provider.

Implementing a new type of custom scan is a three-step process. First, during planning, it is necessary to generate access paths representing a scan using the proposed strategy. Second, if one of those access paths is selected by the planner as the optimal strategy for scanning a particular relation, the access path must be converted to a plan. Finally, it must be possible to execute the plan and generate the same results that would have been generated for any other access path targeting the same relation.

58.1. Creating Custom Scan Paths

A custom scan provider will typically add paths for a base relation by setting the following hook, which is called after the core code has generated all the access paths it can for the relation (except for Gather paths, which are made after this call so that they can use partial paths added by the hook):

```
typedef void (*set_rel_pathlist_hook_type) (PlannerInfo *root,
                                           RelOptInfo *rel,
                                           Index rti,
                                           RangeTblEntry *rte);
extern PGDLLIMPORT set_rel_pathlist_hook_type
  set_rel_pathlist_hook;
```

Although this hook function can be used to examine, modify, or remove paths generated by the core system, a custom scan provider will typically confine itself to generating `CustomPath` objects and adding them to `rel` using `add_path`. The custom scan provider is responsible for initializing the `CustomPath` object, which is declared like this:

```
typedef struct CustomPath
{
    Path      path;
    uint32    flags;
    List      *custom_paths;
    List      *custom_private;
    const CustomPathMethods *methods;
} CustomPath;
```

`path` must be initialized as for any other path, including the row-count estimate, start and total cost, and sort ordering provided by this path. `flags` is a bit mask, which should include `CUSTOM_PATH_SUPPORT_BACKWARD_SCAN` if the custom path can support a backward scan and `CUSTOM_PATH_SUPPORT_MARK_RESTORE` if it can support mark and restore. Both capabilities are optional. An optional `custom_paths` is a list of `Path` nodes used by this custom-path node; these will be transformed into `Plan` nodes by planner. `custom_private` can be used to store the custom path's private data. Private data should be stored in a form that can be handled by `nodeToString`, so that debugging routines that attempt to print the custom path will work as designed. `methods` must point to a (usually statically allocated) object implementing the required custom path methods, of which there is currently only one.

A custom scan provider can also provide join paths. Just as for base relations, such a path must produce the same output as would normally be produced by the join it replaces. To do this, the join provider should set the following hook, and then within the hook function, create `CustomPath` path(s) for the join relation.

```
typedef void (*set_join_pathlist_hook_type) (PlannerInfo *root,
                                             RelOptInfo *joinrel,
                                             RelOptInfo *outerrel,
                                             RelOptInfo *innerrel,
                                             JoinType jointype,
                                             JoinPathExtraData
                                             *extra);
extern PGDLLIMPORT set_join_pathlist_hook_type
set_join_pathlist_hook;
```

This hook will be invoked repeatedly for the same join relation, with different combinations of inner and outer relations; it is the responsibility of the hook to minimize duplicated work.

58.1.1. Custom Scan Path Callbacks

```
Plan *(*PlanCustomPath) (PlannerInfo *root,
                          RelOptInfo *rel,
                          CustomPath *best_path,
                          List *tlist,
                          List *clauses,
                          List *custom_plans);
```

Convert a custom path to a finished plan. The return value will generally be a `CustomScan` object, which the callback must allocate and initialize. See Section 58.2 for more details.

58.2. Creating Custom Scan Plans

A custom scan is represented in a finished plan tree using the following structure:

```
typedef struct CustomScan
{
    Scan        scan;
    uint32     flags;
    List        *custom_plans;
    List        *custom_exprs;
    List        *custom_private;
    List        *custom_scan_tlist;
    Bitmapset   *custom_relids;
    const CustomScanMethods *methods;
} CustomScan;
```

`scan` must be initialized as for any other scan, including estimated costs, target lists, qualifications, and so on. `flags` is a bit mask with the same meaning as in `CustomPath`. `custom_plans` can be used to store child `Plan` nodes. `custom_exprs` should be used to store expression trees that will need to be fixed up by `setrefs.c` and `subselect.c`, while `custom_private` should be used to store other private data that is only used by the custom scan provider itself. `custom_scan_tlist` can be `NIL` when scanning a base relation, indicating that the custom scan returns scan tuples that match the base relation's row type. Otherwise it is a target list describing the actual scan tuples. `custom_scan_tlist` must be provided for joins, and could be provided for scans if the

custom scan provider can compute some non-Var expressions. `custom_relids` is set by the core code to the set of relations (range table indexes) that this scan node handles; except when this scan is replacing a join, it will have only one member. `methods` must point to a (usually statically allocated) object implementing the required custom scan methods, which are further detailed below.

When a `CustomScan` scans a single relation, `scan.scanrelid` must be the range table index of the table to be scanned. When it replaces a join, `scan.scanrelid` should be zero.

Plan trees must be able to be duplicated using `copyObject`, so all the data stored within the “custom” fields must consist of nodes that that function can handle. Furthermore, custom scan providers cannot substitute a larger structure that embeds a `CustomScan` for the structure itself, as would be possible for a `CustomPath` or `CustomScanState`.

58.2.1. Custom Scan Plan Callbacks

```
Node *(*CreateCustomScanState) (CustomScan *cscan);
```

Allocate a `CustomScanState` for this `CustomScan`. The actual allocation will often be larger than required for an ordinary `CustomScanState`, because many providers will wish to embed that as the first field of a larger structure. The value returned must have the node tag and `methods` set appropriately, but other fields should be left as zeroes at this stage; after `ExecInitCustomScan` performs basic initialization, the `BeginCustomScan` callback will be invoked to give the custom scan provider a chance to do whatever else is needed.

58.3. Executing Custom Scans

When a `CustomScan` is executed, its execution state is represented by a `CustomScanState`, which is declared as follows:

```
typedef struct CustomScanState
{
    ScanState ss;
    uint32    flags;
    const CustomExecMethods *methods;
} CustomScanState;
```

`ss` is initialized as for any other scan state, except that if the scan is for a join rather than a base relation, `ss.ss_currentRelation` is left `NULL`. `flags` is a bit mask with the same meaning as in `CustomPath` and `CustomScan`. `methods` must point to a (usually statically allocated) object implementing the required custom scan state methods, which are further detailed below. Typically, a `CustomScanState`, which need not support `copyObject`, will actually be a larger structure embedding the above as its first member.

58.3.1. Custom Scan Execution Callbacks

```
void (*BeginCustomScan) (CustomScanState *node,
                        EState *estate,
                        int eflags);
```

Complete initialization of the supplied `CustomScanState`. Standard fields have been initialized by `ExecInitCustomScan`, but any private fields should be initialized here.

```
TupleTableSlot *(*ExecCustomScan) (CustomScanState *node);
```

Fetch the next scan tuple. If any tuples remain, it should fill `ps_ResultTupleSlot` with the next tuple in the current scan direction, and then return the tuple slot. If not, `NULL` or an empty slot should be returned.

```
void (*EndCustomScan) (CustomScanState *node);
```

Clean up any private data associated with the `CustomScanState`. This method is required, but it does not need to do anything if there is no associated data or it will be cleaned up automatically.

```
void (*ReScanCustomScan) (CustomScanState *node);
```

Rewind the current scan to the beginning and prepare to rescan the relation.

```
void (*MarkPosCustomScan) (CustomScanState *node);
```

Save the current scan position so that it can subsequently be restored by the `RestrPosCustomScan` callback. This callback is optional, and need only be supplied if the `CUSTOMPATH_SUPPORT_MARK_RESTORE` flag is set.

```
void (*RestrPosCustomScan) (CustomScanState *node);
```

Restore the previous scan position as saved by the `MarkPosCustomScan` callback. This callback is optional, and need only be supplied if the `CUSTOMPATH_SUPPORT_MARK_RESTORE` flag is set.

```
Size (*EstimateDSMCustomScan) (CustomScanState *node,  
                               ParallelContext *pcxt);
```

Estimate the amount of dynamic shared memory that will be required for parallel operation. This may be higher than the amount that will actually be used, but it must not be lower. The return value is in bytes. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution.

```
void (*InitializeDSMCustomScan) (CustomScanState *node,  
                                ParallelContext *pcxt,  
                                void *coordinate);
```

Initialize the dynamic shared memory that will be required for parallel operation. `coordinate` points to a shared memory area of size equal to the return value of `EstimateDSMCustomScan`. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution.

```
void (*ReInitializeDSMCustomScan) (CustomScanState *node,  
                                  ParallelContext *pcxt,  
                                  void *coordinate);
```

Re-initialize the dynamic shared memory required for parallel operation when the custom-scan plan node is about to be re-scanned. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution. Recommended practice is that this callback reset only shared state, while the `ReScanCustomScan` callback resets only local state. Currently, this callback will be called before `ReScanCustomScan`, but it's best not to rely on that ordering.

```
void (*InitializeWorkerCustomScan) (CustomScanState *node,  
                                    shm_toc *toc,  
                                    void *coordinate);
```

Initialize a parallel worker's local state based on the shared state set up by the leader during `InitializeDSMCustomScan`. This callback is optional, and need only be supplied if this custom scan provider supports parallel execution.

```
void (*ShutdownCustomScan) (CustomScanState *node);
```

Release resources when it is anticipated the node will not be executed to completion. This is not called in all cases; sometimes, `EndCustomScan` may be called without this function having been called first. Since the DSM segment used by parallel query is destroyed just after this callback is invoked, custom scan providers that wish to take some action before the DSM segment goes away should implement this method.

```
void (*ExplainCustomScan) (CustomScanState *node,  
                           List *ancestors,  
                           ExplainState *es);
```

Output additional information for `EXPLAIN` of a custom-scan plan node. This callback is optional. Common data stored in the `ScanState`, such as the target list and scan relation, will be shown even without this callback, but the callback allows the display of additional, private state.

Chapter 59. Genetic Query Optimizer

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59.1. Query Handling as a Complex Optimization Problem

Among all relational operators the most difficult one to process and optimize is the *join*. The number of possible query plans grows exponentially with the number of joins in the query. Further optimization effort is caused by the support of a variety of *join methods* (e.g., nested loop, hash join, merge join in PostgreSQL) to process individual joins and a diversity of *indexes* (e.g., B-tree, hash, GiST and GIN in PostgreSQL) as access paths for relations.

The normal PostgreSQL query optimizer performs a *near-exhaustive search* over the space of alternative strategies. This algorithm, first introduced in IBM's System R database, produces a near-optimal join order, but can take an enormous amount of time and memory space when the number of joins in the query grows large. This makes the ordinary PostgreSQL query optimizer inappropriate for queries that join a large number of tables.

The Institute of Automatic Control at the University of Mining and Technology, in Freiberg, Germany, encountered some problems when it wanted to use PostgreSQL as the backend for a decision support knowledge based system for the maintenance of an electrical power grid. The DBMS needed to handle large join queries for the inference machine of the knowledge based system. The number of joins in these queries made using the normal query optimizer infeasible.

In the following we describe the implementation of a *genetic algorithm* to solve the join ordering problem in a manner that is efficient for queries involving large numbers of joins.

59.2. Genetic Algorithms

The genetic algorithm (GA) is a heuristic optimization method which operates through randomized search. The set of possible solutions for the optimization problem is considered as a *population* of *individuals*. The degree of adaptation of an individual to its environment is specified by its *fitness*.

The coordinates of an individual in the search space are represented by *chromosomes*, in essence a set of character strings. A *gene* is a subsection of a chromosome which encodes the value of a single parameter being optimized. Typical encodings for a gene could be *binary* or *integer*.

Through simulation of the evolutionary operations *recombination*, *mutation*, and *selection* new generations of search points are found that show a higher average fitness than their ancestors.

According to the comp.ai.genetic FAQ it cannot be stressed too strongly that a GA is not a pure random search for a solution to a problem. A GA uses stochastic processes, but the result is distinctly non-random (better than random).

The GEQO module allows the PostgreSQL query optimizer to support large join queries effectively through non-exhaustive search.

59.3.1. Generating Possible Plans with GEQO

The GEQO planning process uses the standard planner code to generate plans for scans of individual relations. Then join plans are developed using the genetic approach. As shown above, each candidate join plan is represented by a sequence in which to join the base relations. In the initial stage, the GEQO code simply generates some possible join sequences at random. For each join sequence considered, the standard planner code is invoked to estimate the cost of performing the query using that join sequence. (For each step of the join sequence, all three possible join strategies are considered; and all the initially-determined relation scan plans are available. The estimated cost is the cheapest of these possibilities.) Join sequences with lower estimated cost are considered “more fit” than those with higher cost. The genetic algorithm discards the least fit candidates. Then new candidates are generated by combining genes of more-fit candidates — that is, by using randomly-chosen portions of known low-cost join sequences to create new sequences for consideration. This process is repeated until a preset number of join sequences have been considered; then the best one found at any time during the search is used to generate the finished plan.

This process is inherently nondeterministic, because of the randomized choices made during both the initial population selection and subsequent “mutation” of the best candidates. To avoid surprising changes of the selected plan, each run of the GEQO algorithm restarts its random number generator with the current `geqo_seed` parameter setting. As long as `geqo_seed` and the other GEQO parameters are kept fixed, the same plan will be generated for a given query (and other planner inputs such as statistics). To experiment with different search paths, try changing `geqo_seed`.

59.3.2. Future Implementation Tasks for PostgreSQL GEQO

Work is still needed to improve the genetic algorithm parameter settings. In file `src/backend/optimizer/geqo/geqo_main.c`, routines `gimme_pool_size` and `gimme_number_generations`, we have to find a compromise for the parameter settings to satisfy two competing demands:

- Optimality of the query plan
- Computing time

In the current implementation, the fitness of each candidate join sequence is estimated by running the standard planner's join selection and cost estimation code from scratch. To the extent that different candidates use similar sub-sequences of joins, a great deal of work will be repeated. This could be made significantly faster by retaining cost estimates for sub-joins. The problem is to avoid expending unreasonable amounts of memory on retaining that state.

At a more basic level, it is not clear that solving query optimization with a GA algorithm designed for TSP is appropriate. In the TSP case, the cost associated with any substring (partial tour) is independent of the rest of the tour, but this is certainly not true for query optimization. Thus it is questionable whether edge recombination crossover is the most effective mutation procedure.

59.4. Further Reading

The following resources contain additional information about genetic algorithms:

- The Hitch-Hiker's Guide to Evolutionary Computation¹, (FAQ for `news://comp.ai.genetic`)
- Evolutionary Computation and its application to art and design², by Craig Reynolds

¹ <http://www.aip.de/~ast/EvolCompFAQ/>

² <http://www.red3d.com/cwr/evolve.html>

- [elma04]
- [fong]

Chapter 60. Table Access Method Interface Definition

This chapter explains the interface between the core PostgreSQL system and *table access methods*, which manage the storage for tables. The core system knows little about these access methods beyond what is specified here, so it is possible to develop entirely new access method types by writing add-on code.

Each table access method is described by a row in the `pg_am` system catalog. The `pg_am` entry specifies a name and a *handler function* for the table access method. These entries can be created and deleted using the `CREATE ACCESS METHOD` and `DROP ACCESS METHOD` SQL commands.

A table access method handler function must be declared to accept a single argument of type `internal` and to return the pseudo-type `table_am_handler`. The argument is a dummy value that simply serves to prevent handler functions from being called directly from SQL commands. The result of the function must be a pointer to a struct of type `TableAmRoutine`, which contains everything that the core code needs to know to make use of the table access method. The return value needs to be of server lifetime, which is typically achieved by defining it as a `static const` variable in global scope. The `TableAmRoutine` struct, also called the access method's *API struct*, defines the behavior of the access method using callbacks. These callbacks are pointers to plain C functions and are not visible or callable at the SQL level. All the callbacks and their behavior is defined in the `TableAmRoutine` structure (with comments inside the struct defining the requirements for callbacks). Most callbacks have wrapper functions, which are documented from the point of view of a user (rather than an implementor) of the table access method. For details, please refer to the `src/include/access/tableam.h`¹ file.

To implement an access method, an implementor will typically need to implement an AM-specific type of tuple table slot (see `src/include/executor/tuptable.h`²), which allows code outside the access method to hold references to tuples of the AM, and to access the columns of the tuple.

Currently, the way an AM actually stores data is fairly unconstrained. For example, it's possible, but not required, to use postgres' shared buffer cache. In case it is used, it likely makes sense to use PostgreSQL's standard page layout as described in Section 68.6.

One fairly large constraint of the table access method API is that, currently, if the AM wants to support modifications and/or indexes, it is necessary for each tuple to have a tuple identifier (TID) consisting of a block number and an item number (see also Section 68.6). It is not strictly necessary that the sub-parts of TIDs have the same meaning they e.g. have for `heap`, but if bitmap scan support is desired (it is optional), the block number needs to provide locality.

For crash safety, an AM can use postgres' WAL, or a custom implementation. If WAL is chosen, either Generic WAL Records can be used, or a new type of WAL records can be implemented. Generic WAL Records are easy, but imply higher WAL volume. Implementation of a new type of WAL record currently requires modifications to core code (specifically, `src/include/access/rmgrlist.h`).

To implement transactional support in a manner that allows different table access methods be accessed within a single transaction, it likely is necessary to closely integrate with the machinery in `src/backend/access/transam/xlog.c`.

Any developer of a new table access method can refer to the existing heap implementation present in `src/backend/access/heap/heapam_handler.c` for details of its implementation.

¹ <https://git.postgresql.org/gitweb/?p=postgresql.git;a=blob;f=src/include/access/tableam.h;hb=HEAD>

² <https://git.postgresql.org/gitweb/?p=postgresql.git;a=blob;f=src/include/executor/tuptable.h;hb=HEAD>

Chapter 61. Index Access Method Interface Definition

This chapter defines the interface between the core PostgreSQL system and *index access methods*, which manage individual index types. The core system knows nothing about indexes beyond what is specified here, so it is possible to develop entirely new index types by writing add-on code.

All indexes in PostgreSQL are what are known technically as *secondary indexes*; that is, the index is physically separate from the table file that it describes. Each index is stored as its own physical *relation* and so is described by an entry in the `pg_class` catalog. The contents of an index are entirely under the control of its index access method. In practice, all index access methods divide indexes into standard-size pages so that they can use the regular storage manager and buffer manager to access the index contents. (All the existing index access methods furthermore use the standard page layout described in Section 68.6, and most use the same format for index tuple headers; but these decisions are not forced on an access method.)

An index is effectively a mapping from some data key values to *tuple identifiers*, or TIDs, of row versions (tuples) in the index's parent table. A TID consists of a block number and an item number within that block (see Section 68.6). This is sufficient information to fetch a particular row version from the table. Indexes are not directly aware that under MVCC, there might be multiple extant versions of the same logical row; to an index, each tuple is an independent object that needs its own index entry. Thus, an update of a row always creates all-new index entries for the row, even if the key values did not change. (HOT tuples are an exception to this statement; but indexes do not deal with those, either.) Index entries for dead tuples are reclaimed (by vacuuming) when the dead tuples themselves are reclaimed.

61.1. Basic API Structure for Indexes

Each index access method is described by a row in the `pg_am` system catalog. The `pg_am` entry specifies a name and a *handler function* for the index access method. These entries can be created and deleted using the `CREATE ACCESS METHOD` and `DROP ACCESS METHOD` SQL commands.

An index access method handler function must be declared to accept a single argument of type `internal` and to return the pseudo-type `index_am_handler`. The argument is a dummy value that simply serves to prevent handler functions from being called directly from SQL commands. The result of the function must be a palloc'd struct of type `IndexAmRoutine`, which contains everything that the core code needs to know to make use of the index access method. The `IndexAmRoutine` struct, also called the access method's *API struct*, includes fields specifying assorted fixed properties of the access method, such as whether it can support multicolumn indexes. More importantly, it contains pointers to support functions for the access method, which do all of the real work to access indexes. These support functions are plain C functions and are not visible or callable at the SQL level. The support functions are described in Section 61.2.

The structure `IndexAmRoutine` is defined thus:

```
typedef struct IndexAmRoutine
{
    NodeTag      type;

    /*
     * Total number of strategies (operators) by which we can
     * traverse/search
     * this AM. Zero if AM does not have a fixed set of strategy
     * assignments.
     */
}
```

Index Access Method
Interface Definition

```
uint16      amstrategies;
/* total number of support functions that this AM uses */
uint16      amsupport;
/* does AM support ORDER BY indexed column's value? */
bool        amcanorder;
/* does AM support ORDER BY result of an operator on indexed
column? */
bool        amcanorderbyop;
/* does AM support backward scanning? */
bool        amcanbackward;
/* does AM support UNIQUE indexes? */
bool        amcanunique;
/* does AM support multi-column indexes? */
bool        amcanmulticol;
/* does AM require scans to have a constraint on the first
index column? */
bool        amoptionalkey;
/* does AM handle ScalarArrayOpExpr quals? */
bool        amsearcharray;
/* does AM handle IS NULL/IS NOT NULL quals? */
bool        amsearchnulls;
/* can index storage data type differ from column data type? */
bool        amstorage;
/* can an index of this type be clustered on? */
bool        amclusterable;
/* does AM handle predicate locks? */
bool        ampredlocks;
/* does AM support parallel scan? */
bool        amcanparallel;
/* does AM support columns included with clause INCLUDE? */
bool        amcaninclude;
/* type of data stored in index, or InvalidOid if variable */
Oid         amkeytype;

/* interface functions */
ambuild_function ambuild;
ambuildempty_function ambuildempty;
aminsert_function aminsert;
ambulkdelete_function ambulkdelete;
amvacuumcleanup_function amvacuumcleanup;
amcanreturn_function amcanreturn; /* can be NULL */
amcostestimate_function amcostestimate;
amoptions_function amoptions;
amproperty_function amproperty; /* can be NULL */
ambuildphasename_function ambuildphasename; /* can be NULL */
amvalidate_function amvalidate;
ambeginscan_function ambeginscan;
amrescan_function amrescan;
amgettuple_function amgettuple; /* can be NULL */
amgetbitmap_function amgetbitmap; /* can be NULL */
amendscan_function amendscan;
ammarkpos_function ammarkpos; /* can be NULL */
amrestrpos_function amrestrpos; /* can be NULL */

/* interface functions to support parallel index scans */
amestimateparallelscan_function amestimateparallelscan; /*
can be NULL */
```

```

    aminitparallelscan_function aminitparallelscan;    /* can be
NULL */
    amparallelrescan_function amparallelrescan;    /* can be NULL
*/
} IndexAmRoutine;

```

To be useful, an index access method must also have one or more *operator families* and *operator classes* defined in `pg_opfamily`, `pg_opclass`, `pg_amop`, and `pg_amproc`. These entries allow the planner to determine what kinds of query qualifications can be used with indexes of this access method. Operator families and classes are described in Section 37.16, which is prerequisite material for reading this chapter.

An individual index is defined by a `pg_class` entry that describes it as a physical relation, plus a `pg_index` entry that shows the logical content of the index — that is, the set of index columns it has and the semantics of those columns, as captured by the associated operator classes. The index columns (key values) can be either simple columns of the underlying table or expressions over the table rows. The index access method normally has no interest in where the index key values come from (it is always handed precomputed key values) but it will be very interested in the operator class information in `pg_index`. Both of these catalog entries can be accessed as part of the `Relation` data structure that is passed to all operations on the index.

Some of the flag fields of `IndexAmRoutine` have nonobvious implications. The requirements of `amcanunique` are discussed in Section 61.5. The `amcanmulticol` flag asserts that the access method supports multicolumn indexes, while `amoptionalkey` asserts that it allows scans where no indexable restriction clause is given for the first index column. When `amcanmulticol` is false, `amoptionalkey` essentially says whether the access method supports full-index scans without any restriction clause. Access methods that support multiple index columns *must* support scans that omit restrictions on any or all of the columns after the first; however they are permitted to require some restriction to appear for the first index column, and this is signaled by setting `amoptionalkey` false. One reason that an index AM might set `amoptionalkey` false is if it doesn't index null values. Since most indexable operators are strict and hence cannot return true for null inputs, it is at first sight attractive to not store index entries for null values: they could never be returned by an index scan anyway. However, this argument fails when an index scan has no restriction clause for a given index column. In practice this means that indexes that have `amoptionalkey` true must index nulls, since the planner might decide to use such an index with no scan keys at all. A related restriction is that an index access method that supports multiple index columns *must* support indexing null values in columns after the first, because the planner will assume the index can be used for queries that do not restrict these columns. For example, consider an index on (a,b) and a query with `WHERE a = 4`. The system will assume the index can be used to scan for rows with `a = 4`, which is wrong if the index omits rows where `b` is null. It is, however, OK to omit rows where the first indexed column is null. An index access method that does index nulls may also set `amsearchnulls`, indicating that it supports `IS NULL` and `IS NOT NULL` clauses as search conditions.

61.2. Index Access Method Functions

The index construction and maintenance functions that an index access method must provide in `IndexAmRoutine` are:

```

IndexBuildResult *
ambuild (Relation heapRelation,
         Relation indexRelation,
         IndexInfo *indexInfo);

```

Build a new index. The index relation has been physically created, but is empty. It must be filled in with whatever fixed data the access method requires, plus entries for all tuples already existing in the table. Ordinarily the `ambuild` function will call `table_index_build_scan()` to scan the table for existing tuples and compute the keys that need to be inserted into the index. The function must return a palloc'd struct containing statistics about the new index.

```
void  
ambuildempty (Relation indexRelation);
```

Build an empty index, and write it to the initialization fork (INIT_FORKNUM) of the given relation. This method is called only for unlogged indexes; the empty index written to the initialization fork will be copied over the main relation fork on each server restart.

```
bool  
aminsert (Relation indexRelation,  
          Datum *values,  
          bool *isnull,  
          ItemPointer heap_tid,  
          Relation heapRelation,  
          IndexUniqueCheck checkUnique,  
          IndexInfo *indexInfo);
```

Insert a new tuple into an existing index. The `values` and `isnull` arrays give the key values to be indexed, and `heap_tid` is the TID to be indexed. If the access method supports unique indexes (its `amcanunique` flag is true) then `checkUnique` indicates the type of uniqueness check to perform. This varies depending on whether the unique constraint is deferrable; see Section 61.5 for details. Normally the access method only needs the `heapRelation` parameter when performing uniqueness checking (since then it will have to look into the heap to verify tuple liveness).

The function's Boolean result value is significant only when `checkUnique` is `UNIQUE_CHECK_PARTIAL`. In this case a true result means the new entry is known unique, whereas false means it might be non-unique (and a deferred uniqueness check must be scheduled). For other cases a constant false result is recommended.

Some indexes might not index all tuples. If the tuple is not to be indexed, `aminsert` should just return without doing anything.

If the index AM wishes to cache data across successive index insertions within a SQL statement, it can allocate space in `indexInfo->ii_Context` and store a pointer to the data in `indexInfo->ii_AmCache` (which will be NULL initially).

```
IndexBulkDeleteResult *  
ambulkdelete (IndexVacuumInfo *info,  
             IndexBulkDeleteResult *stats,  
             IndexBulkDeleteCallback callback,  
             void *callback_state);
```

Delete tuple(s) from the index. This is a “bulk delete” operation that is intended to be implemented by scanning the whole index and checking each entry to see if it should be deleted. The passed-in callback function must be called, in the style `callback(TID, callback_state)` returns `bool`, to determine whether any particular index entry, as identified by its referenced TID, is to be deleted. Must return either NULL or a palloc'd struct containing statistics about the effects of the deletion operation. It is OK to return NULL if no information needs to be passed on to `amvacuumcleanup`.

Because of limited `maintenance_work_mem`, `ambulkdelete` might need to be called more than once when many tuples are to be deleted. The `stats` argument is the result of the previous call for this index (it is NULL for the first call within a `VACUUM` operation). This allows the AM to accumulate statistics across the whole operation. Typically, `ambulkdelete` will modify and return the same struct if the passed `stats` is not null.

Index Access Method Interface Definition

```
IndexBulkDeleteResult *
amvacuumcleanup (IndexVacuumInfo *info,
                 IndexBulkDeleteResult *stats);
```

Clean up after a VACUUM operation (zero or more `ambulkdelete` calls). This does not have to do anything beyond returning index statistics, but it might perform bulk cleanup such as reclaiming empty index pages. `stats` is whatever the last `ambulkdelete` call returned, or NULL if `ambulkdelete` was not called because no tuples needed to be deleted. If the result is not NULL it must be a palloc'd struct. The statistics it contains will be used to update `pg_class`, and will be reported by VACUUM if VERBOSE is given. It is OK to return NULL if the index was not changed at all during the VACUUM operation, but otherwise correct stats should be returned.

As of PostgreSQL 8.4, `amvacuumcleanup` will also be called at completion of an ANALYZE operation. In this case `stats` is always NULL and any return value will be ignored. This case can be distinguished by checking `info->analyze_only`. It is recommended that the access method do nothing except post-insert cleanup in such a call, and that only in an autovacuum worker process.

```
bool
amcanreturn (Relation indexRelation, int attno);
```

Check whether the index can support *index-only scans* on the given column, by returning the indexed column values for an index entry in the form of an `IndexTuple`. The attribute number is 1-based, i.e. the first column's `attno` is 1. Returns true if supported, else false. If the access method does not support index-only scans at all, the `amcanreturn` field in its `IndexAmRoutine` struct can be set to NULL.

```
void
amcostestimate (PlannerInfo *root,
               IndexPath *path,
               double loop_count,
               Cost *indexStartupCost,
               Cost *indexTotalCost,
               Selectivity *indexSelectivity,
               double *indexCorrelation,
               double *indexPages);
```

Estimate the costs of an index scan. This function is described fully in Section 61.6, below.

```
bytea *
amoptions (ArrayType *reloptions,
           bool validate);
```

Parse and validate the `reloptions` array for an index. This is called only when a non-null `reloptions` array exists for the index. `reloptions` is a text array containing entries of the form `name=value`. The function should construct a `bytea` value, which will be copied into the `rd_options` field of the index's `relcache` entry. The data contents of the `bytea` value are open for the access method to define; most of the standard access methods use struct `StdRdOptions`. When `validate` is true, the function should report a suitable error message if any of the options are unrecognized or have invalid values; when `validate` is false, invalid entries should be silently ignored. (`validate` is false when loading options already stored in `pg_catalog`; an invalid entry could only be found if the access method has changed its rules for options, and in that case ignoring obsolete entries is appropriate.) It is OK to return NULL if default behavior is wanted.

```
bool
amproperty (Oid index_oid, int attno,
            IndexAMProperty prop, const char *propname,
```

```
bool *res, bool *isnull);
```

The `amproperty` method allows index access methods to override the default behavior of `pg_index_column_has_property` and related functions. If the access method does not have any special behavior for index property inquiries, the `amproperty` field in its `IndexAmRoutine` struct can be set to `NULL`. Otherwise, the `amproperty` method will be called with `index_oid` and `attno` both zero for `pg_indexam_has_property` calls, or with `index_oid` valid and `attno` zero for `pg_index_has_property` calls, or with `index_oid` valid and `attno` greater than zero for `pg_index_column_has_property` calls. `prop` is an enum value identifying the property being tested, while `propname` is the original property name string. If the core code does not recognize the property name then `prop` is `AMPROP_UNKNOWN`. Access methods can define custom property names by checking `propname` for a match (use `pg_strcasecmp` to match, for consistency with the core code); for names known to the core code, it's better to inspect `prop`. If the `amproperty` method returns `true` then it has determined the property test result: it must set `*res` to the boolean value to return, or set `*isnull` to `true` to return a `NULL`. (Both of the referenced variables are initialized to `false` before the call.) If the `amproperty` method returns `false` then the core code will proceed with its normal logic for determining the property test result.

Access methods that support ordering operators should implement `AMPROP_DISTANCE_ORDERABLE` property testing, as the core code does not know how to do that and will return `NULL`. It may also be advantageous to implement `AMPROP_RETURNABLE` testing, if that can be done more cheaply than by opening the index and calling `amcanreturn`, which is the core code's default behavior. The default behavior should be satisfactory for all other standard properties.

```
char *  
ambuildphasename (int64 phasenum);
```

Return the textual name of the given build phase number. The phase numbers are those reported during an index build via the `pgstat_progress_update_param` interface. The phase names are then exposed in the `pg_stat_progress_create_index` view.

```
bool  
amvalidate (Oid opclassoid);
```

Validate the catalog entries for the specified operator class, so far as the access method can reasonably do that. For example, this might include testing that all required support functions are provided. The `amvalidate` function must return `false` if the `opclass` is invalid. Problems should be reported with `ereport` messages.

The purpose of an index, of course, is to support scans for tuples matching an indexable `WHERE` condition, often called a *qualifier* or *scan key*. The semantics of index scanning are described more fully in Section 61.3, below. An index access method can support “plain” index scans, “bitmap” index scans, or both. The scan-related functions that an index access method must or may provide are:

```
IndexScanDesc  
ambeginscan (Relation indexRelation,  
             int nkeys,  
             int norderbys);
```

Prepare for an index scan. The `nkeys` and `norderbys` parameters indicate the number of quals and ordering operators that will be used in the scan; these may be useful for space allocation purposes. Note that the actual values of the scan keys aren't provided yet. The result must be a `palloc'd` struct. For implementation reasons the index access method *must* create this struct by calling `RelationGetIndexScan()`. In most cases `ambeginscan` does little beyond making that call and perhaps acquiring locks; the interesting parts of index-scan startup are in `amrescan`.

```
void  
amrescan (IndexScanDesc scan,  
          ScanKey keys,  
          int nkeys,  
          ScanKey orderbys,  
          int norderbys);
```

Start or restart an index scan, possibly with new scan keys. (To restart using previously-passed keys, NULL is passed for `keys` and/or `orderbys`.) Note that it is not allowed for the number of keys or order-by operators to be larger than what was passed to `ambeginscan`. In practice the restart feature is used when a new outer tuple is selected by a nested-loop join and so a new key comparison value is needed, but the scan key structure remains the same.

```
boolean  
amgettupple (IndexScanDesc scan,  
             ScanDirection direction);
```

Fetch the next tuple in the given scan, moving in the given direction (forward or backward in the index). Returns true if a tuple was obtained, false if no matching tuples remain. In the true case the tuple TID is stored into the `scan` structure. Note that “success” means only that the index contains an entry that matches the scan keys, not that the tuple necessarily still exists in the heap or will pass the caller's snapshot test. On success, `amgettupple` must also set `scan->xs_recheck` to true or false. False means it is certain that the index entry matches the scan keys. true means this is not certain, and the conditions represented by the scan keys must be rechecked against the heap tuple after fetching it. This provision supports “lossy” index operators. Note that rechecking will extend only to the scan conditions; a partial index predicate (if any) is never rechecked by `amgettupple` callers.

If the index supports index-only scans (i.e., `amcanreturn` returns true for it), then on success the AM must also check `scan->xs_want_itup`, and if that is true it must return the originally indexed data for the index entry. The data can be returned in the form of an `IndexTuple` pointer stored at `scan->xs_itup`, with tuple descriptor `scan->xs_itupdesc`; or in the form of a `HeapTuple` pointer stored at `scan->xs_hitup`, with tuple descriptor `scan->xs_hitupdesc`. (The latter format should be used when reconstructing data that might possibly not fit into an `IndexTuple`.) In either case, management of the data referenced by the pointer is the access method's responsibility. The data must remain good at least until the next `amgettupple`, `amrescan`, or `amendscan` call for the scan.

The `amgettupple` function need only be provided if the access method supports “plain” index scans. If it doesn't, the `amgettupple` field in its `IndexAmRoutine` struct must be set to NULL.

```
int64  
amgetbitmap (IndexScanDesc scan,  
             TIDBitmap *tbm);
```

Fetch all tuples in the given scan and add them to the caller-supplied `TIDBitmap` (that is, OR the set of tuple IDs into whatever set is already in the bitmap). The number of tuples fetched is returned (this might be just an approximate count, for instance some AMs do not detect duplicates). While inserting tuple IDs into the bitmap, `amgetbitmap` can indicate that rechecking of the scan conditions is required for specific tuple IDs. This is analogous to the `xs_recheck` output parameter of `amgettupple`. Note: in the current implementation, support for this feature is conflated with support for lossy storage of the bitmap itself, and therefore callers recheck both the scan conditions and the partial index predicate (if any) for recheckable tuples. That might not always be true, however. `amgetbitmap` and `amgettupple` cannot be used in the same index scan; there are other restrictions too when using `amgetbitmap`, as explained in Section 61.3.

The `amgetbitmap` function need only be provided if the access method supports “bitmap” index scans. If it doesn't, the `amgetbitmap` field in its `IndexAmRoutine` struct must be set to NULL.

```
void  
amendscan (IndexScanDesc scan);
```

End a scan and release resources. The `scan` struct itself should not be freed, but any locks or pins taken internally by the access method must be released, as well as any other memory allocated by `ambeginscan` and other scan-related functions.

```
void  
ammarkpos (IndexScanDesc scan);
```

Mark current scan position. The access method need only support one remembered scan position per scan.

The `ammarkpos` function need only be provided if the access method supports ordered scans. If it doesn't, the `ammarkpos` field in its `IndexAmRoutine` struct may be set to `NULL`.

```
void  
amrestrpos (IndexScanDesc scan);
```

Restore the scan to the most recently marked position.

The `amrestrpos` function need only be provided if the access method supports ordered scans. If it doesn't, the `amrestrpos` field in its `IndexAmRoutine` struct may be set to `NULL`.

In addition to supporting ordinary index scans, some types of index may wish to support *parallel index scans*, which allow multiple backends to cooperate in performing an index scan. The index access method should arrange things so that each cooperating process returns a subset of the tuples that would be performed by an ordinary, non-parallel index scan, but in such a way that the union of those subsets is equal to the set of tuples that would be returned by an ordinary, non-parallel index scan. Furthermore, while there need not be any global ordering of tuples returned by a parallel scan, the ordering of that subset of tuples returned within each cooperating backend must match the requested ordering. The following functions may be implemented to support parallel index scans:

```
Size  
amestimateparallelscan (void);
```

Estimate and return the number of bytes of dynamic shared memory which the access method will be needed to perform a parallel scan. (This number is in addition to, not in lieu of, the amount of space needed for AM-independent data in `ParallelIndexScanDescData`.)

It is not necessary to implement this function for access methods which do not support parallel scans or for which the number of additional bytes of storage required is zero.

```
void  
aminitparallelscan (void *target);
```

This function will be called to initialize dynamic shared memory at the beginning of a parallel scan. `target` will point to at least the number of bytes previously returned by `amestimateparallelscan`, and this function may use that amount of space to store whatever data it wishes.

It is not necessary to implement this function for access methods which do not support parallel scans or in cases where the shared memory space required needs no initialization.

```
void
```

```
amparallelrescan (IndexScanDesc scan);
```

This function, if implemented, will be called when a parallel index scan must be restarted. It should reset any shared state set up by `aminitparallelscan` such that the scan will be restarted from the beginning.

61.3. Index Scanning

In an index scan, the index access method is responsible for regurgitating the TIDs of all the tuples it has been told about that match the *scan keys*. The access method is *not* involved in actually fetching those tuples from the index's parent table, nor in determining whether they pass the scan's visibility test or other conditions.

A scan key is the internal representation of a `WHERE` clause of the form *index_key operator constant*, where the index key is one of the columns of the index and the operator is one of the members of the operator family associated with that index column. An index scan has zero or more scan keys, which are implicitly ANDed — the returned tuples are expected to satisfy all the indicated conditions.

The access method can report that the index is *lossy*, or requires rechecks, for a particular query. This implies that the index scan will return all the entries that pass the scan key, plus possibly additional entries that do not. The core system's index-scan machinery will then apply the index conditions again to the heap tuple to verify whether or not it really should be selected. If the recheck option is not specified, the index scan must return exactly the set of matching entries.

Note that it is entirely up to the access method to ensure that it correctly finds all and only the entries passing all the given scan keys. Also, the core system will simply hand off all the `WHERE` clauses that match the index keys and operator families, without any semantic analysis to determine whether they are redundant or contradictory. As an example, given `WHERE x > 4 AND x > 14` where `x` is a b-tree indexed column, it is left to the b-tree `amrescan` function to realize that the first scan key is redundant and can be discarded. The extent of preprocessing needed during `amrescan` will depend on the extent to which the index access method needs to reduce the scan keys to a “normalized” form.

Some access methods return index entries in a well-defined order, others do not. There are actually two different ways that an access method can support sorted output:

- Access methods that always return entries in the natural ordering of their data (such as `btree`) should set `amcanorder` to `true`. Currently, such access methods must use `btree-compatible` strategy numbers for their equality and ordering operators.
- Access methods that support ordering operators should set `amcanorderbyop` to `true`. This indicates that the index is capable of returning entries in an order satisfying `ORDER BY index_key operator constant`. Scan modifiers of that form can be passed to `amrescan` as described previously.

The `amgettuple` function has a `direction` argument, which can be either `ForwardScanDirection` (the normal case) or `BackwardScanDirection`. If the first call after `amrescan` specifies `BackwardScanDirection`, then the set of matching index entries is to be scanned back-to-front rather than in the normal front-to-back direction, so `amgettuple` must return the last matching tuple in the index, rather than the first one as it normally would. (This will only occur for access methods that set `amcanorder` to `true`.) After the first call, `amgettuple` must be prepared to advance the scan in either direction from the most recently returned entry. (But if `amcanbackward` is `false`, all subsequent calls will have the same direction as the first one.)

Access methods that support ordered scans must support “marking” a position in a scan and later returning to the marked position. The same position might be restored multiple times. However, only one position need be remembered per scan; a new `ammarkpos` call overrides the previously marked position. An access method that does not support ordered scans need not provide `ammarkpos` and `amrestrpos` functions in `IndexAmRoutine`; set those pointers to `NULL` instead.

Both the scan position and the mark position (if any) must be maintained consistently in the face of concurrent insertions or deletions in the index. It is OK if a freshly-inserted entry is not returned by a scan that would have found the entry if it had existed when the scan started, or for the scan to return such an entry upon rescanning or backing up even though it had not been returned the first time through. Similarly, a concurrent delete might or might not be reflected in the results of a scan. What is important is that insertions or deletions not cause the scan to miss or multiply return entries that were not themselves being inserted or deleted.

If the index stores the original indexed data values (and not some lossy representation of them), it is useful to support index-only scans, in which the index returns the actual data not just the TID of the heap tuple. This will only avoid I/O if the visibility map shows that the TID is on an all-visible page; else the heap tuple must be visited anyway to check MVCC visibility. But that is no concern of the access method's.

Instead of using `amgettuple`, an index scan can be done with `amgetbitmap` to fetch all tuples in one call. This can be noticeably more efficient than `amgettuple` because it allows avoiding lock/unlock cycles within the access method. In principle `amgetbitmap` should have the same effects as repeated `amgettuple` calls, but we impose several restrictions to simplify matters. First of all, `amgetbitmap` returns all tuples at once and marking or restoring scan positions isn't supported. Secondly, the tuples are returned in a bitmap which doesn't have any specific ordering, which is why `amgetbitmap` doesn't take a `direction` argument. (Ordering operators will never be supplied for such a scan, either.) Also, there is no provision for index-only scans with `amgetbitmap`, since there is no way to return the contents of index tuples. Finally, `amgetbitmap` does not guarantee any locking of the returned tuples, with implications spelled out in Section 61.4.

Note that it is permitted for an access method to implement only `amgetbitmap` and not `amgettuple`, or vice versa, if its internal implementation is unsuited to one API or the other.

61.4. Index Locking Considerations

Index access methods must handle concurrent updates of the index by multiple processes. The core PostgreSQL system obtains `AccessShareLock` on the index during an index scan, and `RowExclusiveLock` when updating the index (including plain `VACUUM`). Since these lock types do not conflict, the access method is responsible for handling any fine-grained locking it might need. An exclusive lock on the index as a whole will be taken only during index creation, destruction, or `REINDEX`.

Building an index type that supports concurrent updates usually requires extensive and subtle analysis of the required behavior. For the b-tree and hash index types, you can read about the design decisions involved in `src/backend/access/nbtree/README` and `src/backend/access/hash/README`.

Aside from the index's own internal consistency requirements, concurrent updates create issues about consistency between the parent table (the *heap*) and the index. Because PostgreSQL separates accesses and updates of the heap from those of the index, there are windows in which the index might be inconsistent with the heap. We handle this problem with the following rules:

- A new heap entry is made before making its index entries. (Therefore a concurrent index scan is likely to fail to see the heap entry. This is okay because the index reader would be uninterested in an uncommitted row anyway. But see Section 61.5.)
- When a heap entry is to be deleted (by `VACUUM`), all its index entries must be removed first.
- An index scan must maintain a pin on the index page holding the item last returned by `amgettuple`, and `ambulkdelete` cannot delete entries from pages that are pinned by other backends. The need for this rule is explained below.

Without the third rule, it is possible for an index reader to see an index entry just before it is removed by `VACUUM`, and then to arrive at the corresponding heap entry after that was removed by `VACUUM`. This creates no serious problems if that item number is still unused when the reader reaches it, since

an empty item slot will be ignored by `heap_fetch()`. But what if a third backend has already reused the item slot for something else? When using an MVCC-compliant snapshot, there is no problem because the new occupant of the slot is certain to be too new to pass the snapshot test. However, with a non-MVCC-compliant snapshot (such as `SnapshotAny`), it would be possible to accept and return a row that does not in fact match the scan keys. We could defend against this scenario by requiring the scan keys to be rechecked against the heap row in all cases, but that is too expensive. Instead, we use a pin on an index page as a proxy to indicate that the reader might still be “in flight” from the index entry to the matching heap entry. Making `ambulkdelete` block on such a pin ensures that `VACUUM` cannot delete the heap entry before the reader is done with it. This solution costs little in run time, and adds blocking overhead only in the rare cases where there actually is a conflict.

This solution requires that index scans be “synchronous”: we have to fetch each heap tuple immediately after scanning the corresponding index entry. This is expensive for a number of reasons. An “asynchronous” scan in which we collect many TIDs from the index, and only visit the heap tuples sometime later, requires much less index locking overhead and can allow a more efficient heap access pattern. Per the above analysis, we must use the synchronous approach for non-MVCC-compliant snapshots, but an asynchronous scan is workable for a query using an MVCC snapshot.

In an `amgetbitmap` index scan, the access method does not keep an index pin on any of the returned tuples. Therefore it is only safe to use such scans with MVCC-compliant snapshots.

When the `ampredlocks` flag is not set, any scan using that index access method within a serializable transaction will acquire a nonblocking predicate lock on the full index. This will generate a read-write conflict with the insert of any tuple into that index by a concurrent serializable transaction. If certain patterns of read-write conflicts are detected among a set of concurrent serializable transactions, one of those transactions may be canceled to protect data integrity. When the flag is set, it indicates that the index access method implements finer-grained predicate locking, which will tend to reduce the frequency of such transaction cancellations.

61.5. Index Uniqueness Checks

PostgreSQL enforces SQL uniqueness constraints using *unique indexes*, which are indexes that disallow multiple entries with identical keys. An access method that supports this feature sets `amcanunique` true. (At present, only b-tree supports it.) Columns listed in the `INCLUDE` clause are not considered when enforcing uniqueness.

Because of MVCC, it is always necessary to allow duplicate entries to exist physically in an index: the entries might refer to successive versions of a single logical row. The behavior we actually want to enforce is that no MVCC snapshot could include two rows with equal index keys. This breaks down into the following cases that must be checked when inserting a new row into a unique index:

- If a conflicting valid row has been deleted by the current transaction, it's okay. (In particular, since an `UPDATE` always deletes the old row version before inserting the new version, this will allow an `UPDATE` on a row without changing the key.)
- If a conflicting row has been inserted by an as-yet-uncommitted transaction, the would-be inserter must wait to see if that transaction commits. If it rolls back then there is no conflict. If it commits without deleting the conflicting row again, there is a uniqueness violation. (In practice we just wait for the other transaction to end and then redo the visibility check in toto.)
- Similarly, if a conflicting valid row has been deleted by an as-yet-uncommitted transaction, the would-be inserter must wait for that transaction to commit or abort, and then repeat the test.

Furthermore, immediately before reporting a uniqueness violation according to the above rules, the access method must recheck the liveness of the row being inserted. If it is committed dead then no violation should be reported. (This case cannot occur during the ordinary scenario of inserting a row that's just been created by the current transaction. It can happen during `CREATE UNIQUE INDEX CONCURRENTLY`, however.)

We require the index access method to apply these tests itself, which means that it must reach into the heap to check the commit status of any row that is shown to have a duplicate key according to the index contents. This is without a doubt ugly and non-modular, but it saves redundant work: if we did a separate probe then the index lookup for a conflicting row would be essentially repeated while finding the place to insert the new row's index entry. What's more, there is no obvious way to avoid race conditions unless the conflict check is an integral part of insertion of the new index entry.

If the unique constraint is deferrable, there is additional complexity: we need to be able to insert an index entry for a new row, but defer any uniqueness-violation error until end of statement or even later. To avoid unnecessary repeat searches of the index, the index access method should do a preliminary uniqueness check during the initial insertion. If this shows that there is definitely no conflicting live tuple, we are done. Otherwise, we schedule a recheck to occur when it is time to enforce the constraint. If, at the time of the recheck, both the inserted tuple and some other tuple with the same key are live, then the error must be reported. (Note that for this purpose, “live” actually means “any tuple in the index entry's HOT chain is live”.) To implement this, the `amininsert` function is passed a `checkUnique` parameter having one of the following values:

- `UNIQUE_CHECK_NO` indicates that no uniqueness checking should be done (this is not a unique index).
- `UNIQUE_CHECK_YES` indicates that this is a non-deferrable unique index, and the uniqueness check must be done immediately, as described above.
- `UNIQUE_CHECK_PARTIAL` indicates that the unique constraint is deferrable. PostgreSQL will use this mode to insert each row's index entry. The access method must allow duplicate entries into the index, and report any potential duplicates by returning false from `amininsert`. For each row for which false is returned, a deferred recheck will be scheduled.

The access method must identify any rows which might violate the unique constraint, but it is not an error for it to report false positives. This allows the check to be done without waiting for other transactions to finish; conflicts reported here are not treated as errors and will be rechecked later, by which time they may no longer be conflicts.

- `UNIQUE_CHECK_EXISTING` indicates that this is a deferred recheck of a row that was reported as a potential uniqueness violation. Although this is implemented by calling `amininsert`, the access method must *not* insert a new index entry in this case. The index entry is already present. Rather, the access method must check to see if there is another live index entry. If so, and if the target row is also still live, report error.

It is recommended that in a `UNIQUE_CHECK_EXISTING` call, the access method further verify that the target row actually does have an existing entry in the index, and report error if not. This is a good idea because the index tuple values passed to `amininsert` will have been recomputed. If the index definition involves functions that are not really immutable, we might be checking the wrong area of the index. Checking that the target row is found in the recheck verifies that we are scanning for the same tuple values as were used in the original insertion.

61.6. Index Cost Estimation Functions

The `amcostestimate` function is given information describing a possible index scan, including lists of `WHERE` and `ORDER BY` clauses that have been determined to be usable with the index. It must return estimates of the cost of accessing the index and the selectivity of the `WHERE` clauses (that is, the fraction of parent-table rows that will be retrieved during the index scan). For simple cases, nearly all the work of the cost estimator can be done by calling standard routines in the optimizer; the point of having an `amcostestimate` function is to allow index access methods to provide index-type-specific knowledge, in case it is possible to improve on the standard estimates.

Each `amcostestimate` function must have the signature:

```
void  
amcostestimate (PlannerInfo *root,  
                IndexPath *path,  
                double loop_count,  
                Cost *indexStartupCost,  
                Cost *indexTotalCost,  
                Selectivity *indexSelectivity,  
                double *indexCorrelation,  
                double *indexPages);
```

The first three parameters are inputs:

root

The planner's information about the query being processed.

path

The index access path being considered. All fields except cost and selectivity values are valid.

loop_count

The number of repetitions of the index scan that should be factored into the cost estimates. This will typically be greater than one when considering a parameterized scan for use in the inside of a nestloop join. Note that the cost estimates should still be for just one scan; a larger *loop_count* means that it may be appropriate to allow for some caching effects across multiple scans.

The last five parameters are pass-by-reference outputs:

**indexStartupCost*

Set to cost of index start-up processing

**indexTotalCost*

Set to total cost of index processing

**indexSelectivity*

Set to index selectivity

**indexCorrelation*

Set to correlation coefficient between index scan order and underlying table's order

**indexPages*

Set to number of index leaf pages

Note that cost estimate functions must be written in C, not in SQL or any available procedural language, because they must access internal data structures of the planner/optimizer.

The index access costs should be computed using the parameters used by `src/backend/optimizer/path/costsize.c`: a sequential disk block fetch has cost `seq_page_cost`, a nonsequential fetch has cost `random_page_cost`, and the cost of processing one index row should usually be taken as `cpu_index_tuple_cost`. In addition, an appropriate multiple of `cpu_operator_cost` should be charged for any comparison operators invoked during index processing (especially evaluation of the `indexquals` themselves).

The access costs should include all disk and CPU costs associated with scanning the index itself, but *not* the costs of retrieving or processing the parent-table rows that are identified by the index.

The “start-up cost” is the part of the total scan cost that must be expended before we can begin to fetch the first row. For most indexes this can be taken as zero, but an index type with a high start-up cost might want to set it nonzero.

The *indexSelectivity* should be set to the estimated fraction of the parent table rows that will be retrieved during the index scan. In the case of a lossy query, this will typically be higher than the fraction of rows that actually pass the given qual conditions.

The *indexCorrelation* should be set to the correlation (ranging between -1.0 and 1.0) between the index order and the table order. This is used to adjust the estimate for the cost of fetching rows from the parent table.

The *indexPages* should be set to the number of leaf pages. This is used to estimate the number of workers for parallel index scan.

When *loop_count* is greater than one, the returned numbers should be averages expected for any one scan of the index.

Cost Estimation

A typical cost estimator will proceed as follows:

1. Estimate and return the fraction of parent-table rows that will be visited based on the given qual conditions. In the absence of any index-type-specific knowledge, use the standard optimizer function `clauselist_selectivity()`:

```
*indexSelectivity = clauselist_selectivity(root, path-  
>indexquals,                                     path->indexinfo-  
>rel->reloid,                                     JOIN_INNER, NULL);
```

2. Estimate the number of index rows that will be visited during the scan. For many index types this is the same as *indexSelectivity* times the number of rows in the index, but it might be more. (Note that the index's size in pages and rows is available from the `path->indexinfo` struct.)
3. Estimate the number of index pages that will be retrieved during the scan. This might be just *indexSelectivity* times the index's size in pages.
4. Compute the index access cost. A generic estimator might do this:

```
/*  
 * Our generic assumption is that the index pages will be read  
 * sequentially, so they cost seq_page_cost each, not  
 * random_page_cost.  
 * Also, we charge for evaluation of the indexquals at each  
 * index row.  
 * All the costs are assumed to be paid incrementally during  
 * the scan.  
 */  
cost_qual_eval(&index_qual_cost, path->indexquals, root);  
*indexStartupCost = index_qual_cost.startup;  
*indexTotalCost = seq_page_cost * numIndexPages +  
    (cpu_index_tuple_cost + index_qual_cost.per_tuple) *  
    numIndexTuples;
```

However, the above does not account for amortization of index reads across repeated index scans.

5. Estimate the index correlation. For a simple ordered index on a single field, this can be retrieved from `pg_statistic`. If the correlation is not known, the conservative estimate is zero (no correlation).

Examples of cost estimator functions can be found in `src/backend/utils/adt/selfuncs.c`.

Chapter 62. Generic WAL Records

Although all built-in WAL-logged modules have their own types of WAL records, there is also a generic WAL record type, which describes changes to pages in a generic way. This is useful for extensions that provide custom access methods, because they cannot register their own WAL redo routines.

The API for constructing generic WAL records is defined in `access/generic_xlog.h` and implemented in `access/transam/generic_xlog.c`.

To perform a WAL-logged data update using the generic WAL record facility, follow these steps:

1. `state = GenericXLogStart(relation)` — start construction of a generic WAL record for the given relation.
2. `page = GenericXLogRegisterBuffer(state, buffer, flags)` — register a buffer to be modified within the current generic WAL record. This function returns a pointer to a temporary copy of the buffer's page, where modifications should be made. (Do not modify the buffer's contents directly.) The third argument is a bit mask of flags applicable to the operation. Currently the only such flag is `GENERIC_XLOG_FULL_IMAGE`, which indicates that a full-page image rather than a delta update should be included in the WAL record. Typically this flag would be set if the page is new or has been rewritten completely. `GenericXLogRegisterBuffer` can be repeated if the WAL-logged action needs to modify multiple pages.
3. Apply modifications to the page images obtained in the previous step.
4. `GenericXLogFinish(state)` — apply the changes to the buffers and emit the generic WAL record.

WAL record construction can be canceled between any of the above steps by calling `GenericXLogAbort(state)`. This will discard all changes to the page image copies.

Please note the following points when using the generic WAL record facility:

- No direct modifications of buffers are allowed! All modifications must be done in copies acquired from `GenericXLogRegisterBuffer()`. In other words, code that makes generic WAL records should never call `BufferGetPage()` for itself. However, it remains the caller's responsibility to pin/unpin and lock/unlock the buffers at appropriate times. Exclusive lock must be held on each target buffer from before `GenericXLogRegisterBuffer()` until after `GenericXLogFinish()`.
- Registrations of buffers (step 2) and modifications of page images (step 3) can be mixed freely, i.e., both steps may be repeated in any sequence. Keep in mind that buffers should be registered in the same order in which locks are to be obtained on them during replay.
- The maximum number of buffers that can be registered for a generic WAL record is `MAX_GENERIC_XLOG_PAGES`. An error will be thrown if this limit is exceeded.
- Generic WAL assumes that the pages to be modified have standard layout, and in particular that there is no useful data between `pd_lower` and `pd_upper`.
- Since you are modifying copies of buffer pages, `GenericXLogStart()` does not start a critical section. Thus, you can safely do memory allocation, error throwing, etc. between `GenericXLogStart()` and `GenericXLogFinish()`. The only actual critical section is present inside `GenericXLogFinish()`. There is no need to worry about calling `GenericXLogAbort()` during an error exit, either.
- `GenericXLogFinish()` takes care of marking buffers dirty and setting their LSNs. You do not need to do this explicitly.

- For unlogged relations, everything works the same except that no actual WAL record is emitted. Thus, you typically do not need to do any explicit checks for unlogged relations.
- The generic WAL redo function will acquire exclusive locks to buffers in the same order as they were registered. After redoing all changes, the locks will be released in the same order.
- If `GENERIC_XLOG_FULL_IMAGE` is not specified for a registered buffer, the generic WAL record contains a delta between the old and the new page images. This delta is based on byte-by-byte comparison. This is not very compact for the case of moving data within a page, and might be improved in the future.

Chapter 63. B-Tree Indexes

63.1. Introduction

PostgreSQL includes an implementation of the standard btree (multi-way balanced tree) index data structure. Any data type that can be sorted into a well-defined linear order can be indexed by a btree index. The only limitation is that an index entry cannot exceed approximately one-third of a page (after TOAST compression, if applicable).

Because each btree operator class imposes a sort order on its data type, btree operator classes (or, really, operator families) have come to be used as PostgreSQL's general representation and understanding of sorting semantics. Therefore, they've acquired some features that go beyond what would be needed just to support btree indexes, and parts of the system that are quite distant from the btree AM make use of them.

63.2. Behavior of B-Tree Operator Classes

As shown in Table 37.2, a btree operator class must provide five comparison operators, $<$, $<=$, $=$, $>=$ and $>$. One might expect that $<>$ should also be part of the operator class, but it is not, because it would almost never be useful to use a $<>$ WHERE clause in an index search. (For some purposes, the planner treats $<>$ as associated with a btree operator class; but it finds that operator via the $=$ operator's negator link, rather than from `pg_amop`.)

When several data types share near-identical sorting semantics, their operator classes can be grouped into an operator family. Doing so is advantageous because it allows the planner to make deductions about cross-type comparisons. Each operator class within the family should contain the single-type operators (and associated support functions) for its input data type, while cross-type comparison operators and support functions are “loose” in the family. It is recommendable that a complete set of cross-type operators be included in the family, thus ensuring that the planner can represent any comparison conditions that it deduces from transitivity.

There are some basic assumptions that a btree operator family must satisfy:

- An $=$ operator must be an equivalence relation; that is, for all non-null values A, B, C of the data type:
 - $A = A$ is true (*reflexive law*)
 - if $A = B$, then $B = A$ (*symmetric law*)
 - if $A = B$ and $B = C$, then $A = C$ (*transitive law*)
- A $<$ operator must be a strong ordering relation; that is, for all non-null values A, B, C :
 - $A < A$ is false (*irreflexive law*)
 - if $A < B$ and $B < C$, then $A < C$ (*transitive law*)
- Furthermore, the ordering is total; that is, for all non-null values A, B :
 - exactly one of $A < B$, $A = B$, and $B < A$ is true (*trichotomy law*)(The trichotomy law justifies the definition of the comparison support function, of course.)

The other three operators are defined in terms of $=$ and $<$ in the obvious way, and must act consistently with them.

For an operator family supporting multiple data types, the above laws must hold when A, B, C are taken from any data types in the family. The transitive laws are the trickiest to ensure, as in cross-type situations they represent statements that the behaviors of two or three different operators are consistent.

As an example, it would not work to put `float8` and `numeric` into the same operator family, at least not with the current semantics that `numeric` values are converted to `float8` for comparison to a `float8`. Because of the limited accuracy of `float8`, this means there are distinct `numeric` values that will compare equal to the same `float8` value, and thus the transitive law would fail.

Another requirement for a multiple-data-type family is that any implicit or binary-coercion casts that are defined between data types included in the operator family must not change the associated sort ordering.

It should be fairly clear why a btree index requires these laws to hold within a single data type: without them there is no ordering to arrange the keys with. Also, index searches using a comparison key of a different data type require comparisons to behave sanely across two data types. The extensions to three or more data types within a family are not strictly required by the btree index mechanism itself, but the planner relies on them for optimization purposes.

63.3. B-Tree Support Functions

As shown in Table 37.8, `btree` defines one required and two optional support functions.

For each combination of data types that a btree operator family provides comparison operators for, it must provide a comparison support function, registered in `pg_amproc` with support function number 1 and `amproclefttype/amprocrighttype` equal to the left and right data types for the comparison (i.e., the same data types that the matching operators are registered with in `pg_amop`). The comparison function must take two non-null values *A* and *B* and return an `int32` value that is `< 0`, `0`, or `> 0` when $A < B$, $A = B$, or $A > B$, respectively. A null result is disallowed: all values of the data type must be comparable. See `src/backend/access/nbtree/nbtcompare.c` for examples.

If the compared values are of a collatable data type, the appropriate collation OID will be passed to the comparison support function, using the standard `PG_GET_COLLATION()` mechanism.

Optionally, a btree operator family may provide *sort support* function(s), registered under support function number 2. These functions allow implementing comparisons for sorting purposes in a more efficient way than naively calling the comparison support function. The APIs involved in this are defined in `src/include/utills/sortsupport.h`.

Optionally, a btree operator family may provide *in_range* support function(s), registered under support function number 3. These are not used during btree index operations; rather, they extend the semantics of the operator family so that it can support window clauses containing the `RANGE offset PRECEDING` and `RANGE offset FOLLOWING` frame bound types (see Section 4.2.8). Fundamentally, the extra information provided is how to add or subtract an *offset* value in a way that is compatible with the family's data ordering.

An `in_range` function must have the signature

```
in_range(val type1, base type1, offset type2, sub bool, less bool)
returns bool
```

val and *base* must be of the same type, which is one of the types supported by the operator family (i.e., a type for which it provides an ordering). However, *offset* could be of a different type, which might be one otherwise unsupported by the family. An example is that the built-in `time_ops` family provides an `in_range` function that has *offset* of type `interval`. A family can provide `in_range` functions for any of its supported types and one or more *offset* types. Each `in_range` function should be entered in `pg_amproc` with `amproclefttype` equal to `type1` and `amprocrighttype` equal to `type2`.

The essential semantics of an `in_range` function depend on the two Boolean flag parameters. It should add or subtract *base* and *offset*, then compare *val* to the result, as follows:

- if !sub and !less , return $\text{val} \geq (\text{base} + \text{offset})$
- if !sub and less , return $\text{val} \leq (\text{base} + \text{offset})$
- if sub and !less , return $\text{val} \geq (\text{base} - \text{offset})$
- if sub and less , return $\text{val} \leq (\text{base} - \text{offset})$

Before doing so, the function should check the sign of *offset*: if it is less than zero, raise error `ERRCODE_INVALID_PRECEDING_OR_FOLLOWING_SIZE` (22013) with error text like “invalid preceding or following size in window function”. (This is required by the SQL standard, although nonstandard operator families might perhaps choose to ignore this restriction, since there seems to be little semantic necessity for it.) This requirement is delegated to the `in_range` function so that the core code needn't understand what “less than zero” means for a particular data type.

An additional expectation is that `in_range` functions should, if practical, avoid throwing an error if $\text{base} + \text{offset}$ or $\text{base} - \text{offset}$ would overflow. The correct comparison result can be determined even if that value would be out of the data type's range. Note that if the data type includes concepts such as “infinity” or “NaN”, extra care may be needed to ensure that `in_range`'s results agree with the normal sort order of the operator family.

The results of the `in_range` function must be consistent with the sort ordering imposed by the operator family. To be precise, given any fixed values of *offset* and *sub*, then:

- If `in_range` with $\text{less} = \text{true}$ is true for some val1 and base , it must be true for every $\text{val2} \leq \text{val1}$ with the same base .
- If `in_range` with $\text{less} = \text{true}$ is false for some val1 and base , it must be false for every $\text{val2} \geq \text{val1}$ with the same base .
- If `in_range` with $\text{less} = \text{true}$ is true for some val and base1 , it must be true for every $\text{base2} \geq \text{base1}$ with the same val .
- If `in_range` with $\text{less} = \text{true}$ is false for some val and base1 , it must be false for every $\text{base2} \leq \text{base1}$ with the same val .

Analogous statements with inverted conditions hold when $\text{less} = \text{false}$.

If the type being ordered (`type1`) is collatable, the appropriate collation OID will be passed to the `in_range` function, using the standard `PG_GET_COLLATION()` mechanism.

`in_range` functions need not handle NULL inputs, and typically will be marked strict.

63.4. Implementation

An introduction to the btree index implementation can be found in `src/backend/access/nbtree/README`.

Chapter 64. GiST Indexes

64.1. Introduction

GiST stands for Generalized Search Tree. It is a balanced, tree-structured access method, that acts as a base template in which to implement arbitrary indexing schemes. B-trees, R-trees and many other indexing schemes can be implemented in GiST.

One advantage of GiST is that it allows the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert.

Some of the information here is derived from the University of California at Berkeley's GiST Indexing Project web site¹ and Marcel Kornacker's thesis, Access Methods for Next-Generation Database Systems². The GiST implementation in PostgreSQL is primarily maintained by Teodor Sigaev and Oleg Bartunov, and there is more information on their web site³.

64.2. Built-in Operator Classes

The core PostgreSQL distribution includes the GiST operator classes shown in Table 64.1. (Some of the optional modules described in Appendix F provide additional GiST operator classes.)

Table 64.1. Built-in GiST Operator Classes

Name	Indexed Data Type	Indexable Operators	Ordering Operators
box_ops	box	&& &> &< &< >> << << <@ @> @ &> >> ~ ~=	
circle_ops	circle	&& &> &< &< >> << << <@ @> @ &> >> ~ ~=	<->
inet_ops	inet, cidr	&& >> >>= > >= <> << <<= < <= =	
point_ops	point	>> >^ << <@ <@ <@ <^ ~ =	<->
poly_ops	polygon	&& &> &< &< >> << << <@ @> @ &> >> ~ ~=	<->
range_ops	any range type	&& &> &< >> << <@ - - = @> @>	
tsquery_ops	tsquery	<@ @>	
tsvector_ops	tsvector	@@	

For historical reasons, the `inet_ops` operator class is not the default class for types `inet` and `cidr`. To use it, mention the class name in `CREATE INDEX`, for example

```
CREATE INDEX ON my_table USING GIST (my_inet_column inet_ops);
```

¹ <http://gist.cs.berkeley.edu/>

² <http://www.sai.msu.su/~megeera/postgres/gist/papers/concurrency/access-methods-for-next-generation.pdf.gz>

³ <http://www.sai.msu.su/~megeera/postgres/gist/>

64.3. Extensibility

Traditionally, implementing a new index access method meant a lot of difficult work. It was necessary to understand the inner workings of the database, such as the lock manager and Write-Ahead Log. The GiST interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The GiST layer itself takes care of concurrency, logging and searching the tree structure.

This extensibility should not be confused with the extensibility of the other standard search trees in terms of the data they can handle. For example, PostgreSQL supports extensible B-trees and hash indexes. That means that you can use PostgreSQL to build a B-tree or hash over any data type you want. But B-trees only support range predicates ($<$, $=$, $>$), and hash indexes only support equality queries.

So if you index, say, an image collection with a PostgreSQL B-tree, you can only issue queries such as “is imagex equal to imagey”, “is imagex less than imagey” and “is imagex greater than imagey”. Depending on how you define “equals”, “less than” and “greater than” in this context, this could be useful. However, by using a GiST based index, you could create ways to ask domain-specific questions, perhaps “find all images of horses” or “find all over-exposed images”.

All it takes to get a GiST access method up and running is to implement several user-defined methods, which define the behavior of keys in the tree. Of course these methods have to be pretty fancy to support fancy queries, but for all the standard queries (B-trees, R-trees, etc.) they're relatively straightforward. In short, GiST combines extensibility along with generality, code reuse, and a clean interface.

There are five methods that an index operator class for GiST must provide, and four that are optional. Correctness of the index is ensured by proper implementation of the `same`, `consistent` and `union` methods, while efficiency (size and speed) of the index will depend on the `penalty` and `picksplit` methods. Two optional methods are `compress` and `decompress`, which allow an index to have internal tree data of a different type than the data it indexes. The leaves are to be of the indexed data type, while the other tree nodes can be of any C struct (but you still have to follow PostgreSQL data type rules here, see about `varlena` for variable sized data). If the tree's internal data type exists at the SQL level, the `STORAGE` option of the `CREATE OPERATOR CLASS` command can be used. The optional eighth method is `distance`, which is needed if the operator class wishes to support ordered scans (nearest-neighbor searches). The optional ninth method `fetch` is needed if the operator class wishes to support index-only scans, except when the `compress` method is omitted.

`consistent`

Given an index entry `p` and a query value `q`, this function determines whether the index entry is “consistent” with the query; that is, could the predicate “`indexed_column indexable_operator q`” be true for any row represented by the index entry? For a leaf index entry this is equivalent to testing the indexable condition, while for an internal tree node this determines whether it is necessary to scan the subtree of the index represented by the tree node. When the result is `true`, a `recheck` flag must also be returned. This indicates whether the predicate is certainly true or only possibly true. If `recheck = false` then the index has tested the predicate condition exactly, whereas if `recheck = true` the row is only a candidate match. In that case the system will automatically evaluate the `indexable_operator` against the actual row value to see if it is really a match. This convention allows GiST to support both lossless and lossy index structures.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_consistent(internal, data_type,
    smallint, oid, internal)
RETURNS bool
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_consistent);

Datum
my_consistent(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    data_type *query = PG_GETARG_DATA_TYPE_P(1);
    StrategyNumber strategy = (StrategyNumber)
PG_GETARG_UINT16(2);
    /* Oid subtype = PG_GETARG_OID(3); */
    bool *recheck = (bool *) PG_GETARG_POINTER(4);
    data_type *key = DatumGetDataTypes(entry->key);
    bool retval;

    /*
     * determine return value as a function of strategy, key and
     * query.
     *
     * Use GIST_LEAF(entry) to know where you're called in the
     * index tree,
     * which comes handy when supporting the = operator for
     * example (you could
     * check for non empty union() in non-leaf nodes and
     * equality in leaf
     * nodes).
     */

    *recheck = true; /* or false if check is exact */

    PG_RETURN_BOOL(retval);
}

```

Here, `key` is an element in the index and `query` the value being looked up in the index. The `StrategyNumber` parameter indicates which operator of your operator class is being applied — it matches one of the operator numbers in the `CREATE OPERATOR CLASS` command.

Depending on which operators you have included in the class, the data type of `query` could vary with the operator, since it will be whatever type is on the righthand side of the operator, which might be different from the indexed data type appearing on the lefthand side. (The above code skeleton assumes that only one type is possible; if not, fetching the `query` argument value would have to depend on the operator.) It is recommended that the SQL declaration of the `consistent` function use the opclass's indexed data type for the `query` argument, even though the actual type might be something else depending on the operator.

`union`

This method consolidates information in the tree. Given a set of entries, this function generates a new index entry that represents all the given entries.

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_union(internal, internal)
RETURNS storage_type
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_union);

Datum
my_union(PG_FUNCTION_ARGS)
{
    GistEntryVector *entryvec = (GistEntryVector *)
PG_GETARG_POINTER(0);
    GISTENTRY *ent = entryvec->vector;
    data_type *out,
                *tmp,
                *old;
    int        numranges,
                i = 0;

    numranges = entryvec->n;
    tmp = DatumGetDataType(ent[0].key);
    out = tmp;

    if (numranges == 1)
    {
        out = data_type_deep_copy(tmp);

        PG_RETURN_DATA_TYPE_P(out);
    }

    for (i = 1; i < numranges; i++)
    {
        old = out;
        tmp = DatumGetDataType(ent[i].key);
        out = my_union_implementation(out, tmp);
    }

    PG_RETURN_DATA_TYPE_P(out);
}

```

As you can see, in this skeleton we're dealing with a data type where $\text{union}(X, Y, Z) = \text{union}(\text{union}(X, Y), Z)$. It's easy enough to support data types where this is not the case, by implementing the proper union algorithm in this GiST support method.

The result of the union function must be a value of the index's storage type, whatever that is (it might or might not be different from the indexed column's type). The union function should return a pointer to newly `palloc()`ed memory. You can't just return the input value as-is, even if there is no type change.

As shown above, the union function's first internal argument is actually a `GistEntryVector` pointer. The second argument is a pointer to an integer variable, which can be ignored. (It used to be required that the union function store the size of its result value into that variable, but this is no longer necessary.)

compress

Converts a data item into a format suitable for physical storage in an index page. If the `compress` method is omitted, data items are stored in the index without modification.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_compress(internal)
```

```

RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_compress);

Datum
my_compress(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    GISTENTRY *retval;

    if (entry->leafkey)
    {
        /* replace entry->key with a compressed version */
        compressed_data_type *compressed_data =
        palloc(sizeof(compressed_data_type));

        /* fill *compressed_data from entry->key ... */

        retval = palloc(sizeof(GISTENTRY));
        gistentryinit(retval, PointerGetDatum(compressed_data),
                      entry->rel, entry->page, entry->offset,
FALSE);
    }
    else
    {
        /* typically we needn't do anything with non-leaf
entries */
        retval = entry;
    }

    PG_RETURN_POINTER(retval);
}

```

You have to adapt *compressed_data_type* to the specific type you're converting to in order to compress your leaf nodes, of course.

decompress

Converts the stored representation of a data item into a format that can be manipulated by the other GiST methods in the operator class. If the `decompress` method is omitted, it is assumed that the other GiST methods can work directly on the stored data format. (`decompress` is not necessarily the reverse of the `compress` method; in particular, if `compress` is lossy then it's impossible for `decompress` to exactly reconstruct the original data. `decompress` is not necessarily equivalent to `fetch`, either, since the other GiST methods might not require full reconstruction of the data.)

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_decompress(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_decompress);

Datum
my_decompress(PG_FUNCTION_ARGS)
{
    PG_RETURN_POINTER(PG_GETARG_POINTER(0));
}
```

The above skeleton is suitable for the case where no decompression is needed. (But, of course, omitting the method altogether is even easier, and is recommended in such cases.)

penalty

Returns a value indicating the “cost” of inserting the new entry into a particular branch of the tree. Items will be inserted down the path of least `penalty` in the tree. Values returned by `penalty` should be non-negative. If a negative value is returned, it will be treated as zero.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_penalty(internal, internal,
    internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT; -- in some cases penalty functions need not
    be strict
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_penalty);

Datum
my_penalty(PG_FUNCTION_ARGS)
{
    GISTENTRY *origentry = (GISTENTRY *) PG_GETARG_POINTER(0);
    GISTENTRY *newentry = (GISTENTRY *) PG_GETARG_POINTER(1);
    float *penalty = (float *) PG_GETARG_POINTER(2);
    data_type *orig = DatumGetDataTypes(origentry->key);
    data_type *new = DatumGetDataTypes(newentry->key);

    *penalty = my_penalty_implementation(orig, new);
    PG_RETURN_POINTER(penalty);
}
```

For historical reasons, the `penalty` function doesn't just return a `float` result; instead it has to store the value at the location indicated by the third argument. The return value per se is ignored, though it's conventional to pass back the address of that argument.

The `penalty` function is crucial to good performance of the index. It'll get used at insertion time to determine which branch to follow when choosing where to add the new entry in the tree. At query time, the more balanced the index, the quicker the lookup.

picksplit

When an index page split is necessary, this function decides which entries on the page are to stay on the old page, and which are to move to the new page.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_picksplit(internal, internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_picksplit);

Datum
my_picksplit(PG_FUNCTION_ARGS)
{
    GistEntryVector *entryvec = (GistEntryVector *)
PG_GETARG_POINTER(0);
    GIST_SPLITVEC *v = (GIST_SPLITVEC *) PG_GETARG_POINTER(1);
    OffsetNumber maxoff = entryvec->n - 1;
    GISTENTRY *ent = entryvec->vector;
    int i,
        nbytes;
    OffsetNumber *left,
        *right;
    data_type *tmp_union;
    data_type *unionL;
    data_type *unionR;
    GISTENTRY **raw_entryvec;

    maxoff = entryvec->n - 1;
    nbytes = (maxoff + 1) * sizeof(OffsetNumber);

    v->spl_left = (OffsetNumber *) palloc(nbytes);
    left = v->spl_left;
    v->spl_nleft = 0;

    v->spl_right = (OffsetNumber *) palloc(nbytes);
    right = v->spl_right;
    v->spl_nright = 0;

    unionL = NULL;
    unionR = NULL;

    /* Initialize the raw entry vector. */
    raw_entryvec = (GISTENTRY **) malloc(entryvec->n *
sizeof(void *));
    for (i = FirstOffsetNumber; i <= maxoff; i =
OffsetNumberNext(i))
        raw_entryvec[i] = &(entryvec->vector[i]);

    for (i = FirstOffsetNumber; i <= maxoff; i =
OffsetNumberNext(i))
    {
        int real_index = raw_entryvec[i] - entryvec-
>vector;

        tmp_union = DatumGetDataType(entryvec-
>vector[real_index].key);
        Assert(tmp_union != NULL);
    }
}
```

```

        /*
         * Choose where to put the index entries and update
unionL and unionR
         * accordingly. Append the entries to either v->spl_left
or
         * v->spl_right, and care about the counters.
        */

        if (my_choice_is_left(unionL, curl, unionR, curr))
        {
            if (unionL == NULL)
                unionL = tmp_union;
            else
                unionL = my_union_implementation(unionL,
tmp_union);

            *left = real_index;
            ++left;
            ++(v->spl_nleft);
        }
        else
        {
            /*
             * Same on the right
            */
        }
    }

    v->spl_ldatum = DataTypeGetDatum(unionL);
    v->spl_rdatum = DataTypeGetDatum(unionR);
    PG_RETURN_POINTER(v);
}

```

Notice that the `picksplit` function's result is delivered by modifying the passed-in `v` structure. The return value per se is ignored, though it's conventional to pass back the address of `v`.

Like `penalty`, the `picksplit` function is crucial to good performance of the index. Designing suitable `penalty` and `picksplit` implementations is where the challenge of implementing well-performing GiST indexes lies.

same

Returns true if two index entries are identical, false otherwise. (An “index entry” is a value of the index's storage type, not necessarily the original indexed column's type.)

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_same(storage_type, storage_type,
    internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_same);

```

```

Datum
my_same(PG_FUNCTION_ARGS)
{
    prefix_range *v1 = PG_GETARG_PREFIX_RANGE_P(0);
    prefix_range *v2 = PG_GETARG_PREFIX_RANGE_P(1);
    bool          *result = (bool *) PG_GETARG_POINTER(2);

    *result = my_eq(v1, v2);
    PG_RETURN_POINTER(result);
}

```

For historical reasons, the same function doesn't just return a Boolean result; instead it has to store the flag at the location indicated by the third argument. The return value per se is ignored, though it's conventional to pass back the address of that argument.

distance

Given an index entry *p* and a query value *q*, this function determines the index entry's “distance” from the query value. This function must be supplied if the operator class contains any ordering operators. A query using the ordering operator will be implemented by returning index entries with the smallest “distance” values first, so the results must be consistent with the operator's semantics. For a leaf index entry the result just represents the distance to the index entry; for an internal tree node, the result must be the smallest distance that any child entry could have.

The SQL declaration of the function must look like this:

```

CREATE OR REPLACE FUNCTION my_distance(internal, data_type,
    smallint, oid, internal)
RETURNS float8
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

```

And the matching code in the C module could then follow this skeleton:

```

PG_FUNCTION_INFO_V1(my_distance);

Datum
my_distance(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    data_type *query = PG_GETARG_DATA_TYPE_P(1);
    StrategyNumber strategy = (StrategyNumber)
    PG_GETARG_UINT16(2);
    /* Oid subtype = PG_GETARG_OID(3); */
    /* bool *recheck = (bool *) PG_GETARG_POINTER(4); */
    data_type *key = DatumGetDataTypes(entry->key);
    double     retval;

    /*
     * determine return value as a function of strategy, key and
     * query.
     */

    PG_RETURN_FLOAT8(retval);
}

```

The arguments to the distance function are identical to the arguments of the consistent function.

Some approximation is allowed when determining the distance, so long as the result is never greater than the entry's actual distance. Thus, for example, distance to a bounding box is usually sufficient in geometric applications. For an internal tree node, the distance returned must not be greater than the distance to any of the child nodes. If the returned distance is not exact, the function must set `*recheck` to true. (This is not necessary for internal tree nodes; for them, the calculation is always assumed to be inexact.) In this case the executor will calculate the accurate distance after fetching the tuple from the heap, and reorder the tuples if necessary.

If the distance function returns `*recheck = true` for any leaf node, the original ordering operator's return type must be `float8` or `float4`, and the distance function's result values must be comparable to those of the original ordering operator, since the executor will sort using both distance function results and recalculated ordering-operator results. Otherwise, the distance function's result values can be any finite `float8` values, so long as the relative order of the result values matches the order returned by the ordering operator. (Infinity and minus infinity are used internally to handle cases such as nulls, so it is not recommended that distance functions return these values.)

`fetch`

Converts the compressed index representation of a data item into the original data type, for index-only scans. The returned data must be an exact, non-lossy copy of the originally indexed value.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_fetch(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

The argument is a pointer to a `GISTENTRY` struct. On entry, its key field contains a non-NULL leaf datum in compressed form. The return value is another `GISTENTRY` struct, whose key field contains the same datum in its original, uncompressed form. If the opclass's compress function does nothing for leaf entries, the `fetch` method can return the argument as-is. Or, if the opclass does not have a compress function, the `fetch` method can be omitted as well, since it would necessarily be a no-op.

The matching code in the C module could then follow this skeleton:

```
PG_FUNCTION_INFO_V1(my_fetch);

Datum
my_fetch(PG_FUNCTION_ARGS)
{
    GISTENTRY *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    input_data_type *in = DatumGetPointer(entry->key);
    fetched_data_type *fetched_data;
    GISTENTRY *retval;

    retval = palloc(sizeof(GISTENTRY));
    fetched_data = palloc(sizeof(fetched_data_type));

    /*
     * Convert 'fetched_data' into the a Datum of the original
     * datatype.
     */
}
```

```

/* fill *retval from fetched_data. */
gistentryinit(*retval, PointerGetDatum(converted_datum),
              entry->rel, entry->page, entry->offset,
              FALSE);

PG_RETURN_POINTER(retval);
}

```

If the compress method is lossy for leaf entries, the operator class cannot support index-only scans, and must not define a `fetch` function.

All the GiST support methods are normally called in short-lived memory contexts; that is, `CurrentMemoryContext` will get reset after each tuple is processed. It is therefore not very important to worry about pfree'ing everything you palloc. However, in some cases it's useful for a support method to cache data across repeated calls. To do that, allocate the longer-lived data in `fcinfo->flinfo->fn_mcxt`, and keep a pointer to it in `fcinfo->flinfo->fn_extra`. Such data will survive for the life of the index operation (e.g., a single GiST index scan, index build, or index tuple insertion). Be careful to pfree the previous value when replacing a `fn_extra` value, or the leak will accumulate for the duration of the operation.

64.4. Implementation

64.4.1. GiST Buffering Build

Building large GiST indexes by simply inserting all the tuples tends to be slow, because if the index tuples are scattered across the index and the index is large enough to not fit in cache, the insertions need to perform a lot of random I/O. Beginning in version 9.2, PostgreSQL supports a more efficient method to build GiST indexes based on buffering, which can dramatically reduce the number of random I/Os needed for non-ordered data sets. For well-ordered data sets the benefit is smaller or non-existent, because only a small number of pages receive new tuples at a time, and those pages fit in cache even if the index as whole does not.

However, buffering index build needs to call the `penalty` function more often, which consumes some extra CPU resources. Also, the buffers used in the buffering build need temporary disk space, up to the size of the resulting index. Buffering can also influence the quality of the resulting index, in both positive and negative directions. That influence depends on various factors, like the distribution of the input data and the operator class implementation.

By default, a GiST index build switches to the buffering method when the index size reaches `effective_cache_size`. It can be manually turned on or off by the `buffering` parameter to the `CREATE INDEX` command. The default behavior is good for most cases, but turning buffering off might speed up the build somewhat if the input data is ordered.

64.5. Examples

The PostgreSQL source distribution includes several examples of index methods implemented using GiST. The core system currently provides text search support (indexing for `tsvector` and `tsquery`) as well as R-Tree equivalent functionality for some of the built-in geometric data types (see `src/backend/access/gist/gistproc.c`). The following `contrib` modules also contain GiST operator classes:

`btree_gist`

B-tree equivalent functionality for several data types

`cube`

Indexing for multidimensional cubes

hstore

Module for storing (key, value) pairs

intarray

RD-Tree for one-dimensional array of int4 values

ltree

Indexing for tree-like structures

pg_trgm

Text similarity using trigram matching

seg

Indexing for “float ranges”

Chapter 65. SP-GiST Indexes

65.1. Introduction

SP-GiST is an abbreviation for space-partitioned GiST. SP-GiST supports partitioned search trees, which facilitate development of a wide range of different non-balanced data structures, such as quad-trees, k-d trees, and radix trees (tries). The common feature of these structures is that they repeatedly divide the search space into partitions that need not be of equal size. Searches that are well matched to the partitioning rule can be very fast.

These popular data structures were originally developed for in-memory usage. In main memory, they are usually designed as a set of dynamically allocated nodes linked by pointers. This is not suitable for direct storing on disk, since these chains of pointers can be rather long which would require too many disk accesses. In contrast, disk-based data structures should have a high fanout to minimize I/O. The challenge addressed by SP-GiST is to map search tree nodes to disk pages in such a way that a search need access only a few disk pages, even if it traverses many nodes.

Like GiST, SP-GiST is meant to allow the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert.

Some of the information here is derived from Purdue University's SP-GiST Indexing Project web site¹. The SP-GiST implementation in PostgreSQL is primarily maintained by Teodor Sigaev and Oleg Bartunov, and there is more information on their web site².

65.2. Built-in Operator Classes

The core PostgreSQL distribution includes the SP-GiST operator classes shown in Table 65.1.

Table 65.1. Built-in SP-GiST Operator Classes

Name	Indexed Data Type	Indexable Operators	Ordering Operators
kd_point_ops	point	<< <@ <^ >> >^ ~ =	<->
quad_point_ops	point	<< <@ <^ >> >^ ~ =	<->
range_ops	any range type	&& &< &> - - << <@ = >> @>	
box_ops	box	<< &< && &> >> ~ = @> <@ &< << >> &>	
poly_ops	polygon	<< &< && &> >> ~ = @> <@ &< << >> &>	<->
text_ops	text	< < = = > > = ~ < = ~ ~ < ~ ~ > = ~ ~ ~ ~ ^ @	
inet_ops	inet, cidr	&& >> >> = > = <> << << = < < = =	

Of the two operator classes for type `point`, `quad_point_ops` is the default. `kd_point_ops` supports the same operators but uses a different index data structure that may offer better performance in some applications.

The `quad_point_ops`, `kd_point_ops` and `poly_ops` operator classes support the `<->` ordering operator, which enables the k-nearest neighbor (k-NN) search over indexed point or polygon data sets.

¹ <https://www.cs.purdue.edu/spgist/>

² http://www.sai.msu.su/~megeera/wiki/spgist_dev

65.3. Extensibility

SP-GiST offers an interface with a high level of abstraction, requiring the access method developer to implement only methods specific to a given data type. The SP-GiST core is responsible for efficient disk mapping and searching the tree structure. It also takes care of concurrency and logging considerations.

Leaf tuples of an SP-GiST tree contain values of the same data type as the indexed column. Leaf tuples at the root level will always contain the original indexed data value, but leaf tuples at lower levels might contain only a compressed representation, such as a suffix. In that case the operator class support functions must be able to reconstruct the original value using information accumulated from the inner tuples that are passed through to reach the leaf level.

Inner tuples are more complex, since they are branching points in the search tree. Each inner tuple contains a set of one or more *nodes*, which represent groups of similar leaf values. A node contains a downlink that leads either to another, lower-level inner tuple, or to a short list of leaf tuples that all lie on the same index page. Each node normally has a *label* that describes it; for example, in a radix tree the node label could be the next character of the string value. (Alternatively, an operator class can omit the node labels, if it works with a fixed set of nodes for all inner tuples; see Section 65.4.2.) Optionally, an inner tuple can have a *prefix* value that describes all its members. In a radix tree this could be the common prefix of the represented strings. The prefix value is not necessarily really a prefix, but can be any data needed by the operator class; for example, in a quad-tree it can store the central point that the four quadrants are measured with respect to. A quad-tree inner tuple would then also contain four nodes corresponding to the quadrants around this central point.

Some tree algorithms require knowledge of level (or depth) of the current tuple, so the SP-GiST core provides the possibility for operator classes to manage level counting while descending the tree. There is also support for incrementally reconstructing the represented value when that is needed, and for passing down additional data (called *traverse values*) during a tree descent.

Note

The SP-GiST core code takes care of null entries. Although SP-GiST indexes do store entries for nulls in indexed columns, this is hidden from the index operator class code: no null index entries or search conditions will ever be passed to the operator class methods. (It is assumed that SP-GiST operators are strict and so cannot succeed for null values.) Null values are therefore not discussed further here.

There are five user-defined methods that an index operator class for SP-GiST must provide, and one is optional. All five mandatory methods follow the convention of accepting two `internal` arguments, the first of which is a pointer to a C struct containing input values for the support method, while the second argument is a pointer to a C struct where output values must be placed. Four of the mandatory methods just return `void`, since all their results appear in the output struct; but `leaf_consistent` additionally returns a `boolean` result. The methods must not modify any fields of their input structs. In all cases, the output struct is initialized to zeroes before calling the user-defined method. The optional sixth method `compress` accepts `datum` to be indexed as the only argument and returns a value suitable for physical storage in a leaf tuple.

The five mandatory user-defined methods are:

`config`

Returns static information about the index implementation, including the data type OIDs of the prefix and node label data types.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_config(internal, internal) RETURNS void ...
```

The first argument is a pointer to a `spgConfigIn` C struct, containing input data for the function. The second argument is a pointer to a `spgConfigOut` C struct, which the function must fill with result data.

```
typedef struct spgConfigIn
{
    Oid          attType;          /* Data type to be indexed */
} spgConfigIn;

typedef struct spgConfigOut
{
    Oid          prefixType;       /* Data type of inner-tuple
prefixes */
    Oid          labelType;       /* Data type of inner-tuple node
labels */
    Oid          leafType;        /* Data type of leaf-tuple
values */
    bool         canReturnData;   /* Opclass can reconstruct
original data */
    bool         longValuesOK;    /* Opclass can cope with values
> 1 page */
} spgConfigOut;
```

`attType` is passed in order to support polymorphic index operator classes; for ordinary fixed-data-type operator classes, it will always have the same value and so can be ignored.

For operator classes that do not use prefixes, `prefixType` can be set to `VOIDOID`. Likewise, for operator classes that do not use node labels, `labelType` can be set to `VOIDOID`. `canReturnData` should be set true if the operator class is capable of reconstructing the originally-supplied index value. `longValuesOK` should be set true only when the `attType` is of variable length and the operator class is capable of segmenting long values by repeated suffixing (see Section 65.4.1).

`leafType` is typically the same as `attType`. For the reasons of backward compatibility, method `config` can leave `leafType` uninitialized; that would give the same effect as setting `leafType` equal to `attType`. When `attType` and `leafType` are different, then optional method `compress` must be provided. Method `compress` is responsible for transformation of datums to be indexed from `attType` to `leafType`. Note: both consistent functions will get `scankeys` unchanged, without transformation using `compress`.

choose

Chooses a method for inserting a new value into an inner tuple.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_choose(internal, internal) RETURNS void ...
```

The first argument is a pointer to a `spgChooseIn` C struct, containing input data for the function. The second argument is a pointer to a `spgChooseOut` C struct, which the function must fill with result data.

```
typedef struct spgChooseIn
{
    Datum       datum;           /* original datum to be indexed
*/
```

```

    Datum      leafDatum;      /* current datum to be stored at
leaf */
    int        level;          /* current level (counting from
zero) */

    /* Data from current inner tuple */
    bool       allTheSame;     /* tuple is marked all-the-same?
*/
    bool       hasPrefix;      /* tuple has a prefix? */
    Datum      prefixDatum;    /* if so, the prefix value */
    int        nNodes;         /* number of nodes in the inner
tuple */
    Datum      *nodeLabels;    /* node label values (NULL if
none) */
} spgChooseIn;

typedef enum spgChooseResultType
{
    spgMatchNode = 1,          /* descend into existing node */
    spgAddNode,                /* add a node to the inner tuple
*/
    spgSplitTuple              /* split inner tuple (change its
prefix) */
} spgChooseResultType;

typedef struct spgChooseOut
{
    spgChooseResultType resultType; /* action code, see
above */
    union
    {
        struct                /* results for spgMatchNode */
        {
            int                /* descend to this node
(index from 0) */
            int                /* increment level by this
much */
            Datum              /* new leaf datum */
        } matchNode;
        struct                /* results for spgAddNode */
        {
            Datum              /* new node's label */
            int                /* where to insert it (index
from 0) */
        } addNode;
        struct                /* results for spgSplitTuple */
        {
            /* Info to form new upper-level inner tuple with one
child tuple */
            bool               /* tuple should have
a prefix? */
            Datum              /* if so, its value
*/
            int                /* number of nodes
*/
            Datum              /* their labels (or
NULL for
                               * no labels) */
        }
    }
};

```

```

        int            childNodeN;            /* which node gets
child tuple */

        /* Info to form new lower-level inner tuple with all
old nodes */
        bool          postfixHasPrefix;      /* tuple should have
a prefix? */
        Datum         postfixPrefixDatum;    /* if so, its value
*/
    }                splitTuple;
}                result;
} spgChooseOut;

```

datum is the original datum of `spgConfigIn.attType` type that was to be inserted into the index. `leafDatum` is a value of `spgConfigOut.leafType` type, which is initially a result of method `compress` applied to `datum` when method `compress` is provided, or the same value as `datum` otherwise. `leafDatum` can change at lower levels of the tree if the `choose` or `picksplit` methods change it. When the insertion search reaches a leaf page, the current value of `leafDatum` is what will be stored in the newly created leaf tuple. `level` is the current inner tuple's level, starting at zero for the root level. `allTheSame` is true if the current inner tuple is marked as containing multiple equivalent nodes (see Section 65.4.3). `hasPrefix` is true if the current inner tuple contains a prefix; if so, `prefixDatum` is its value. `nNodes` is the number of child nodes contained in the inner tuple, and `nodeLabels` is an array of their label values, or NULL if there are no labels.

The `choose` function can determine either that the new value matches one of the existing child nodes, or that a new child node must be added, or that the new value is inconsistent with the tuple prefix and so the inner tuple must be split to create a less restrictive prefix.

If the new value matches one of the existing child nodes, set `resultType` to `spgMatchNode`. Set `nodeN` to the index (from zero) of that node in the node array. Set `levelAdd` to the increment in `level` caused by descending through that node, or leave it as zero if the operator class does not use levels. Set `restDatum` to equal `leafDatum` if the operator class does not modify datums from one level to the next, or otherwise set it to the modified value to be used as `leafDatum` at the next level.

If a new child node must be added, set `resultType` to `spgAddNode`. Set `nodeLabel` to the label to be used for the new node, and set `nodeN` to the index (from zero) at which to insert the node in the node array. After the node has been added, the `choose` function will be called again with the modified inner tuple; that call should result in an `spgMatchNode` result.

If the new value is inconsistent with the tuple prefix, set `resultType` to `spgSplitTuple`. This action moves all the existing nodes into a new lower-level inner tuple, and replaces the existing inner tuple with a tuple having a single downlink pointing to the new lower-level inner tuple. Set `prefixHasPrefix` to indicate whether the new upper tuple should have a prefix, and if so set `prefixPrefixDatum` to the prefix value. This new prefix value must be sufficiently less restrictive than the original to accept the new value to be indexed. Set `prefixNNodes` to the number of nodes needed in the new tuple, and set `prefixNodeLabels` to a palloc'd array holding their labels, or to NULL if node labels are not required. Note that the total size of the new upper tuple must be no more than the total size of the tuple it is replacing; this constrains the lengths of the new prefix and new labels. Set `childNodeN` to the index (from zero) of the node that will downlink to the new lower-level inner tuple. Set `postfixHasPrefix` to indicate whether the new lower-level inner tuple should have a prefix, and if so set `postfixPrefixDatum` to the prefix value. The combination of these two prefixes and the downlink node's label (if any) must have the same meaning as the original prefix, because there is no opportunity to alter the node labels that are moved to the new lower-level tuple, nor to change any child index entries. After the node has been split, the `choose` function will be called again with the replacement inner tuple. That call may return an `spgAddNode` result, if no suitable node was

created by the `spgSplitTuple` action. Eventually choose must return `spgMatchNode` to allow the insertion to descend to the next level.

`picksplit`

Decides how to create a new inner tuple over a set of leaf tuples.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_picksplit(internal, internal) RETURNS
void ...
```

The first argument is a pointer to a `spgPickSplitIn` C struct, containing input data for the function. The second argument is a pointer to a `spgPickSplitOut` C struct, which the function must fill with result data.

```
typedef struct spgPickSplitIn
{
    int          nTuples;          /* number of leaf tuples */
    Datum        *datums;          /* their datums (array of length
nTuples) */
    int          level;           /* current level (counting from
zero) */
} spgPickSplitIn;

typedef struct spgPickSplitOut
{
    bool         hasPrefix;        /* new inner tuple should have a
prefix? */
    Datum        prefixDatum;      /* if so, its value */

    int          nNodes;          /* number of nodes for new inner
tuple */
    Datum        *nodeLabels;      /* their labels (or NULL for no
labels) */

    int          *mapTuplesToNodes; /* node index for each leaf
tuple */
    Datum        *leafTupleDatums; /* datum to store in each
new leaf tuple */
} spgPickSplitOut;
```

`nTuples` is the number of leaf tuples provided. `datums` is an array of their datum values of `spgConfigOut.leafType` type. `level` is the current level that all the leaf tuples share, which will become the level of the new inner tuple.

Set `hasPrefix` to indicate whether the new inner tuple should have a prefix, and if so set `prefixDatum` to the prefix value. Set `nNodes` to indicate the number of nodes that the new inner tuple will contain, and set `nodeLabels` to an array of their label values, or to `NULL` if node labels are not required. Set `mapTuplesToNodes` to an array that gives the index (from zero) of the node that each leaf tuple should be assigned to. Set `leafTupleDatums` to an array of the values to be stored in the new leaf tuples (these will be the same as the input datums if the operator class does not modify datums from one level to the next). Note that the `picksplit` function is responsible for `palloc`'ing the `nodeLabels`, `mapTuplesToNodes` and `leafTupleDatums` arrays.

If more than one leaf tuple is supplied, it is expected that the `picksplit` function will classify them into more than one node; otherwise it is not possible to split the leaf tuples across multiple

pages, which is the ultimate purpose of this operation. Therefore, if the `picksplit` function ends up placing all the leaf tuples in the same node, the core SP-GiST code will override that decision and generate an inner tuple in which the leaf tuples are assigned at random to several identically-labeled nodes. Such a tuple is marked `allTheSame` to signify that this has happened. The `choose` and `inner_consistent` functions must take suitable care with such inner tuples. See Section 65.4.3 for more information.

`picksplit` can be applied to a single leaf tuple only in the case that the `config` function set `longValuesOK` to true and a larger-than-a-page input value has been supplied. In this case the point of the operation is to strip off a prefix and produce a new, shorter leaf datum value. The call will be repeated until a leaf datum short enough to fit on a page has been produced. See Section 65.4.1 for more information.

`inner_consistent`

Returns set of nodes (branches) to follow during tree search.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_inner_consistent(internal, internal) RETURNS
void ...
```

The first argument is a pointer to a `spgInnerConsistentIn` C struct, containing input data for the function. The second argument is a pointer to a `spgInnerConsistentOut` C struct, which the function must fill with result data.

```
typedef struct spgInnerConsistentIn
{
    ScanKey      scankeys;          /* array of operators and
comparison values */
    ScanKey      orderbys;          /* array of ordering operators
and comparison
                                     * values */
    int          nkeys;             /* length of scankeys array */
    int          norderbys;         /* length of orderbys array */

    Datum        reconstructedValue; /* value reconstructed
at parent */
    void         *traversalValue;    /* opclass-specific traverse
value */
    MemoryContext traversalMemoryContext; /* put new traverse
values here */
    int          level;             /* current level (counting from
zero) */
    bool         returnData;        /* original data must be
returned? */

    /* Data from current inner tuple */
    bool         allTheSame;        /* tuple is marked all-the-same?
*/
    bool         hasPrefix;         /* tuple has a prefix? */
    Datum        prefixDatum;       /* if so, the prefix value */
    int          nNodes;            /* number of nodes in the inner
tuple */
    Datum        *nodeLabels;       /* node label values (NULL if
none) */
} spgInnerConsistentIn;
```

```

typedef struct spgInnerConsistentOut
{
    int          nNodes;          /* number of child nodes to be
visited */
    int          *nodeNumbers;    /* their indexes in the node
array */
    int          *levelAdds;     /* increment level by this much
for each */
    Datum        *reconstructedValues; /* associated
reconstructed values */
    void         **traversalValues; /* opclass-specific
traverse values */
    double       **distances;    /* associated distances
*/
} spgInnerConsistentOut;

```

The array `scankeys`, of length `nkeys`, describes the index search condition(s). These conditions are combined with AND — only index entries that satisfy all of them are interesting. (Note that `nkeys = 0` implies that all index entries satisfy the query.) Usually the consistent function only cares about the `sk_strategy` and `sk_argument` fields of each array entry, which respectively give the indexable operator and comparison value. In particular it is not necessary to check `sk_flags` to see if the comparison value is NULL, because the SP-GiST core code will filter out such conditions. The array `orderbys`, of length `norderbys`, describes ordering operators (if any) in the same manner. `reconstructedValue` is the value reconstructed for the parent tuple; it is (Datum) 0 at the root level or if the `inner_consistent` function did not provide a value at the parent level. `reconstructedValue` is always of `spgConfigOut.leafType` type. `traversalValue` is a pointer to any traverse data passed down from the previous call of `inner_consistent` on the parent index tuple, or NULL at the root level. `traversalMemoryContext` is the memory context in which to store output traverse values (see below). `level` is the current inner tuple's level, starting at zero for the root level. `returnData` is true if reconstructed data is required for this query; this will only be so if the `config` function asserted `canReturnData`. `allTheSame` is true if the current inner tuple is marked “all-the-same”; in this case all the nodes have the same label (if any) and so either all or none of them match the query (see Section 65.4.3). `hasPrefix` is true if the current inner tuple contains a prefix; if so, `prefixDatum` is its value. `nNodes` is the number of child nodes contained in the inner tuple, and `nodeLabels` is an array of their label values, or NULL if the nodes do not have labels.

`nNodes` must be set to the number of child nodes that need to be visited by the search, and `nodeNumbers` must be set to an array of their indexes. If the operator class keeps track of levels, set `levelAdds` to an array of the level increments required when descending to each node to be visited. (Often these increments will be the same for all the nodes, but that's not necessarily so, so an array is used.) If value reconstruction is needed, set `reconstructedValues` to an array of the values of `spgConfigOut.leafType` type reconstructed for each child node to be visited; otherwise, leave `reconstructedValues` as NULL. If ordered search is performed, set `distances` to an array of distance values according to `orderbys` array (nodes with lowest distances will be processed first). Leave it NULL otherwise. If it is desired to pass down additional out-of-band information (“traverse values”) to lower levels of the tree search, set `traversalValues` to an array of the appropriate traverse values, one for each child node to be visited; otherwise, leave `traversalValues` as NULL. Note that the `inner_consistent` function is responsible for `palloc`'ing the `nodeNumbers`, `levelAdds`, `distances`, `reconstructedValues`, and `traversalValues` arrays in the current memory context. However, any output traverse values pointed to by the `traversalValues` array should be allocated in `traversalMemoryContext`. Each traverse value must be a single `palloc`'d chunk.

`leaf_consistent`

Returns true if a leaf tuple satisfies a query.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_leaf_consistent(internal, internal) RETURNS
bool ...
```

The first argument is a pointer to a `spgLeafConsistentIn` C struct, containing input data for the function. The second argument is a pointer to a `spgLeafConsistentOut` C struct, which the function must fill with result data.

```
typedef struct spgLeafConsistentIn
{
    ScanKey    scankeys;        /* array of operators and
comparison values */
    ScanKey    orderbys;       /* array of ordering operators
and comparison
                                * values */
    int        nkeys;          /* length of scankeys array */
    int        norderbys;      /* length of orderbys array */

    Datum      reconstructedValue; /* value reconstructed
at parent */
    void      *traversalValue; /* opclass-specific traverse
value */
    int        level;          /* current level (counting from
zero) */
    bool       returnData;     /* original data must be
returned? */

    Datum      leafDatum;      /* datum in leaf tuple */
} spgLeafConsistentIn;

typedef struct spgLeafConsistentOut
{
    Datum      leafValue;      /* reconstructed original
data, if any */
    bool       recheck;        /* set true if operator must
be rechecked */
    bool       recheckDistances; /* set true if distances must
be rechecked */
    double     *distances;     /* associated distances */
} spgLeafConsistentOut;
```

The array `scankeys`, of length `nkeys`, describes the index search condition(s). These conditions are combined with AND — only index entries that satisfy all of them satisfy the query. (Note that `nkeys = 0` implies that all index entries satisfy the query.) Usually the consistent function only cares about the `sk_strategy` and `sk_argument` fields of each array entry, which respectively give the indexable operator and comparison value. In particular it is not necessary to check `sk_flags` to see if the comparison value is NULL, because the SP-GiST core code will filter out such conditions. The array `orderbys`, of length `norderbys`, describes the ordering operators in the same manner. `reconstructedValue` is the value reconstructed for the parent tuple; it is (Datum) 0 at the root level or if the `inner_consistent` function did not provide a value at the parent level. `reconstructedValue` is always of `spgConfigOut.leafType` type. `traversalValue` is a pointer to any traverse data passed down from the previous call of `inner_consistent` on the parent index tuple, or NULL at the root level. `level` is the current leaf tuple's level, starting at zero for the root level. `returnData` is true if reconstructed data is required for this query; this will only be so if the `config` function asserted `canReturnData`. `leafDatum` is the key value of `spgConfigOut.leafType` stored in the current leaf tuple.

The function must return `true` if the leaf tuple matches the query, or `false` if not. In the `true` case, if `returnData` is `true` then `leafValue` must be set to the value of `spgConfigIn.attType` type originally supplied to be indexed for this leaf tuple. Also, `recheck` may be set to `true` if the match is uncertain and so the operator(s) must be re-applied to the actual heap tuple to verify the match. If ordered search is performed, set `distances` to an array of distance values according to `orderbys` array. Leave it `NULL` otherwise. If at least one of returned distances is not exact, set `recheckDistances` to `true`. In this case, the executor will calculate the exact distances after fetching the tuple from the heap, and will reorder the tuples if needed.

The optional user-defined method is:

```
Datum compress(Datum in)
```

Converts the data item into a format suitable for physical storage in a leaf tuple of index page. It accepts `spgConfigIn.attType` value and returns `spgConfigOut.leafType` value. Output value should not be toasted.

All the SP-GiST support methods are normally called in a short-lived memory context; that is, `CurrentMemoryContext` will be reset after processing of each tuple. It is therefore not very important to worry about freeing everything you palloc. (The `config` method is an exception: it should try to avoid leaking memory. But usually the `config` method need do nothing but assign constants into the passed parameter struct.)

If the indexed column is of a collatable data type, the index collation will be passed to all the support methods, using the standard `PG_GET_COLLATION()` mechanism.

65.4. Implementation

This section covers implementation details and other tricks that are useful for implementers of SP-GiST operator classes to know.

65.4.1. SP-GiST Limits

Individual leaf tuples and inner tuples must fit on a single index page (8kB by default). Therefore, when indexing values of variable-length data types, long values can only be supported by methods such as radix trees, in which each level of the tree includes a prefix that is short enough to fit on a page, and the final leaf level includes a suffix also short enough to fit on a page. The operator class should set `longValuesOK` to `true` only if it is prepared to arrange for this to happen. Otherwise, the SP-GiST core will reject any request to index a value that is too large to fit on an index page.

Likewise, it is the operator class's responsibility that inner tuples do not grow too large to fit on an index page; this limits the number of child nodes that can be used in one inner tuple, as well as the maximum size of a prefix value.

Another limitation is that when an inner tuple's node points to a set of leaf tuples, those tuples must all be in the same index page. (This is a design decision to reduce seeking and save space in the links that chain such tuples together.) If the set of leaf tuples grows too large for a page, a split is performed and an intermediate inner tuple is inserted. For this to fix the problem, the new inner tuple *must* divide the set of leaf values into more than one node group. If the operator class's `picksplit` function fails to do that, the SP-GiST core resorts to extraordinary measures described in Section 65.4.3.

65.4.2. SP-GiST Without Node Labels

Some tree algorithms use a fixed set of nodes for each inner tuple; for example, in a quad-tree there are always exactly four nodes corresponding to the four quadrants around the inner tuple's centroid point. In such a case the code typically works with the nodes by number, and there is no need for explicit node labels. To suppress node labels (and thereby save some space), the `picksplit` function can return `NULL` for the `nodeLabels` array, and likewise the `choose` function can return `NULL` for the

`prefixNodeLabels` array during a `spgSplitTuple` action. This will in turn result in `nodeLabels` being `NULL` during subsequent calls to `choose` and `inner_consistent`. In principle, node labels could be used for some inner tuples and omitted for others in the same index.

When working with an inner tuple having unlabeled nodes, it is an error for `choose` to return `spgAddNode`, since the set of nodes is supposed to be fixed in such cases.

65.4.3. “All-the-Same” Inner Tuples

The SP-GiST core can override the results of the operator class's `picksplit` function when `picksplit` fails to divide the supplied leaf values into at least two node categories. When this happens, the new inner tuple is created with multiple nodes that each have the same label (if any) that `picksplit` gave to the one node it did use, and the leaf values are divided at random among these equivalent nodes. The `allTheSame` flag is set on the inner tuple to warn the `choose` and `inner_consistent` functions that the tuple does not have the node set that they might otherwise expect.

When dealing with an `allTheSame` tuple, a `choose` result of `spgMatchNode` is interpreted to mean that the new value can be assigned to any of the equivalent nodes; the core code will ignore the supplied `nodeN` value and descend into one of the nodes at random (so as to keep the tree balanced). It is an error for `choose` to return `spgAddNode`, since that would make the nodes not all equivalent; the `spgSplitTuple` action must be used if the value to be inserted doesn't match the existing nodes.

When dealing with an `allTheSame` tuple, the `inner_consistent` function should return either all or none of the nodes as targets for continuing the index search, since they are all equivalent. This may or may not require any special-case code, depending on how much the `inner_consistent` function normally assumes about the meaning of the nodes.

65.5. Examples

The PostgreSQL source distribution includes several examples of index operator classes for SP-GiST, as described in Table 65.1. Look into `src/backend/access/spgist/` and `src/backend/utils/adt/` to see the code.

Chapter 66. GIN Indexes

66.1. Introduction

GIN stands for Generalized Inverted Index. GIN is designed for handling cases where the items to be indexed are composite values, and the queries to be handled by the index need to search for element values that appear within the composite items. For example, the items could be documents, and the queries could be searches for documents containing specific words.

We use the word *item* to refer to a composite value that is to be indexed, and the word *key* to refer to an element value. GIN always stores and searches for keys, not item values per se.

A GIN index stores a set of (key, posting list) pairs, where a *posting list* is a set of row IDs in which the key occurs. The same row ID can appear in multiple posting lists, since an item can contain more than one key. Each key value is stored only once, so a GIN index is very compact for cases where the same key appears many times.

GIN is generalized in the sense that the GIN access method code does not need to know the specific operations that it accelerates. Instead, it uses custom strategies defined for particular data types. The strategy defines how keys are extracted from indexed items and query conditions, and how to determine whether a row that contains some of the key values in a query actually satisfies the query.

One advantage of GIN is that it allows the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert. This is much the same advantage as using GiST.

The GIN implementation in PostgreSQL is primarily maintained by Teodor Sigaev and Oleg Bartunov. There is more information about GIN on their website¹.

66.2. Built-in Operator Classes

The core PostgreSQL distribution includes the GIN operator classes shown in Table 66.1. (Some of the optional modules described in Appendix F provide additional GIN operator classes.)

Table 66.1. Built-in GIN Operator Classes

Name	Indexed Data Type	Indexable Operators
array_ops	anyarray	&& <@ = @>
jsonb_ops	jsonb	? ?& ? @> @? @@
jsonb_path_ops	jsonb	@> @? @@
tsvector_ops	tsvector	@@ @@@

Of the two operator classes for type `jsonb`, `jsonb_ops` is the default. `jsonb_path_ops` supports fewer operators but offers better performance for those operators. See Section 8.14.4 for details.

66.3. Extensibility

The GIN interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The GIN layer itself takes care of concurrency, logging and searching the tree structure.

¹ <http://www.sai.msu.su/~megeera/wiki/Gin>

All it takes to get a GIN access method working is to implement a few user-defined methods, which define the behavior of keys in the tree and the relationships between keys, indexed items, and indexable queries. In short, GIN combines extensibility with generality, code reuse, and a clean interface.

There are two methods that an operator class for GIN must provide:

```
Datum *extractValue(Datum itemValue, int32 *nkeys, bool **nullFlags)
```

Returns a palloc'd array of keys given an item to be indexed. The number of returned keys must be stored into `*nkeys`. If any of the keys can be null, also palloc an array of `*nkeys` `bool` fields, store its address at `*nullFlags`, and set these null flags as needed. `*nullFlags` can be left `NULL` (its initial value) if all keys are non-null. The return value can be `NULL` if the item contains no keys.

```
Datum *extractQuery(Datum query, int32 *nkeys, StrategyNumber n, bool
**pmatch, Pointer **extra_data, bool **nullFlags, int32 *searchMode)
```

Returns a palloc'd array of keys given a value to be queried; that is, `query` is the value on the right-hand side of an indexable operator whose left-hand side is the indexed column. `n` is the strategy number of the operator within the operator class (see Section 37.16.2). Often, `extractQuery` will need to consult `n` to determine the data type of `query` and the method it should use to extract key values. The number of returned keys must be stored into `*nkeys`. If any of the keys can be null, also palloc an array of `*nkeys` `bool` fields, store its address at `*nullFlags`, and set these null flags as needed. `*nullFlags` can be left `NULL` (its initial value) if all keys are non-null. The return value can be `NULL` if the query contains no keys.

`searchMode` is an output argument that allows `extractQuery` to specify details about how the search will be done. If `*searchMode` is set to `GIN_SEARCH_MODE_DEFAULT` (which is the value it is initialized to before call), only items that match at least one of the returned keys are considered candidate matches. If `*searchMode` is set to `GIN_SEARCH_MODE_INCLUDE_EMPTY`, then in addition to items containing at least one matching key, items that contain no keys at all are considered candidate matches. (This mode is useful for implementing is-subset-of operators, for example.) If `*searchMode` is set to `GIN_SEARCH_MODE_ALL`, then all non-null items in the index are considered candidate matches, whether they match any of the returned keys or not. (This mode is much slower than the other two choices, since it requires scanning essentially the entire index, but it may be necessary to implement corner cases correctly. An operator that needs this mode in most cases is probably not a good candidate for a GIN operator class.) The symbols to use for setting this mode are defined in `access/gin.h`.

`pmatch` is an output argument for use when partial match is supported. To use it, `extractQuery` must allocate an array of `*nkeys` `bool`s and store its address at `*pmatch`. Each element of the array should be set to true if the corresponding key requires partial match, false if not. If `*pmatch` is set to `NULL` then GIN assumes partial match is not required. The variable is initialized to `NULL` before call, so this argument can simply be ignored by operator classes that do not support partial match.

`extra_data` is an output argument that allows `extractQuery` to pass additional data to the `consistent` and `comparePartial` methods. To use it, `extractQuery` must allocate an array of `*nkeys` pointers and store its address at `*extra_data`, then store whatever it wants to into the individual pointers. The variable is initialized to `NULL` before call, so this argument can simply be ignored by operator classes that do not require extra data. If `*extra_data` is set, the whole array is passed to the `consistent` method, and the appropriate element to the `comparePartial` method.

An operator class must also provide a function to check if an indexed item matches the query. It comes in two flavors, a Boolean `consistent` function, and a ternary `triConsistent` function. `triConsistent` covers the functionality of both, so providing `triConsistent` alone is sufficient. However, if the Boolean variant is significantly cheaper to calculate, it can be advantageous to provide both. If only the Boolean variant is provided, some optimizations that depend on refuting index items before fetching all the keys are disabled.

```
bool consistent(bool check[], StrategyNumber n, Datum query, int32
nkeys, Pointer extra_data[], bool *recheck, Datum queryKeys[], bool
nullFlags[])
```

Returns true if an indexed item satisfies the query operator with strategy number `n` (or might satisfy it, if the `recheck` indication is returned). This function does not have direct access to the indexed item's value, since GIN does not store items explicitly. Rather, what is available is knowledge about which key values extracted from the query appear in a given indexed item. The `check` array has length `nkeys`, which is the same as the number of keys previously returned by `extractQuery` for this query datum. Each element of the `check` array is true if the indexed item contains the corresponding query key, i.e., if `(check[i] == true)` the `i`-th key of the `extractQuery` result array is present in the indexed item. The original query datum is passed in case the `consistent` method needs to consult it, and so are the `queryKeys[]` and `nullFlags[]` arrays previously returned by `extractQuery`. `extra_data` is the extra-data array returned by `extractQuery`, or NULL if none.

When `extractQuery` returns a null key in `queryKeys[]`, the corresponding `check[]` element is true if the indexed item contains a null key; that is, the semantics of `check[]` are like `IS NOT DISTINCT FROM`. The `consistent` function can examine the corresponding `nullFlags[]` element if it needs to tell the difference between a regular value match and a null match.

On success, `*recheck` should be set to true if the heap tuple needs to be rechecked against the query operator, or false if the index test is exact. That is, a false return value guarantees that the heap tuple does not match the query; a true return value with `*recheck` set to false guarantees that the heap tuple does match the query; and a true return value with `*recheck` set to true means that the heap tuple might match the query, so it needs to be fetched and rechecked by evaluating the query operator directly against the originally indexed item.

```
GinTernaryValue triConsistent(GinTernaryValue check[], StrategyNum-
ber n, Datum query, int32 nkeys, Pointer extra_data[], Datum
queryKeys[], bool nullFlags[])
```

`triConsistent` is similar to `consistent`, but instead of Booleans in the `check` vector, there are three possible values for each key: `GIN_TRUE`, `GIN_FALSE` and `GIN_MAYBE`. `GIN_FALSE` and `GIN_TRUE` have the same meaning as regular Boolean values, while `GIN_MAYBE` means that the presence of that key is not known. When `GIN_MAYBE` values are present, the function should only return `GIN_TRUE` if the item certainly matches whether or not the index item contains the corresponding query keys. Likewise, the function must return `GIN_FALSE` only if the item certainly does not match, whether or not it contains the `GIN_MAYBE` keys. If the result depends on the `GIN_MAYBE` entries, i.e., the match cannot be confirmed or refuted based on the known query keys, the function must return `GIN_MAYBE`.

When there are no `GIN_MAYBE` values in the `check` vector, a `GIN_MAYBE` return value is the equivalent of setting the `recheck` flag in the Boolean `consistent` function.

In addition, GIN must have a way to sort the key values stored in the index. The operator class can define the sort ordering by specifying a comparison method:

```
int compare(Datum a, Datum b)
```

Compares two keys (not indexed items!) and returns an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second. Null keys are never passed to this function.

Alternatively, if the operator class does not provide a `compare` method, GIN will look up the default btree operator class for the index key data type, and use its comparison function. It is recommended to specify the comparison function in a GIN operator class that is meant for just one data type, as looking up the btree operator class costs a few cycles. However, polymorphic GIN operator classes (such as `array_ops`) typically cannot specify a single comparison function.

Optionally, an operator class for GIN can supply the following method:

```
int comparePartial(Datum partial_key, Datum key, StrategyNumber n,
Pointer extra_data)
```

Compare a partial-match query key to an index key. Returns an integer whose sign indicates the result: less than zero means the index key does not match the query, but the index scan should continue; zero means that the index key does match the query; greater than zero indicates that the index scan should stop because no more matches are possible. The strategy number *n* of the operator that generated the partial match query is provided, in case its semantics are needed to determine when to end the scan. Also, *extra_data* is the corresponding element of the extra-data array made by `extractQuery`, or `NULL` if none. Null keys are never passed to this function.

To support “partial match” queries, an operator class must provide the `comparePartial` method, and its `extractQuery` method must set the `pmatch` parameter when a partial-match query is encountered. See Section 66.4.2 for details.

The actual data types of the various `Datum` values mentioned above vary depending on the operator class. The item values passed to `extractValue` are always of the operator class's input type, and all key values must be of the class's `STORAGE` type. The type of the `query` argument passed to `extractQuery`, `consistent` and `triConsistent` is whatever is the right-hand input type of the class member operator identified by the strategy number. This need not be the same as the indexed type, so long as key values of the correct type can be extracted from it. However, it is recommended that the SQL declarations of these three support functions use the `opclass`'s indexed data type for the `query` argument, even though the actual type might be something else depending on the operator.

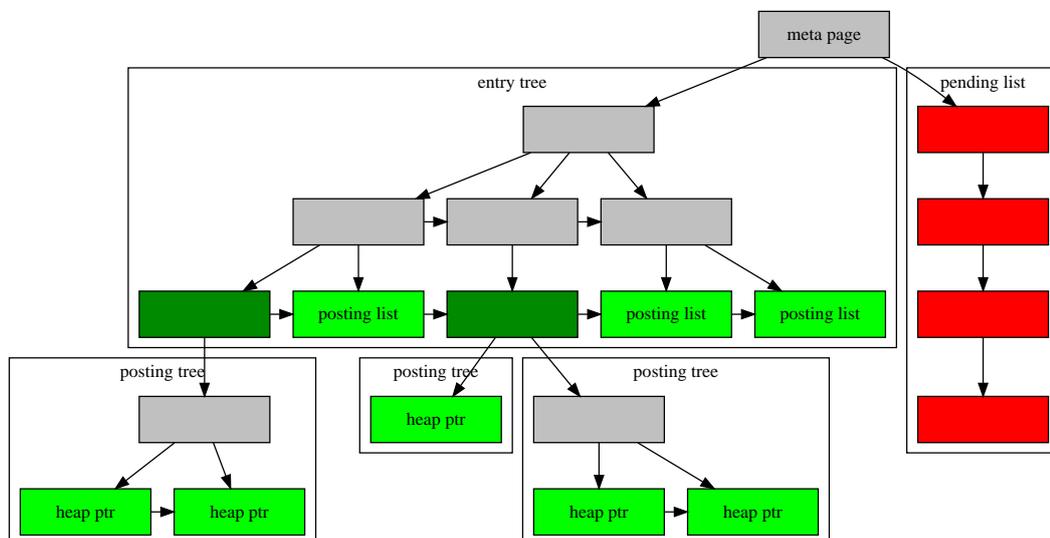
66.4. Implementation

Internally, a GIN index contains a B-tree index constructed over keys, where each key is an element of one or more indexed items (a member of an array, for example) and where each tuple in a leaf page contains either a pointer to a B-tree of heap pointers (a “posting tree”), or a simple list of heap pointers (a “posting list”) when the list is small enough to fit into a single index tuple along with the key value. Figure 66.1 illustrates these components of a GIN index.

As of PostgreSQL 9.1, null key values can be included in the index. Also, placeholder nulls are included in the index for indexed items that are null or contain no keys according to `extractValue`. This allows searches that should find empty items to do so.

Multicolumn GIN indexes are implemented by building a single B-tree over composite values (column number, key value). The key values for different columns can be of different types.

Figure 66.1. GIN Internals



66.4.1. GIN Fast Update Technique

Updating a GIN index tends to be slow because of the intrinsic nature of inverted indexes: inserting or updating one heap row can cause many inserts into the index (one for each key extracted from the indexed item). As of PostgreSQL 8.4, GIN is capable of postponing much of this work by inserting new tuples into a temporary, unsorted list of pending entries. When the table is vacuumed or autoanalyzed, or when `gin_clean_pending_list` function is called, or if the pending list becomes larger than `gin_pending_list_limit`, the entries are moved to the main GIN data structure using the same bulk insert techniques used during initial index creation. This greatly improves GIN index update speed, even counting the additional vacuum overhead. Moreover the overhead work can be done by a background process instead of in foreground query processing.

The main disadvantage of this approach is that searches must scan the list of pending entries in addition to searching the regular index, and so a large list of pending entries will slow searches significantly. Another disadvantage is that, while most updates are fast, an update that causes the pending list to become “too large” will incur an immediate cleanup cycle and thus be much slower than other updates. Proper use of autovacuum can minimize both of these problems.

If consistent response time is more important than update speed, use of pending entries can be disabled by turning off the `fastupdate` storage parameter for a GIN index. See `CREATE INDEX` for details.

66.4.2. Partial Match Algorithm

GIN can support “partial match” queries, in which the query does not determine an exact match for one or more keys, but the possible matches fall within a reasonably narrow range of key values (within the key sorting order determined by the `compare` support method). The `extractQuery` method, instead of returning a key value to be matched exactly, returns a key value that is the lower bound of the range to be searched, and sets the `pmatch` flag true. The key range is then scanned using the `comparePartial` method. `comparePartial` must return zero for a matching index key, less than zero for a non-match that is still within the range to be searched, or greater than zero if the index key is past the range that could match.

66.5. GIN Tips and Tricks

Create vs. insert

Insertion into a GIN index can be slow due to the likelihood of many keys being inserted for each item. So, for bulk insertions into a table it is advisable to drop the GIN index and recreate it after finishing bulk insertion.

As of PostgreSQL 8.4, this advice is less necessary since delayed indexing is used (see Section 66.4.1 for details). But for very large updates it may still be best to drop and recreate the index.

`maintenance_work_mem`

Build time for a GIN index is very sensitive to the `maintenance_work_mem` setting; it doesn't pay to skimp on work memory during index creation.

`gin_pending_list_limit`

During a series of insertions into an existing GIN index that has `fastupdate` enabled, the system will clean up the pending-entry list whenever the list grows larger than `gin_pending_list_limit`. To avoid fluctuations in observed response time, it's desirable to have pending-list cleanup occur in the background (i.e., via autovacuum). Foreground cleanup operations can be avoided by increasing `gin_pending_list_limit` or making autovacuum more aggressive. However, enlarging the threshold of the cleanup operation means that if a foreground cleanup does occur, it will take even longer.

`gin_pending_list_limit` can be overridden for individual GIN indexes by changing storage parameters, and which allows each GIN index to have its own cleanup threshold. For example, it's possible to increase the threshold only for the GIN index which can be updated heavily, and decrease it otherwise.

`gin_fuzzy_search_limit`

The primary goal of developing GIN indexes was to create support for highly scalable full-text search in PostgreSQL, and there are often situations when a full-text search returns a very large set of results. Moreover, this often happens when the query contains very frequent words, so that the large result set is not even useful. Since reading many tuples from the disk and sorting them could take a lot of time, this is unacceptable for production. (Note that the index search itself is very fast.)

To facilitate controlled execution of such queries, GIN has a configurable soft upper limit on the number of rows returned: the `gin_fuzzy_search_limit` configuration parameter. It is set to 0 (meaning no limit) by default. If a non-zero limit is set, then the returned set is a subset of the whole result set, chosen at random.

“Soft” means that the actual number of returned results could differ somewhat from the specified limit, depending on the query and the quality of the system's random number generator.

From experience, values in the thousands (e.g., 5000 — 20000) work well.

66.6. Limitations

GIN assumes that indexable operators are strict. This means that `extractValue` will not be called at all on a null item value (instead, a placeholder index entry is created automatically), and `extractQuery` will not be called on a null query value either (instead, the query is presumed to be unsatisfiable). Note however that null key values contained within a non-null composite item or query value are supported.

66.7. Examples

The core PostgreSQL distribution includes the GIN operator classes previously shown in Table 66.1. The following `contrib` modules also contain GIN operator classes:

`btree_gin`

B-tree equivalent functionality for several data types

`hstore`

Module for storing (key, value) pairs

`intarray`

Enhanced support for `int[]`

`pg_trgm`

Text similarity using trigram matching

Chapter 67. BRIN Indexes

67.1. Introduction

BRIN stands for Block Range Index. BRIN is designed for handling very large tables in which certain columns have some natural correlation with their physical location within the table. A *block range* is a group of pages that are physically adjacent in the table; for each block range, some summary info is stored by the index. For example, a table storing a store's sale orders might have a date column on which each order was placed, and most of the time the entries for earlier orders will appear earlier in the table as well; a table storing a ZIP code column might have all codes for a city grouped together naturally.

BRIN indexes can satisfy queries via regular bitmap index scans, and will return all tuples in all pages within each range if the summary info stored by the index is *consistent* with the query conditions. The query executor is in charge of rechecking these tuples and discarding those that do not match the query conditions — in other words, these indexes are lossy. Because a BRIN index is very small, scanning the index adds little overhead compared to a sequential scan, but may avoid scanning large parts of the table that are known not to contain matching tuples.

The specific data that a BRIN index will store, as well as the specific queries that the index will be able to satisfy, depend on the operator class selected for each column of the index. Data types having a linear sort order can have operator classes that store the minimum and maximum value within each block range, for instance; geometrical types might store the bounding box for all the objects in the block range.

The size of the block range is determined at index creation time by the `pages_per_range` storage parameter. The number of index entries will be equal to the size of the relation in pages divided by the selected value for `pages_per_range`. Therefore, the smaller the number, the larger the index becomes (because of the need to store more index entries), but at the same time the summary data stored can be more precise and more data blocks can be skipped during an index scan.

67.1.1. Index Maintenance

At the time of creation, all existing heap pages are scanned and a summary index tuple is created for each range, including the possibly-incomplete range at the end. As new pages are filled with data, page ranges that are already summarized will cause the summary information to be updated with data from the new tuples. When a new page is created that does not fall within the last summarized range, that range does not automatically acquire a summary tuple; those tuples remain unsummarized until a summarization run is invoked later, creating initial summaries. This process can be invoked manually using the `brin_summarize_range(regclass, bigint)` or `brin_summarize_new_values(regclass)` functions; automatically when `VACUUM` processes the table; or by automatic summarization executed by `autovacuum`, as insertions occur. (This last trigger is disabled by default and can be enabled with the `autosummarize` parameter.) Conversely, a range can be de-summarized using the `brin_desummarize_range(regclass, bigint)` function, which is useful when the index tuple is no longer a very good representation because the existing values have changed.

When autosummarization is enabled, each time a page range is filled a request is sent to `autovacuum` for it to execute a targeted summarization for that range, to be fulfilled at the end of the next worker run on the same database. If the request queue is full, the request is not recorded and a message is sent to the server log:

```
LOG:  request for BRIN range summarization for index "brin_wi_idx"  
      page 128 was not recorded
```

When this happens, the range will be summarized normally during the next regular vacuum of the table.

67.2. Built-in Operator Classes

The core PostgreSQL distribution includes the BRIN operator classes shown in Table 67.1.

The *minmax* operator classes store the minimum and the maximum values appearing in the indexed column within the range. The *inclusion* operator classes store a value which includes the values in the indexed column within the range.

Table 67.1. Built-in BRIN Operator Classes

Name	Indexed Data Type	Indexable Operators
int8_minmax_ops	bigint	< <= = >= >
bit_minmax_ops	bit	< <= = >= >
varbit_minmax_ops	bit varying	< <= = >= >
box_inclusion_ops	box	<< &< && &> >> ~ = @ > <@ &< << >> &>
bytea_minmax_ops	bytea	< <= = >= >
bpchar_minmax_ops	character	< <= = >= >
char_minmax_ops	"char"	< <= = >= >
date_minmax_ops	date	< <= = >= >
float8_minmax_ops	double precision	< <= = >= >
inet_minmax_ops	inet	< <= = >= >
network_inclusion_ops	inet	&& >> = << = = >> <<
int4_minmax_ops	integer	< <= = >= >
interval_minmax_ops	interval	< <= = >= >
macaddr_minmax_ops	macaddr	< <= = >= >
macaddr8_minmax_ops	macaddr8	< <= = >= >
name_minmax_ops	name	< <= = >= >
numeric_minmax_ops	numeric	< <= = >= >
pg_lsn_minmax_ops	pg_lsn	< <= = >= >
oid_minmax_ops	oid	< <= = >= >
range_inclusion_ops	any range type	<< &< && &> >> @ > <@ - - = < <= = > = >
float4_minmax_ops	real	< <= = >= >
int2_minmax_ops	smallint	< <= = >= >
text_minmax_ops	text	< <= = >= >
tid_minmax_ops	tid	< <= = >= >
timestamp_minmax_ops	timestamp without time zone	< <= = >= >
timestamp_tz_minmax_ops	timestamp with time zone	< <= = >= >
time_minmax_ops	time without time zone	< <= = >= >
time_tz_minmax_ops	time with time zone	< <= = >= >
uuid_minmax_ops	uuid	< <= = >= >

67.3. Extensibility

The BRIN interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The BRIN layer itself takes care of concurrency, logging and searching the index structure.

All it takes to get a BRIN access method working is to implement a few user-defined methods, which define the behavior of summary values stored in the index and the way they interact with scan keys. In short, BRIN combines extensibility with generality, code reuse, and a clean interface.

There are four methods that an operator class for BRIN must provide:

```
BrinOpcInfo *opcInfo(Oid type_oid)
```

Returns internal information about the indexed columns' summary data. The return value must point to a `malloc'd` `BrinOpcInfo`, which has this definition:

```
typedef struct BrinOpcInfo
{
    /* Number of columns stored in an index column of this
    opclass */
    uint16      oi_nstored;

    /* Opaque pointer for the opclass' private use */
    void        *oi_opaque;

    /* Type cache entries of the stored columns */
    TypeCacheEntry *oi_typcache[FLEXIBLE_ARRAY_MEMBER];
} BrinOpcInfo;
```

`BrinOpcInfo.oi_opaque` can be used by the operator class routines to pass information between support functions during an index scan.

```
bool consistent(BrinDesc *bdesc, BrinValues *column, ScanKey key)
```

Returns whether the `ScanKey` is consistent with the given indexed values for a range. The attribute number to use is passed as part of the scan key.

```
bool addValue(BrinDesc *bdesc, BrinValues *column, Datum newval, bool
isnull)
```

Given an index tuple and an indexed value, modifies the indicated attribute of the tuple so that it additionally represents the new value. If any modification was done to the tuple, `true` is returned.

```
bool unionTuples(BrinDesc *bdesc, BrinValues *a, BrinValues *b)
```

Consolidates two index tuples. Given two index tuples, modifies the indicated attribute of the first of them so that it represents both tuples. The second tuple is not modified.

The core distribution includes support for two types of operator classes: `minmax` and `inclusion`. Operator class definitions using them are shipped for in-core data types as appropriate. Additional operator classes can be defined by the user for other data types using equivalent definitions, without having to write any source code; appropriate catalog entries being declared is enough. Note that assumptions about the semantics of operator strategies are embedded in the support functions' source code.

Operator classes that implement completely different semantics are also possible, provided implementations of the four main support functions described above are written. Note that backwards compat-

ibility across major releases is not guaranteed: for example, additional support functions might be required in later releases.

To write an operator class for a data type that implements a totally ordered set, it is possible to use the minmax support functions alongside the corresponding operators, as shown in Table 67.2. All operator class members (functions and operators) are mandatory.

Table 67.2. Function and Support Numbers for Minmax Operator Classes

Operator class member	Object
Support Function 1	internal function <code>brin_minmax_opcinfo()</code>
Support Function 2	internal function <code>brin_minmax_add_value()</code>
Support Function 3	internal function <code>brin_minmax_consistent()</code>
Support Function 4	internal function <code>brin_minmax_union()</code>
Operator Strategy 1	operator less-than
Operator Strategy 2	operator less-than-or-equal-to
Operator Strategy 3	operator equal-to
Operator Strategy 4	operator greater-than-or-equal-to
Operator Strategy 5	operator greater-than

To write an operator class for a complex data type which has values included within another type, it's possible to use the inclusion support functions alongside the corresponding operators, as shown in Table 67.3. It requires only a single additional function, which can be written in any language. More functions can be defined for additional functionality. All operators are optional. Some operators require other operators, as shown as dependencies on the table.

Table 67.3. Function and Support Numbers for Inclusion Operator Classes

Operator class member	Object	Dependency
Support Function 1	internal function <code>brin_inclusion_opcinfo()</code>	
Support Function 2	internal function <code>brin_inclusion_add_value()</code>	
Support Function 3	internal function <code>brin_inclusion_consistent()</code>	
Support Function 4	internal function <code>brin_inclusion_union()</code>	
Support Function 11	function to merge two elements	
Support Function 12	optional function to check whether two elements are mergeable	
Support Function 13	optional function to check if an element is contained within another	
Support Function 14	optional function to check whether an element is empty	
Operator Strategy 1	operator left-of	Operator Strategy 4
Operator Strategy 2	operator does-not-extend-to-the-right-of	Operator Strategy 5

Operator class member	Object	Dependency
Operator Strategy 3	operator overlaps	
Operator Strategy 4	operator does-not-extend-to-the-left-of	Operator Strategy 1
Operator Strategy 5	operator right-of	Operator Strategy 2
Operator Strategy 6, 18	operator same-as-or-equal-to	Operator Strategy 7
Operator Strategy 7, 13, 16, 24, 25	operator contains-or-equal-to	
Operator Strategy 8, 14, 26, 27	operator is-contained-by-or-equal-to	Operator Strategy 3
Operator Strategy 9	operator does-not-extend-above	Operator Strategy 11
Operator Strategy 10	operator is-below	Operator Strategy 12
Operator Strategy 11	operator is-above	Operator Strategy 9
Operator Strategy 12	operator does-not-extend-below	Operator Strategy 10
Operator Strategy 20	operator less-than	Operator Strategy 5
Operator Strategy 21	operator less-than-or-equal-to	Operator Strategy 5
Operator Strategy 22	operator greater-than	Operator Strategy 1
Operator Strategy 23	operator greater-than-or-equal-to	Operator Strategy 1

Support function numbers 1-10 are reserved for the BRIN internal functions, so the SQL level functions start with number 11. Support function number 11 is the main function required to build the index. It should accept two arguments with the same data type as the operator class, and return the union of them. The inclusion operator class can store union values with different data types if it is defined with the `STORAGE` parameter. The return value of the union function should match the `STORAGE` data type.

Support function numbers 12 and 14 are provided to support irregularities of built-in data types. Function number 12 is used to support network addresses from different families which are not mergeable. Function number 14 is used to support empty ranges. Function number 13 is an optional but recommended one, which allows the new value to be checked before it is passed to the union function. As the BRIN framework can shortcut some operations when the union is not changed, using this function can improve index performance.

Both minmax and inclusion operator classes support cross-data-type operators, though with these the dependencies become more complicated. The minmax operator class requires a full set of operators to be defined with both arguments having the same data type. It allows additional data types to be supported by defining extra sets of operators. Inclusion operator class operator strategies are dependent on another operator strategy as shown in Table 67.3, or the same operator strategy as themselves. They require the dependency operator to be defined with the `STORAGE` data type as the left-hand-side argument and the other supported data type to be the right-hand-side argument of the supported operator. See `float4_minmax_ops` as an example of minmax, and `box_inclusion_ops` as an example of inclusion.

Chapter 68. Database Physical Storage

This chapter provides an overview of the physical storage format used by PostgreSQL databases.

68.1. Database File Layout

This section describes the storage format at the level of files and directories.

Traditionally, the configuration and data files used by a database cluster are stored together within the cluster's data directory, commonly referred to as PGDATA (after the name of the environment variable that can be used to define it). A common location for PGDATA is `/var/lib/pgsql/data`. Multiple clusters, managed by different server instances, can exist on the same machine.

The PGDATA directory contains several subdirectories and control files, as shown in Table 68.1. In addition to these required items, the cluster configuration files `postgresql.conf`, `pg_hba.conf`, and `pg_ident.conf` are traditionally stored in PGDATA, although it is possible to place them elsewhere.

Table 68.1. Contents of PGDATA

Item	Description
PG_VERSION	A file containing the major version number of PostgreSQL
base	Subdirectory containing per-database subdirectories
current_logfiles	File recording the log file(s) currently written to by the logging collector
global	Subdirectory containing cluster-wide tables, such as <code>pg_database</code>
pg_commit_ts	Subdirectory containing transaction commit timestamp data
pg_dynshmem	Subdirectory containing files used by the dynamic shared memory subsystem
pg_logical	Subdirectory containing status data for logical decoding
pg_multixact	Subdirectory containing multitransaction status data (used for shared row locks)
pg_notify	Subdirectory containing LISTEN/NOTIFY status data
pg_replslot	Subdirectory containing replication slot data
pg_serial	Subdirectory containing information about committed serializable transactions
pg_snapshots	Subdirectory containing exported snapshots
pg_stat	Subdirectory containing permanent files for the statistics subsystem
pg_stat_tmp	Subdirectory containing temporary files for the statistics subsystem
pg_subtrans	Subdirectory containing subtransaction status data

Item	Description
<code>pg_tblspc</code>	Subdirectory containing symbolic links to tablespaces
<code>pg_twophase</code>	Subdirectory containing state files for prepared transactions
<code>pg_wal</code>	Subdirectory containing WAL (Write Ahead Log) files
<code>pg_xact</code>	Subdirectory containing transaction commit status data
<code>postgresql.auto.conf</code>	A file used for storing configuration parameters that are set by <code>ALTER SYSTEM</code>
<code>postmaster.opts</code>	A file recording the command-line options the server was last started with
<code>postmaster.pid</code>	A lock file recording the current postmaster process ID (PID), cluster data directory path, postmaster start timestamp, port number, Unix-domain socket directory path (empty on Windows), first valid <code>listen_address</code> (IP address or *, or empty if not listening on TCP), and shared memory segment ID (this file is not present after server shutdown)

For each database in the cluster there is a subdirectory within `PGDATA/base`, named after the database's OID in `pg_database`. This subdirectory is the default location for the database's files; in particular, its system catalogs are stored there.

Note that the following sections describe the behavior of the builtin `heap` table access method, and the builtin index access methods. Due to the extensible nature of PostgreSQL, other access methods might work differently.

Each table and index is stored in a separate file. For ordinary relations, these files are named after the table or index's *filenode* number, which can be found in `pg_class.relfilenode`. But for temporary relations, the file name is of the form `tBBB_FFF`, where *BBB* is the backend ID of the backend which created the file, and *FFF* is the filenode number. In either case, in addition to the main file (a/k/a main fork), each table and index has a *free space map* (see Section 68.3), which stores information about free space available in the relation. The free space map is stored in a file named with the filenode number plus the suffix `_fsm`. Tables also have a *visibility map*, stored in a fork with the suffix `_vm`, to track which pages are known to have no dead tuples. The visibility map is described further in Section 68.4. Unlogged tables and indexes have a third fork, known as the initialization fork, which is stored in a fork with the suffix `_init` (see Section 68.5).

Caution

Note that while a table's filenode often matches its OID, this is *not* necessarily the case; some operations, like `TRUNCATE`, `REINDEX`, `CLUSTER` and some forms of `ALTER TABLE`, can change the filenode while preserving the OID. Avoid assuming that filenode and table OID are the same. Also, for certain system catalogs including `pg_class` itself, `pg_class.relfilenode` contains zero. The actual filenode number of these catalogs is stored in a lower-level data structure, and can be obtained using the `pg_relation_filenode()` function.

When a table or index exceeds 1 GB, it is divided into gigabyte-sized *segments*. The first segment's file name is the same as the filenode; subsequent segments are named `filenode.1`, `filenode.2`, etc. This arrangement avoids problems on platforms that have file size limitations. (Actually, 1 GB is just the

default segment size. The segment size can be adjusted using the configuration option `--with-segsize` when building PostgreSQL.) In principle, free space map and visibility map forks could require multiple segments as well, though this is unlikely to happen in practice.

A table that has columns with potentially large entries will have an associated *TOAST* table, which is used for out-of-line storage of field values that are too large to keep in the table rows proper. `pg_class.reltoastrelid` links from a table to its TOAST table, if any. See Section 68.2 for more information.

The contents of tables and indexes are discussed further in Section 68.6.

Tablespaces make the scenario more complicated. Each user-defined tablespace has a symbolic link inside the `PGDATA/pg_tblspc` directory, which points to the physical tablespace directory (i.e., the location specified in the tablespace's `CREATE TABLESPACE` command). This symbolic link is named after the tablespace's OID. Inside the physical tablespace directory there is a subdirectory with a name that depends on the PostgreSQL server version, such as `PG_9.0_201008051`. (The reason for using this subdirectory is so that successive versions of the database can use the same `CREATE TABLESPACE` location value without conflicts.) Within the version-specific subdirectory, there is a subdirectory for each database that has elements in the tablespace, named after the database's OID. Tables and indexes are stored within that directory, using the filenode naming scheme. The `pg_default` tablespace is not accessed through `pg_tblspc`, but corresponds to `PGDATA/base`. Similarly, the `pg_global` tablespace is not accessed through `pg_tblspc`, but corresponds to `PGDATA/global`.

The `pg_relation_filepath()` function shows the entire path (relative to `PGDATA`) of any relation. It is often useful as a substitute for remembering many of the above rules. But keep in mind that this function just gives the name of the first segment of the main fork of the relation — you may need to append a segment number and/or `_fsm`, `_vm`, or `_init` to find all the files associated with the relation.

Temporary files (for operations such as sorting more data than can fit in memory) are created within `PGDATA/base/pgsql_tmp`, or within a `pgsql_tmp` subdirectory of a tablespace directory if a tablespace other than `pg_default` is specified for them. The name of a temporary file has the form `pgsql_tmpPPP.NNN`, where `PPP` is the PID of the owning backend and `NNN` distinguishes different temporary files of that backend.

68.2. TOAST

This section provides an overview of TOAST (The Oversized-Attribute Storage Technique).

PostgreSQL uses a fixed page size (commonly 8 kB), and does not allow tuples to span multiple pages. Therefore, it is not possible to store very large field values directly. To overcome this limitation, large field values are compressed and/or broken up into multiple physical rows. This happens transparently to the user, with only small impact on most of the backend code. The technique is affectionately known as TOAST (or “the best thing since sliced bread”). The TOAST infrastructure is also used to improve handling of large data values in-memory.

Only certain data types support TOAST — there is no need to impose the overhead on data types that cannot produce large field values. To support TOAST, a data type must have a variable-length (*varlena*) representation, in which, ordinarily, the first four-byte word of any stored value contains the total length of the value in bytes (including itself). TOAST does not constrain the rest of the data type's representation. The special representations collectively called *TOASTed values* work by modifying or reinterpreting this initial length word. Therefore, the C-level functions supporting a TOAST-able data type must be careful about how they handle potentially TOASTed input values: an input might not actually consist of a four-byte length word and contents until after it's been *detoasted*. (This is normally done by invoking `PG_DETOAST_DATUM` before doing anything with an input value, but in some cases more efficient approaches are possible. See Section 37.13.1 for more detail.)

TOAST usurps two bits of the *varlena* length word (the high-order bits on big-endian machines, the low-order bits on little-endian machines), thereby limiting the logical size of any value of a TOAST-

able data type to 1 GB (2^{30} - 1 bytes). When both bits are zero, the value is an ordinary un-TOASTed value of the data type, and the remaining bits of the length word give the total datum size (including length word) in bytes. When the highest-order or lowest-order bit is set, the value has only a single-byte header instead of the normal four-byte header, and the remaining bits of that byte give the total datum size (including length byte) in bytes. This alternative supports space-efficient storage of values shorter than 127 bytes, while still allowing the data type to grow to 1 GB at need. Values with single-byte headers aren't aligned on any particular boundary, whereas values with four-byte headers are aligned on at least a four-byte boundary; this omission of alignment padding provides additional space savings that is significant compared to short values. As a special case, if the remaining bits of a single-byte header are all zero (which would be impossible for a self-inclusive length), the value is a pointer to out-of-line data, with several possible alternatives as described below. The type and size of such a *TOAST pointer* are determined by a code stored in the second byte of the datum. Lastly, when the highest-order or lowest-order bit is clear but the adjacent bit is set, the content of the datum has been compressed and must be decompressed before use. In this case the remaining bits of the four-byte length word give the total size of the compressed datum, not the original data. Note that compression is also possible for out-of-line data but the varlena header does not tell whether it has occurred — the content of the TOAST pointer tells that, instead.

As mentioned, there are multiple types of TOAST pointer datums. The oldest and most common type is a pointer to out-of-line data stored in a *TOAST table* that is separate from, but associated with, the table containing the TOAST pointer datum itself. These *on-disk* pointer datums are created by the TOAST management code (in `access/heap/tuptoaster.c`) when a tuple to be stored on disk is too large to be stored as-is. Further details appear in Section 68.2.1. Alternatively, a TOAST pointer datum can contain a pointer to out-of-line data that appears elsewhere in memory. Such datums are necessarily short-lived, and will never appear on-disk, but they are very useful for avoiding copying and redundant processing of large data values. Further details appear in Section 68.2.2.

The compression technique used for either in-line or out-of-line compressed data is a fairly simple and very fast member of the LZ family of compression techniques. See `src/common/pg_lzcompress.c` for the details.

68.2.1. Out-of-Line, On-Disk TOAST Storage

If any of the columns of a table are TOAST-able, the table will have an associated TOAST table, whose OID is stored in the table's `pg_class.reltoastrelid` entry. On-disk TOASTed values are kept in the TOAST table, as described in more detail below.

Out-of-line values are divided (after compression if used) into chunks of at most `TOAST_MAX_CHUNK_SIZE` bytes (by default this value is chosen so that four chunk rows will fit on a page, making it about 2000 bytes). Each chunk is stored as a separate row in the TOAST table belonging to the owning table. Every TOAST table has the columns `chunk_id` (an OID identifying the particular TOASTed value), `chunk_seq` (a sequence number for the chunk within its value), and `chunk_data` (the actual data of the chunk). A unique index on `chunk_id` and `chunk_seq` provides fast retrieval of the values. A pointer datum representing an out-of-line on-disk TOASTed value therefore needs to store the OID of the TOAST table in which to look and the OID of the specific value (its `chunk_id`). For convenience, pointer datums also store the logical datum size (original uncompressed data length) and physical stored size (different if compression was applied). Allowing for the varlena header bytes, the total size of an on-disk TOAST pointer datum is therefore 18 bytes regardless of the actual size of the represented value.

The TOAST management code is triggered only when a row value to be stored in a table is wider than `TOAST_TUPLE_THRESHOLD` bytes (normally 2 kB). The TOAST code will compress and/or move field values out-of-line until the row value is shorter than `TOAST_TUPLE_TARGET` bytes (also normally 2 kB, adjustable) or no more gains can be had. During an UPDATE operation, values of unchanged fields are normally preserved as-is; so an UPDATE of a row with out-of-line values incurs no TOAST costs if none of the out-of-line values change.

The TOAST management code recognizes four different strategies for storing TOAST-able columns on disk:

- `PLAIN` prevents either compression or out-of-line storage; furthermore it disables use of single-byte headers for varlena types. This is the only possible strategy for columns of non-TOAST-able data types.
- `EXTENDED` allows both compression and out-of-line storage. This is the default for most TOAST-able data types. Compression will be attempted first, then out-of-line storage if the row is still too big.
- `EXTERNAL` allows out-of-line storage but not compression. Use of `EXTERNAL` will make substring operations on wide `text` and `bytea` columns faster (at the penalty of increased storage space) because these operations are optimized to fetch only the required parts of the out-of-line value when it is not compressed.
- `MAIN` allows compression but not out-of-line storage. (Actually, out-of-line storage will still be performed for such columns, but only as a last resort when there is no other way to make the row small enough to fit on a page.)

Each TOAST-able data type specifies a default strategy for columns of that data type, but the strategy for a given table column can be altered with `ALTER TABLE ... SET STORAGE`.

`TOAST_TUPLE_TARGET` can be adjusted for each table using `ALTER TABLE ... SET (toast_tuple_target = N)`

This scheme has a number of advantages compared to a more straightforward approach such as allowing row values to span pages. Assuming that queries are usually qualified by comparisons against relatively small key values, most of the work of the executor will be done using the main row entry. The big values of TOASTed attributes will only be pulled out (if selected at all) at the time the result set is sent to the client. Thus, the main table is much smaller and more of its rows fit in the shared buffer cache than would be the case without any out-of-line storage. Sort sets shrink also, and sorts will more often be done entirely in memory. A little test showed that a table containing typical HTML pages and their URLs was stored in about half of the raw data size including the TOAST table, and that the main table contained only about 10% of the entire data (the URLs and some small HTML pages). There was no run time difference compared to an un-TOASTed comparison table, in which all the HTML pages were cut down to 7 kB to fit.

68.2.2. Out-of-Line, In-Memory TOAST Storage

TOAST pointers can point to data that is not on disk, but is elsewhere in the memory of the current server process. Such pointers obviously cannot be long-lived, but they are nonetheless useful. There are currently two sub-cases: pointers to *indirect* data and pointers to *expanded* data.

Indirect TOAST pointers simply point at a non-indirect varlena value stored somewhere in memory. This case was originally created merely as a proof of concept, but it is currently used during logical decoding to avoid possibly having to create physical tuples exceeding 1 GB (as pulling all out-of-line field values into the tuple might do). The case is of limited use since the creator of the pointer datum is entirely responsible that the referenced data survives for as long as the pointer could exist, and there is no infrastructure to help with this.

Expanded TOAST pointers are useful for complex data types whose on-disk representation is not especially suited for computational purposes. As an example, the standard varlena representation of a PostgreSQL array includes dimensionality information, a nulls bitmap if there are any null elements, then the values of all the elements in order. When the element type itself is variable-length, the only way to find the N th element is to scan through all the preceding elements. This representation is appropriate for on-disk storage because of its compactness, but for computations with the array it's much nicer to have an “expanded” or “deconstructed” representation in which all the element starting locations have been identified. The TOAST pointer mechanism supports this need by allowing a pass-by-reference Datum to point to either a standard varlena value (the on-disk representation) or a TOAST pointer that points to an expanded representation somewhere in memory. The details of this expanded representation are up to the data type, though it must have a standard header and meet the other API requirements given in `src/include/utils/expandeddatum.h`. C-level functions

working with the data type can choose to handle either representation. Functions that do not know about the expanded representation, but simply apply `PG_DETOAST_DATUM` to their inputs, will automatically receive the traditional varlena representation; so support for an expanded representation can be introduced incrementally, one function at a time.

TOAST pointers to expanded values are further broken down into *read-write* and *read-only* pointers. The pointed-to representation is the same either way, but a function that receives a read-write pointer is allowed to modify the referenced value in-place, whereas one that receives a read-only pointer must not; it must first create a copy if it wants to make a modified version of the value. This distinction and some associated conventions make it possible to avoid unnecessary copying of expanded values during query execution.

For all types of in-memory TOAST pointer, the TOAST management code ensures that no such pointer datum can accidentally get stored on disk. In-memory TOAST pointers are automatically expanded to normal in-line varlena values before storage — and then possibly converted to on-disk TOAST pointers, if the containing tuple would otherwise be too big.

68.3. Free Space Map

Each heap and index relation, except for hash indexes, has a Free Space Map (FSM) to keep track of available space in the relation. It's stored alongside the main relation data in a separate relation fork, named after the filenode number of the relation, plus a `_fsm` suffix. For example, if the filenode of a relation is 12345, the FSM is stored in a file called `12345_fsm`, in the same directory as the main relation file.

The Free Space Map is organized as a tree of FSM pages. The bottom level FSM pages store the free space available on each heap (or index) page, using one byte to represent each such page. The upper levels aggregate information from the lower levels.

Within each FSM page is a binary tree, stored in an array with one byte per node. Each leaf node represents a heap page, or a lower level FSM page. In each non-leaf node, the higher of its children's values is stored. The maximum value in the leaf nodes is therefore stored at the root.

See `src/backend/storage/freespace/README` for more details on how the FSM is structured, and how it's updated and searched. The `pg_freemap` module can be used to examine the information stored in free space maps.

68.4. Visibility Map

Each heap relation has a Visibility Map (VM) to keep track of which pages contain only tuples that are known to be visible to all active transactions; it also keeps track of which pages contain only frozen tuples. It's stored alongside the main relation data in a separate relation fork, named after the filenode number of the relation, plus a `_vm` suffix. For example, if the filenode of a relation is 12345, the VM is stored in a file called `12345_vm`, in the same directory as the main relation file. Note that indexes do not have VMs.

The visibility map stores two bits per heap page. The first bit, if set, indicates that the page is all-visible, or in other words that the page does not contain any tuples that need to be vacuumed. This information can also be used by *index-only scans* to answer queries using only the index tuple. The second bit, if set, means that all tuples on the page have been frozen. That means that even an anti-wraparound vacuum need not revisit the page.

The map is conservative in the sense that we make sure that whenever a bit is set, we know the condition is true, but if a bit is not set, it might or might not be true. Visibility map bits are only set by vacuum, but are cleared by any data-modifying operations on a page.

The `pg_visibility` module can be used to examine the information stored in the visibility map.

68.5. The Initialization Fork

Each unlogged table, and each index on an unlogged table, has an initialization fork. The initialization fork is an empty table or index of the appropriate type. When an unlogged table must be reset to empty due to a crash, the initialization fork is copied over the main fork, and any other forks are erased (they will be recreated automatically as needed).

68.6. Database Page Layout

This section provides an overview of the page format used within PostgreSQL tables and indexes.¹ Sequences and TOAST tables are formatted just like a regular table.

In the following explanation, a *byte* is assumed to contain 8 bits. In addition, the term *item* refers to an individual data value that is stored on a page. In a table, an item is a row; in an index, an item is an index entry.

Every table and index is stored as an array of *pages* of a fixed size (usually 8 kB, although a different page size can be selected when compiling the server). In a table, all the pages are logically equivalent, so a particular item (row) can be stored in any page. In indexes, the first page is generally reserved as a *metapage* holding control information, and there can be different types of pages within the index, depending on the index access method.

Table 68.2 shows the overall layout of a page. There are five parts to each page.

Table 68.2. Overall Page Layout

Item	Description
PageHeaderData	24 bytes long. Contains general information about the page, including free space pointers.
ItemIdData	Array of item identifiers pointing to the actual items. Each entry is an (offset,length) pair. 4 bytes per item.
Free space	The unallocated space. New item identifiers are allocated from the start of this area, new items from the end.
Items	The actual items themselves.
Special space	Index access method specific data. Different methods store different data. Empty in ordinary tables.

The first 24 bytes of each page consists of a page header (*PageHeaderData*). Its format is detailed in Table 68.3. The first field tracks the most recent WAL entry related to this page. The second field contains the page checksum if data checksums are enabled. Next is a 2-byte field containing flag bits. This is followed by three 2-byte integer fields (*pd_lower*, *pd_upper*, and *pd_special*). These contain byte offsets from the page start to the start of unallocated space, to the end of unallocated space, and to the start of the special space. The next 2 bytes of the page header, *pd_pagesize_version*, store both the page size and a version indicator. Beginning with PostgreSQL 8.3 the version number is 4; PostgreSQL 8.1 and 8.2 used version number 3; PostgreSQL 8.0 used version number 2; PostgreSQL 7.3 and 7.4 used version number 1; prior releases used version number 0. (The basic page layout and header format has not changed in most of these versions, but the layout of heap row headers has.) The page size is basically only present as a cross-check; there is no support for having more than one page size in an installation. The last field is a hint that shows whether pruning the page is likely to be profitable: it tracks the oldest un-pruned XMAX on the page.

¹ Actually, use of this page format is not required for either table or index access methods. The heap table access method always uses this format. All the existing index methods also use the basic format, but the data kept on index metapages usually doesn't follow the item layout rules.

Table 68.3. PageHeaderData Layout

Field	Type	Length	Description
pd_lsn	PageXLogRecPtr	8 bytes	LSN: next byte after last byte of WAL record for last change to this page
pd_checksum	uint16	2 bytes	Page checksum
pd_flags	uint16	2 bytes	Flag bits
pd_lower	LocationIndex	2 bytes	Offset to start of free space
pd_upper	LocationIndex	2 bytes	Offset to end of free space
pd_special	LocationIndex	2 bytes	Offset to start of special space
pd_pagesize_version	uint16	2 bytes	Page size and layout version number information
pd_prune_xid	TransactionId	4 bytes	Oldest unpruned XMAX on page, or zero if none

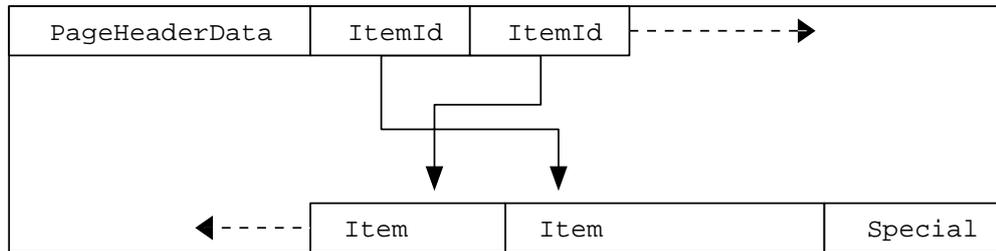
All the details can be found in `src/include/storage/bufpage.h`.

Following the page header are item identifiers (`ItemIdData`), each requiring four bytes. An item identifier contains a byte-offset to the start of an item, its length in bytes, and a few attribute bits which affect its interpretation. New item identifiers are allocated as needed from the beginning of the unallocated space. The number of item identifiers present can be determined by looking at `pd_lower`, which is increased to allocate a new identifier. Because an item identifier is never moved until it is freed, its index can be used on a long-term basis to reference an item, even when the item itself is moved around on the page to compact free space. In fact, every pointer to an item (`ItemPointer`, also known as `CTID`) created by PostgreSQL consists of a page number and the index of an item identifier.

The items themselves are stored in space allocated backwards from the end of unallocated space. The exact structure varies depending on what the table is to contain. Tables and sequences both use a structure named `HeapTupleHeaderData`, described below.

The final section is the “special section” which can contain anything the access method wishes to store. For example, b-tree indexes store links to the page's left and right siblings, as well as some other data relevant to the index structure. Ordinary tables do not use a special section at all (indicated by setting `pd_special` to equal the page size).

Figure 68.1 illustrates how these parts are laid out in a page.

Figure 68.1. Page Layout

68.6.1. Table Row Layout

All table rows are structured in the same way. There is a fixed-size header (occupying 23 bytes on most machines), followed by an optional null bitmap, an optional object ID field, and the user data. The header is detailed in Table 68.4. The actual user data (columns of the row) begins at the offset indicated by `t_hoff`, which must always be a multiple of the `MAXALIGN` distance for the platform. The null bitmap is only present if the `HEAP_HASNULL` bit is set in `t_infomask`. If it is present it begins just after the fixed header and occupies enough bytes to have one bit per data column (that is, the number of bits that equals the attribute count in `t_infomask2`). In this list of bits, a 1 bit indicates not-null, a 0 bit is a null. When the bitmap is not present, all columns are assumed not-null. The object ID is only present if the `HEAP_HASOID_OLD` bit is set in `t_infomask`. If present, it appears just before the `t_hoff` boundary. Any padding needed to make `t_hoff` a `MAXALIGN` multiple will appear between the null bitmap and the object ID. (This in turn ensures that the object ID is suitably aligned.)

Table 68.4. HeapTupleHeaderData Layout

Field	Type	Length	Description
<code>t_xmin</code>	TransactionId	4 bytes	insert XID stamp
<code>t_xmax</code>	TransactionId	4 bytes	delete XID stamp
<code>t_cid</code>	CommandId	4 bytes	insert and/or delete CID stamp (overlays with <code>t_xvac</code>)
<code>t_xvac</code>	TransactionId	4 bytes	XID for VACUUM operation moving a row version
<code>t_ctid</code>	ItemPointerData	6 bytes	current TID of this or newer row version
<code>t_infomask2</code>	uint16	2 bytes	number of attributes, plus various flag bits
<code>t_infomask</code>	uint16	2 bytes	various flag bits
<code>t_hoff</code>	uint8	1 byte	offset to user data

All the details can be found in `src/include/access/htup_details.h`.

Interpreting the actual data can only be done with information obtained from other tables, mostly `pg_attribute`. The key values needed to identify field locations are `attlen` and `attalign`. There is no way to directly get a particular attribute, except when there are only fixed width fields and no null values. All this trickery is wrapped up in the functions `heap_getattr`, `fastgetattr` and `heap_getsysattr`.

To read the data you need to examine each attribute in turn. First check whether the field is NULL according to the null bitmap. If it is, go to the next. Then make sure you have the right alignment. If the field is a fixed width field, then all the bytes are simply placed. If it's a variable length field (`attlen = -1`) then it's a bit more complicated. All variable-length data types share the common header structure `struct varlena`, which includes the total length of the stored value and some flag bits. Depending on the flags, the data can be either inline or in a TOAST table; it might be compressed, too (see Section 68.2).

Chapter 69. System Catalog Declarations and Initial Contents

PostgreSQL uses many different system catalogs to keep track of the existence and properties of database objects, such as tables and functions. Physically there is no difference between a system catalog and a plain user table, but the backend C code knows the structure and properties of each catalog, and can manipulate it directly at a low level. Thus, for example, it is inadvisable to attempt to alter the structure of a catalog on-the-fly; that would break assumptions built into the C code about how rows of the catalog are laid out. But the structure of the catalogs can change between major versions.

The structures of the catalogs are declared in specially formatted C header files in the `src/include/catalog/` directory of the source tree. In particular, for each catalog there is a header file named after the catalog (e.g., `pg_class.h` for `pg_class`), which defines the set of columns the catalog has, as well as some other basic properties such as its OID. Other critical files defining the catalog structure include `indexing.h`, which defines the indexes present on all the system catalogs, and `toasting.h`, which defines TOAST tables for catalogs that need one.

Many of the catalogs have initial data that must be loaded into them during the “bootstrap” phase of `initdb`, to bring the system up to a point where it is capable of executing SQL commands. (For example, `pg_class.h` must contain an entry for itself, as well as one for each other system catalog and `index`.) This initial data is kept in editable form in data files that are also stored in the `src/include/catalog/` directory. For example, `pg_proc.dat` describes all the initial rows that must be inserted into the `pg_proc` catalog.

To create the catalog files and load this initial data into them, a backend running in bootstrap mode reads a BKI (Backend Interface) file containing commands and initial data. The `postgres.bki` file used in this mode is prepared from the aforementioned header and data files, while building a PostgreSQL distribution, by a Perl script named `genbki.pl`. Although it's specific to a particular PostgreSQL release, `postgres.bki` is platform-independent and is installed in the `share` subdirectory of the installation tree.

`genbki.pl` also produces a derived header file for each catalog, for example `pg_class_d.h` for the `pg_class` catalog. This file contains automatically-generated macro definitions, and may contain other macros, enum declarations, and so on that can be useful for client C code that reads a particular catalog.

Most PostgreSQL developers don't need to be directly concerned with the BKI file, but almost any nontrivial feature addition in the backend will require modifying the catalog header files and/or initial data files. The rest of this chapter gives some information about that, and for completeness describes the BKI file format.

69.1. System Catalog Declaration Rules

The key part of a catalog header file is a C structure definition describing the layout of each row of the catalog. This begins with a `CATALOG` macro, which so far as the C compiler is concerned is just shorthand for `typedef struct FormData_catalogname`. Each field in the struct gives rise to a catalog column. Fields can be annotated using the BKI property macros described in `genbki.h`, for example to define a default value for a field or mark it as nullable or not nullable. The `CATALOG` line can also be annotated, with some other BKI property macros described in `genbki.h`, to define other properties of the catalog as a whole, such as whether it is a shared relation.

The system catalog cache code (and most catalog-munging code in general) assumes that the fixed-length portions of all system catalog tuples are in fact present, because it maps this C struct declaration onto them. Thus, all variable-length fields and nullable fields must be placed at the end, and they cannot be accessed as struct fields. For example, if you tried to set `pg_type.typrelid` to be `NULL`, it would fail when some piece of code tried to reference `typetup->typrelid` (or worse,

`typetup->typelem`, because that follows `typrelid`). This would result in random errors or even segmentation violations.

As a partial guard against this type of error, variable-length or nullable fields should not be made directly visible to the C compiler. This is accomplished by wrapping them in `#ifdef CATALOG_VARLEN ... #endif` (where `CATALOG_VARLEN` is a symbol that is never defined). This prevents C code from carelessly trying to access fields that might not be there or might be at some other offset. As an independent guard against creating incorrect rows, we require all columns that should be non-nullable to be marked so in `pg_attribute`. The bootstrap code will automatically mark catalog columns as `NOT NULL` if they are fixed-width and are not preceded by any nullable column. Where this rule is inadequate, you can force correct marking by using `BKI_FORCE_NOT_NULL` and `BKI_FORCE_NULL` annotations as needed. But note that `NOT NULL` constraints are only enforced in the executor, not against tuples that are generated by random C code, so care is still needed when manually creating or updating catalog rows.

Frontend code should not include any `pg_XXX.h` catalog header file, as these files may contain C code that won't compile outside the backend. (Typically, that happens because these files also contain declarations for functions in `src/backend/catalog/` files.) Instead, frontend code may include the corresponding generated `pg_XXX_d.h` header, which will contain `OID` `#defines` and any other data that might be of use on the client side. If you want macros or other code in a catalog header to be visible to frontend code, write `#ifdef EXPOSE_TO_CLIENT_CODE ... #endif` around that section to instruct `genbki.pl` to copy that section to the `pg_XXX_d.h` header.

A few of the catalogs are so fundamental that they can't even be created by the BKI `create` command that's used for most catalogs, because that command needs to write information into these catalogs to describe the new catalog. These are called *bootstrap* catalogs, and defining one takes a lot of extra work: you have to manually prepare appropriate entries for them in the pre-loaded contents of `pg_class` and `pg_type`, and those entries will need to be updated for subsequent changes to the catalog's structure. (Bootstrap catalogs also need pre-loaded entries in `pg_attribute`, but fortunately `genbki.pl` handles that chore nowadays.) Avoid making new catalogs be bootstrap catalogs if at all possible.

69.2. System Catalog Initial Data

Each catalog that has any manually-created initial data (some do not) has a corresponding `.dat` file that contains its initial data in an editable format.

69.2.1. Data File Format

Each `.dat` file contains Perl data structure literals that are simply eval'd to produce an in-memory data structure consisting of an array of hash references, one per catalog row. A slightly modified excerpt from `pg_database.dat` will demonstrate the key features:

```
[
# A comment could appear here.
{ oid => '1', oid_symbol => 'TemplateDbOid',
  descr => 'database\'s default template',
  datname => 'template1', encoding => 'ENCODING', datcollate =>
  'LC_COLLATE',
  datatype => 'LC_CTYPE', datistemplate => 't', datallowconn =>
  't',
  datconnlimit => '-1', datlastsysoid => '0', datfrozenxid => '0',
  datminmxid => '1', dattablespace => 'pg_default', datacl =>
  '_null_' },
]
```

Points to note:

- The overall file layout is: open square bracket, one or more sets of curly braces each of which represents a catalog row, close square bracket. Write a comma after each closing curly brace.
- Within each catalog row, write comma-separated *key => value* pairs. The allowed *keys* are the names of the catalog's columns, plus the metadata keys `oid`, `oid_symbol`, `array_type_oid`, and `descr`. (The use of `oid` and `oid_symbol` is described in Section 69.2.2 below, while `array_type_oid` is described in Section 69.2.4. `descr` supplies a description string for the object, which will be inserted into `pg_description` or `pg_shdescription` as appropriate.) While the metadata keys are optional, the catalog's defined columns must all be provided, except when the catalog's `.h` file specifies a default value for the column. (In the example above, the `datdba` field has been omitted because `pg_database.h` supplies a suitable default value for it.)
- All values must be single-quoted. Escape single quotes used within a value with a backslash. Backslashes meant as data can, but need not, be doubled; this follows Perl's rules for simple quoted literals. Note that backslashes appearing as data will be treated as escapes by the bootstrap scanner, according to the same rules as for escape string constants (see Section 4.1.2.2); for example `\t` converts to a tab character. If you actually want a backslash in the final value, you will need to write four of them: Perl strips two, leaving `\\` for the bootstrap scanner to see.
- Null values are represented by `_null_`. (Note that there is no way to create a value that is just that string.)
- Comments are preceded by `#`, and must be on their own lines.
- Field values that are OIDs of other catalog entries should be represented by symbolic names rather than actual numeric OIDs. (In the example above, `dattablespace` contains such a reference.) This is described in Section 69.2.3 below.
- Since hashes are unordered data structures, field order and line layout aren't semantically significant. However, to maintain a consistent appearance, we set a few rules that are applied by the formatting script `reformat_dat_file.pl`:
 - Within each pair of curly braces, the metadata fields `oid`, `oid_symbol`, `array_type_oid`, and `descr` (if present) come first, in that order, then the catalog's own fields appear in their defined order.
 - Newlines are inserted between fields as needed to limit line length to 80 characters, if possible. A newline is also inserted between the metadata fields and the regular fields.
 - If the catalog's `.h` file specifies a default value for a column, and a data entry has that same value, `reformat_dat_file.pl` will omit it from the data file. This keeps the data representation compact.
 - `reformat_dat_file.pl` preserves blank lines and comment lines as-is. It's recommended to run `reformat_dat_file.pl` before submitting catalog data patches. For convenience, you can simply change to `src/include/catalog/` and run `make reformat-dat-files`.
- If you want to add a new method of making the data representation smaller, you must implement it in `reformat_dat_file.pl` and also teach `Catalog::ParseData()` how to expand the data back into the full representation.

69.2.2. OID Assignment

A catalog row appearing in the initial data can be given a manually-assigned OID by writing an `oid => nnnn` metadata field. Furthermore, if an OID is assigned, a C macro for that OID can be created by writing an `oid_symbol => name` metadata field.

Pre-loaded catalog rows must have preassigned OIDs if there are OID references to them in other pre-loaded rows. A preassigned OID is also needed if the row's OID must be referenced from C code. If neither case applies, the `oid` metadata field can be omitted, in which case the bootstrap code assigns an OID automatically. In practice we usually preassign OIDs for all or none of the pre-loaded rows in a given catalog, even if only some of them are actually cross-referenced.

Writing the actual numeric value of any OID in C code is considered very bad form; always use a macro, instead. Direct references to `pg_proc` OIDs are common enough that there's a special mechanism to create the necessary macros automatically; see `src/backend/utils/Gen_fmgrtab.pl`. Similarly — but, for historical reasons, not done the same way — there's an automatic method for creating macros for `pg_type` OIDs. `oid_symbol` entries are therefore not necessary in those two catalogs. Likewise, macros for the `pg_class` OIDs of system catalogs and indexes are set up automatically. For all other system catalogs, you have to manually specify any macros you need via `oid_symbol` entries.

To find an available OID for a new pre-loaded row, run the script `src/include/catalog/unused_oids`. It prints inclusive ranges of unused OIDs (e.g., the output line “45-900” means OIDs 45 through 900 have not been allocated yet). Currently, OIDs 1-9999 are reserved for manual assignment; the `unused_oids` script simply looks through the catalog headers and `.dat` files to see which ones do not appear. You can also use the `duplicate_oids` script to check for mistakes. (`genbki.pl` will assign OIDs for any rows that didn't get one hand-assigned to them, and it will also detect duplicate OIDs at compile time.)

When choosing OIDs for a patch that is not expected to be committed immediately, best practice is to use a group of more-or-less consecutive OIDs starting with some random choice in the range 8000—9999. This minimizes the risk of OID collisions with other patches being developed concurrently. To keep the 8000—9999 range free for development purposes, after a patch has been committed to the master git repository its OIDs should be renumbered into available space below that range. Typically, this will be done near the end of each development cycle, moving all OIDs consumed by patches committed in that cycle at the same time. The script `renumber_oids.pl` can be used for this purpose. If an uncommitted patch is found to have OID conflicts with some recently-committed patch, `renumber_oids.pl` may also be useful for recovering from that situation.

Because of this convention of possibly renumbering OIDs assigned by patches, the OIDs assigned by a patch should not be considered stable until the patch has been included in an official release. We do not change manually-assigned object OIDs once released, however, as that would create assorted compatibility problems.

If `genbki.pl` needs to assign an OID to a catalog entry that does not have a manually-assigned OID, it will use a value in the range 10000—11999. The server's OID counter is set to 12000 at the start of a bootstrap run. Thus objects created by regular SQL commands during the later phases of bootstrap, such as objects created while running the `information_schema.sql` script, receive OIDs of 12000 or above.

OIDs assigned during normal database operation are constrained to be 16384 or higher. This ensures that the range 10000—16383 is free for OIDs assigned automatically by `genbki.pl` or during bootstrap. These automatically-assigned OIDs are not considered stable, and may change from one installation to another.

69.2.3. OID Reference Lookup

In principle, cross-references from one initial catalog row to another could be written just by writing the preassigned OID of the referenced row in the referencing field. However, that is against project policy, because it is error-prone, hard to read, and subject to breakage if a newly-assigned OID is renumbered. Therefore `genbki.pl` provides mechanisms to write symbolic references instead. The rules are as follows:

- Use of symbolic references is enabled in a particular catalog column by attaching `BKI_LOOKUP(lookuprule)` to the column's definition, where *lookuprule* is the name of

the referenced catalog, e.g. `pg_proc`. `BKI_LOOKUP` can be attached to columns of type `Oid`, `regproc`, `oidvector`, or `Oid[]`; in the latter two cases it implies performing a lookup on each element of the array.

- It's also permissible to attach `BKI_LOOKUP(encoding)` to integer columns to reference character set encodings, which are not currently represented as catalog OIDs, but have a set of values known to `genbki.pl`.
- In such a column, all entries must use the symbolic format except when writing 0 for `InvalidOid`. (If the column is declared `regproc`, you can optionally write `-` instead of 0.) `genbki.pl` will warn about unrecognized names.
- Most kinds of catalog objects are simply referenced by their names. Note that type names must exactly match the referenced `pg_type` entry's `typname`; you do not get to use any aliases such as `integer` for `int4`.
- A function can be represented by its `proname`, if that is unique among the `pg_proc.dat` entries (this works like `regproc` input). Otherwise, write it as `proname(argtypename, argtypename, ...)`, like `regprocedure`. The argument type names must be spelled exactly as they are in the `pg_proc.dat` entry's `proargtypes` field. Do not insert any spaces.
- Operators are represented by `oprname(lefttype, righttype)`, writing the type names exactly as they appear in the `pg_operator.dat` entry's `oprleft` and `oprright` fields. (Write 0 for the omitted operand of a unary operator.)
- The names of `opclasses` and `opfamilies` are only unique within an access method, so they are represented by `access_method_name/object_name`.
- In none of these cases is there any provision for schema-qualification; all objects created during bootstrap are expected to be in the `pg_catalog` schema.
- In addition to the generic lookup mechanisms, there is a special convention that `PGNSP` is replaced by the OID of the `pg_catalog` schema, and `PGUID` is replaced by the OID of the bootstrap superuser role. These usages are somewhat historical but so far there hasn't been a need to generalize them.

`genbki.pl` resolves all symbolic references while it runs, and puts simple numeric OIDs into the emitted BKI file. There is therefore no need for the bootstrap backend to deal with symbolic references.

69.2.4. Automatic Creation of Array Types

Most scalar data types should have a corresponding array type (that is, a standard varlena array type whose element type is the scalar type, and which is referenced by the `typarray` field of the scalar type's `pg_type` entry). `genbki.pl` is able to generate the `pg_type` entry for the array type automatically in most cases.

To use this facility, just write an `array_type_oid => nnnn` metadata field in the scalar type's `pg_type` entry, specifying the OID to use for the array type. You may then omit the `typarray` field, since it will be filled automatically with that OID.

The generated array type's name is the scalar type's name with an underscore prepended. The array entry's other fields are filled from `BKI_ARRAY_DEFAULT(value)` annotations in `pg_type.h`, or if there isn't one, copied from the scalar type. (There's also a special case for `typalign`.) Then the `typelem` and `typarray` fields of the two entries are set to cross-reference each other.

69.2.5. Recipes for Editing Data Files

Here are some suggestions about the easiest ways to perform common tasks when updating catalog data files.

Add a new column with a default to a catalog: Add the column to the header file with a `BKI_DEFAULT(value)` annotation. The data file need only be adjusted by adding the field in existing rows where a non-default value is needed.

Add a default value to an existing column that doesn't have one: Add a `BKI_DEFAULT` annotation to the header file, then run `make reformat-dat-files` to remove now-redundant field entries.

Remove a column, whether it has a default or not: Remove the column from the header, then run `make reformat-dat-files` to remove now-useless field entries.

Change or remove an existing default value: You cannot simply change the header file, since that will cause the current data to be interpreted incorrectly. First run `make expand-dat-files` to rewrite the data files with all default values inserted explicitly, then change or remove the `BKI_DEFAULT` annotation, then run `make reformat-dat-files` to remove superfluous fields again.

Ad-hoc bulk editing: `reformat_dat_file.pl` can be adapted to perform many kinds of bulk changes. Look for its block comments showing where one-off code can be inserted. In the following example, we are going to consolidate two boolean fields in `pg_proc` into a char field:

1. Add the new column, with a default, to `pg_proc.h`:

```
+ /* see PROKIND_ categories below */
+ char          prokind BKI_DEFAULT(f);
```

2. Create a new script based on `reformat_dat_file.pl` to insert appropriate values on-the-fly:

```
-          # At this point we have the full row in memory as a
hash
-          # and can do any operations we want. As written, it
only
-          # removes default values, but this script can be
adapted to
-          # do one-off bulk-editing.
+          # One-off change to migrate to prokind
+          # Default has already been filled in by now, so
change to other
+          # values as appropriate
+          if ($values{proisagg} eq 't')
+          {
+              $values{prokind} = 'a';
+          }
+          elsif ($values{proiswindow} eq 't')
+          {
+              $values{prokind} = 'w';
+          }
```

3. Run the new script:

```
$ cd src/include/catalog
$ perl rewrite_dat_with_prokind.pl pg_proc.dat
```

At this point `pg_proc.dat` has all three columns, `prokind`, `proisagg`, and `proiswindow`, though they will appear only in rows where they have non-default values.

4. Remove the old columns from `pg_proc.h`:

```

-    /* is it an aggregate? */
-    bool        proisagg BKI_DEFAULT(f);
-
-    /* is it a window function? */
-    bool        proiswindow BKI_DEFAULT(f);

```

5. Finally, run `make reformat-dat-files` to remove the useless old entries from `pg_proc.dat`.

For further examples of scripts used for bulk editing, see `convert_oid2name.pl` and `remove_pg_type_oid_symbols.pl` attached to this message: <https://www.postgresql.org/message-id/CAJVSXG8gXnPm+Xa=DxR7kFYprcQ1tNcCT5D0O3ShfnM6jehA@mail.gmail.com>

69.3. BKI File Format

This section describes how the PostgreSQL backend interprets BKI files. This description will be easier to understand if the `postgres.bki` file is at hand as an example.

BKI input consists of a sequence of commands. Commands are made up of a number of tokens, depending on the syntax of the command. Tokens are usually separated by whitespace, but need not be if there is no ambiguity. There is no special command separator; the next token that syntactically cannot belong to the preceding command starts a new one. (Usually you would put a new command on a new line, for clarity.) Tokens can be certain key words, special characters (parentheses, commas, etc.), numbers, or double-quoted strings. Everything is case sensitive.

Lines starting with `#` are ignored.

69.4. BKI Commands

```

create tablename tableoid [bootstrap] [shared_relation] [rowtype_oid oid]
(name1 = type1 [FORCE NOT NULL | FORCE NULL] [, name2 = type2 [FORCE NOT NULL
| FORCE NULL] , ...])

```

Create a table named *tablename*, and having the OID *tableoid*, with the columns given in parentheses.

The following column types are supported directly by `bootstrap.c`: `bool`, `bytea`, `char` (1 byte), `name`, `int2`, `int4`, `regproc`, `regclass`, `regtype`, `text`, `oid`, `tid`, `xid`, `cid`, `int2vector`, `oidvector`, `_int4` (array), `_text` (array), `_oid` (array), `_char` (array), `_aclitem` (array). Although it is possible to create tables containing columns of other types, this cannot be done until after `pg_type` has been created and filled with appropriate entries. (That effectively means that only these column types can be used in bootstrap catalogs, but non-bootstrap catalogs can contain any built-in type.)

When `bootstrap` is specified, the table will only be created on disk; nothing is entered into `pg_class`, `pg_attribute`, etc, for it. Thus the table will not be accessible by ordinary SQL operations until such entries are made the hard way (with `insert` commands). This option is used for creating `pg_class` etc themselves.

The table is created as shared if `shared_relation` is specified. The table's row type OID (`pg_type` OID) can optionally be specified via the `rowtype_oid` clause; if not specified, an OID is automatically generated for it. (The `rowtype_oid` clause is useless if `bootstrap` is specified, but it can be provided anyway for documentation.)

```
open tablename
```

Open the table named *tablename* for insertion of data. Any currently open table is closed.

`close tablename`

Close the open table. The name of the table must be given as a cross-check.

`insert ([oid_value] value1 value2 ...)`

Insert a new row into the open table using *value1*, *value2*, etc., for its column values.

NULL values can be specified using the special key word `_null_`. Values that do not look like identifiers or digit strings must be double quoted.

`declare [unique] index indexname indexoid on tablename using amname (op-
class1 name1 [, ...])`

Create an index named *indexname*, having OID *indexoid*, on the table named *tablename*, using the *amname* access method. The fields to index are called *name1*, *name2* etc., and the operator classes to use are *opclass1*, *opclass2* etc., respectively. The index file is created and appropriate catalog entries are made for it, but the index contents are not initialized by this command.

`declare toast toasttableoid toastindexoid on tablename`

Create a TOAST table for the table named *tablename*. The TOAST table is assigned OID *toasttableoid* and its index is assigned OID *toastindexoid*. As with `declare index`, filling of the index is postponed.

`build indices`

Fill in the indices that have previously been declared.

69.5. Structure of the Bootstrap BKI File

The `open` command cannot be used until the tables it uses exist and have entries for the table that is to be opened. (These minimum tables are `pg_class`, `pg_attribute`, `pg_proc`, and `pg_type`.) To allow those tables themselves to be filled, `create` with the `bootstrap` option implicitly opens the created table for data insertion.

Also, the `declare index` and `declare toast` commands cannot be used until the system catalogs they need have been created and filled in.

Thus, the structure of the `postgres.bki` file has to be:

1. `create bootstrap` one of the critical tables
2. `insert` data describing at least the critical tables
3. `close`
4. Repeat for the other critical tables.
5. `create` (without `bootstrap`) a noncritical table
6. `open`
7. `insert` desired data
8. `close`
9. Repeat for the other noncritical tables.
10. Define indexes and toast tables.

```
11.build indices
```

There are doubtless other, undocumented ordering dependencies.

69.6. BKI Example

The following sequence of commands will create the table `test_table` with OID 420, having three columns `oid`, `cola` and `colb` of type `oid`, `int4` and `text`, respectively, and insert two rows into the table:

```
create test_table 420 (oid = oid, cola = int4, colb = text)
open test_table
insert ( 421 1 "value1" )
insert ( 422 2 _null_ )
close test_table
```

Chapter 70. How the Planner Uses Statistics

This chapter builds on the material covered in Section 14.1 and Section 14.2 to show some additional details about how the planner uses the system statistics to estimate the number of rows each part of a query might return. This is a significant part of the planning process, providing much of the raw material for cost calculation.

The intent of this chapter is not to document the code in detail, but to present an overview of how it works. This will perhaps ease the learning curve for someone who subsequently wishes to read the code.

70.1. Row Estimation Examples

The examples shown below use tables in the PostgreSQL regression test database. The outputs shown are taken from version 8.3. The behavior of earlier (or later) versions might vary. Note also that since ANALYZE uses random sampling while producing statistics, the results will change slightly after any new ANALYZE.

Let's start with a very simple query:

```
EXPLAIN SELECT * FROM tenk1;
```

QUERY PLAN

```
-----  
Seq Scan on tenk1 (cost=0.00..458.00 rows=10000 width=244)
```

How the planner determines the cardinality of `tenk1` is covered in Section 14.2, but is repeated here for completeness. The number of pages and rows is looked up in `pg_class`:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 'tenk1';
```

```
relpages | reltuples  
-----+-----  
      358 |      10000
```

These numbers are current as of the last VACUUM or ANALYZE on the table. The planner then fetches the actual current number of pages in the table (this is a cheap operation, not requiring a table scan). If that is different from `relpages` then `reltuples` is scaled accordingly to arrive at a current number-of-rows estimate. In the example above, the value of `relpages` is up-to-date so the rows estimate is the same as `reltuples`.

Let's move on to an example with a range condition in its WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 1000;
```

QUERY PLAN

```
-----  
Bitmap Heap Scan on tenk1 (cost=24.06..394.64 rows=1007  
width=244)  
  Recheck Cond: (unique1 < 1000)  
    -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..23.80  
rows=1007 width=0)
```

Index Cond: (unique1 < 1000)

The planner examines the WHERE clause condition and looks up the selectivity function for the operator < in pg_operator. This is held in the column oprrest, and the entry in this case is scalarltsel. The scalarltsel function retrieves the histogram for unique1 from pg_statistic. For manual queries it is more convenient to look in the simpler pg_stats view:

```
SELECT histogram_bounds FROM pg_stats
WHERE tablename='tenk1' AND attname='unique1';
```

```
          histogram_bounds
-----
{0,993,1997,3050,4040,5036,5957,7057,8029,9016,9995}
```

Next the fraction of the histogram occupied by “< 1000” is worked out. This is the selectivity. The histogram divides the range into equal frequency buckets, so all we have to do is locate the bucket that our value is in and count *part* of it and *all* of the ones before. The value 1000 is clearly in the second bucket (993-1997). Assuming a linear distribution of values inside each bucket, we can calculate the selectivity as:

```
selectivity = (1 + (1000 - bucket[2].min)/(bucket[2].max -
                bucket[2].min))/num_buckets
              = (1 + (1000 - 993)/(1997 - 993))/10
              = 0.100697
```

that is, one whole bucket plus a linear fraction of the second, divided by the number of buckets. The estimated number of rows can now be calculated as the product of the selectivity and the cardinality of tenk1:

```
rows = rel_cardinality * selectivity
      = 10000 * 0.100697
      = 1007 (rounding off)
```

Next let's consider an example with an equality condition in its WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE stringul = 'CRAAAA';
```

```
          QUERY PLAN
-----
Seq Scan on tenk1 (cost=0.00..483.00 rows=30 width=244)
  Filter: (stringul = 'CRAAAA'::name)
```

Again the planner examines the WHERE clause condition and looks up the selectivity function for =, which is eqsel. For equality estimation the histogram is not useful; instead the list of *most common values* (MCVs) is used to determine the selectivity. Let's have a look at the MCVs, with some additional columns that will be useful later:

```
SELECT null_frac, n_distinct, most_common_vals, most_common_freqs
FROM pg_stats
WHERE tablename='tenk1' AND attname='stringul';
```

```
 null_frac      | 0
n_distinct     | 676
most_common_vals |
{EJAAAA, BBAAAA, CRAAAA, FCAAAA, FEAAAA, GSAAAA, JOAAAA, MCAAAA, NAAAAA, WGAAAA}
```

```
most_common_freqs |
{0.00333333,0.003,0.003,0.003,0.003,0.003,0.003,0.003,0.003,0.003}
```

Since CRAAAA appears in the list of MCVs, the selectivity is merely the corresponding entry in the list of most common frequencies (MCFs):

```
selectivity = mcf[3]
            = 0.003
```

As before, the estimated number of rows is just the product of this with the cardinality of `tenk1`:

```
rows = 10000 * 0.003
      = 30
```

Now consider the same query, but with a constant that is not in the MCV list:

```
EXPLAIN SELECT * FROM tenk1 WHERE stringul = 'xxx';
```

QUERY PLAN

```
-----
Seq Scan on tenk1 (cost=0.00..483.00 rows=15 width=244)
  Filter: (stringul = 'xxx'::name)
```

This is quite a different problem: how to estimate the selectivity when the value is *not* in the MCV list. The approach is to use the fact that the value is not in the list, combined with the knowledge of the frequencies for all of the MCVs:

```
selectivity = (1 - sum(mvf))/(num_distinct - num_mcv)
            = (1 - (0.00333333 + 0.003 + 0.003 + 0.003 + 0.003 +
0.003 +
                    0.003 + 0.003 + 0.003 + 0.003))/(676 - 10)
            = 0.0014559
```

That is, add up all the frequencies for the MCVs and subtract them from one, then divide by the number of *other* distinct values. This amounts to assuming that the fraction of the column that is not any of the MCVs is evenly distributed among all the other distinct values. Notice that there are no null values so we don't have to worry about those (otherwise we'd subtract the null fraction from the numerator as usual). The estimated number of rows is then calculated as usual:

```
rows = 10000 * 0.0014559
      = 15 (rounding off)
```

The previous example with `unique1 < 1000` was an oversimplification of what `scalarltsel` really does; now that we have seen an example of the use of MCVs, we can fill in some more detail. The example was correct as far as it went, because since `unique1` is a unique column it has no MCVs (obviously, no value is any more common than any other value). For a non-unique column, there will normally be both a histogram and an MCV list, and *the histogram does not include the portion of the column population represented by the MCVs*. We do things this way because it allows more precise estimation. In this situation `scalarltsel` directly applies the condition (e.g., “< 1000”) to each value of the MCV list, and adds up the frequencies of the MCVs for which the condition is true. This gives an exact estimate of the selectivity within the portion of the table that is MCVs. The histogram is then used in the same way as above to estimate the selectivity in the portion of the table that is not MCVs, and then the two numbers are combined to estimate the overall selectivity. For example, consider

```
EXPLAIN SELECT * FROM tenk1 WHERE stringul < 'IAAAAA';
```

```
QUERY PLAN
```

```
-----
Seq Scan on tenk1 (cost=0.00..483.00 rows=3077 width=244)
  Filter: (stringul < 'IAAAAA'::name)
```

We already saw the MCV information for stringul, and here is its histogram:

```
SELECT histogram_bounds FROM pg_stats
WHERE tablename='tenk1' AND attname='stringul';
```

```
histogram_bounds
```

```
-----
{AAAAAA,CQAAAA,FRAAAA,IBAAAA,KRAAAA,NFAAAA,PSAAAA,SGAAAA,VAAAAA,XLAAAA,ZZAAAA}
```

Checking the MCV list, we find that the condition `stringul < 'IAAAAA'` is satisfied by the first six entries and not the last four, so the selectivity within the MCV part of the population is

```
selectivity = sum(relevant mvfs)
             = 0.00333333 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003
             = 0.01833333
```

Summing all the MCFs also tells us that the total fraction of the population represented by MCVs is 0.03033333, and therefore the fraction represented by the histogram is 0.96966667 (again, there are no nulls, else we'd have to exclude them here). We can see that the value `IAAAAA` falls nearly at the end of the third histogram bucket. Using some rather cheesy assumptions about the frequency of different characters, the planner arrives at the estimate 0.298387 for the portion of the histogram population that is less than `IAAAAA`. We then combine the estimates for the MCV and non-MCV populations:

```
selectivity = mcv_selectivity + histogram_selectivity *
             histogram_fraction
             = 0.01833333 + 0.298387 * 0.96966667
             = 0.307669
```

```
rows       = 10000 * 0.307669
           = 3077 (rounding off)
```

In this particular example, the correction from the MCV list is fairly small, because the column distribution is actually quite flat (the statistics showing these particular values as being more common than others are mostly due to sampling error). In a more typical case where some values are significantly more common than others, this complicated process gives a useful improvement in accuracy because the selectivity for the most common values is found exactly.

Now let's consider a case with more than one condition in the `WHERE` clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 1000 AND stringul =
'xxx';
```

```
QUERY PLAN
```

```
-----
Bitmap Heap Scan on tenk1 (cost=23.80..396.91 rows=1 width=244)
  Recheck Cond: (unique1 < 1000)
  Filter: (stringul = 'xxx'::name)
```

```

-> Bitmap Index Scan on tenk1_unique1 (cost=0.00..23.80
rows=1007 width=0)
    Index Cond: (unique1 < 1000)

```

The planner assumes that the two conditions are independent, so that the individual selectivities of the clauses can be multiplied together:

```

selectivity = selectivity(unique1 < 1000) * selectivity(stringul =
'xxx')
              = 0.100697 * 0.0014559
              = 0.0001466

rows         = 10000 * 0.0001466
              = 1 (rounding off)

```

Notice that the number of rows estimated to be returned from the bitmap index scan reflects only the condition used with the index; this is important since it affects the cost estimate for the subsequent heap fetches.

Finally we will examine a query that involves a join:

```

EXPLAIN SELECT * FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 50 AND t1.unique2 = t2.unique2;

```

QUERY PLAN

```

-----
Nested Loop (cost=4.64..456.23 rows=50 width=488)
  -> Bitmap Heap Scan on tenk1 t1 (cost=4.64..142.17 rows=50
width=244)
      Recheck Cond: (unique1 < 50)
      -> Bitmap Index Scan on tenk1_unique1 (cost=0.00..4.63
rows=50 width=0)
          Index Cond: (unique1 < 50)
      -> Index Scan using tenk2_unique2 on tenk2 t2 (cost=0.00..6.27
rows=1 width=244)
          Index Cond: (unique2 = t1.unique2)

```

The restriction on tenk1, unique1 < 50, is evaluated before the nested-loop join. This is handled analogously to the previous range example. This time the value 50 falls into the first bucket of the unique1 histogram:

```

selectivity = (0 + (50 - bucket[1].min)/(bucket[1].max -
bucket[1].min))/num_buckets
              = (0 + (50 - 0)/(993 - 0))/10
              = 0.005035

rows         = 10000 * 0.005035
              = 50 (rounding off)

```

The restriction for the join is t2.unique2 = t1.unique2. The operator is just our familiar =, however the selectivity function is obtained from the oprjoin column of pg_operator, and is eqjoinsel. eqjoinsel looks up the statistical information for both tenk2 and tenk1:

```

SELECT tablename, null_frac, n_distinct, most_common_vals FROM
pg_stats

```

```
WHERE tablename IN ('tenk1', 'tenk2') AND attname='unique2';
```

tablename	null_frac	n_distinct	most_common_vals
tenk1	0	-1	
tenk2	0	-1	

In this case there is no MCV information for `unique2` because all the values appear to be unique, so we use an algorithm that relies only on the number of distinct values for both relations together with their null fractions:

```
selectivity = (1 - null_frac1) * (1 - null_frac2) * min(1/
num_distinct1, 1/num_distinct2)
            = (1 - 0) * (1 - 0) / max(10000, 10000)
            = 0.0001
```

This is, subtract the null fraction from one for each of the relations, and divide by the maximum of the numbers of distinct values. The number of rows that the join is likely to emit is calculated as the cardinality of the Cartesian product of the two inputs, multiplied by the selectivity:

```
rows = (outer_cardinality * inner_cardinality) * selectivity
      = (50 * 10000) * 0.0001
      = 50
```

Had there been MCV lists for the two columns, `eqjoinsel` would have used direct comparison of the MCV lists to determine the join selectivity within the part of the column populations represented by the MCVs. The estimate for the remainder of the populations follows the same approach shown here.

Notice that we showed `inner_cardinality` as 10000, that is, the unmodified size of `tenk2`. It might appear from inspection of the EXPLAIN output that the estimate of join rows comes from $50 * 1$, that is, the number of outer rows times the estimated number of rows obtained by each inner index scan on `tenk2`. But this is not the case: the join relation size is estimated before any particular join plan has been considered. If everything is working well then the two ways of estimating the join size will produce about the same answer, but due to round-off error and other factors they sometimes diverge significantly.

For those interested in further details, estimation of the size of a table (before any WHERE clauses) is done in `src/backend/optimizer/util/plancat.c`. The generic logic for clause selectivities is in `src/backend/optimizer/path/clausesel.c`. The operator-specific selectivity functions are mostly found in `src/backend/utils/adtselfuncs.c`.

70.2. Multivariate Statistics Examples

70.2.1. Functional Dependencies

Multivariate correlation can be demonstrated with a very simple data set — a table with two columns, both containing the same values:

```
CREATE TABLE t (a INT, b INT);
INSERT INTO t SELECT i % 100, i % 100 FROM generate_series(1,
10000) s(i);
ANALYZE t;
```

As explained in Section 14.2, the planner can determine cardinality of `t` using the number of pages and rows obtained from `pg_class`:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 't';
```

```
relpages | reltuples
-----+-----
         45 |      10000
```

The data distribution is very simple; there are only 100 distinct values in each column, uniformly distributed.

The following example shows the result of estimating a WHERE condition on the a column:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1;
          QUERY PLAN
```

```
-----
Seq Scan on t  (cost=0.00..170.00 rows=100 width=8) (actual
rows=100 loops=1)
  Filter: (a = 1)
  Rows Removed by Filter: 9900
```

The planner examines the condition and determines the selectivity of this clause to be 1%. By comparing this estimate and the actual number of rows, we see that the estimate is very accurate (in fact exact, as the table is very small). Changing the WHERE condition to use the b column, an identical plan is generated. But observe what happens if we apply the same condition on both columns, combining them with AND:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
1;
          QUERY PLAN
```

```
-----
Seq Scan on t  (cost=0.00..195.00 rows=1 width=8) (actual rows=100
loops=1)
  Filter: ((a = 1) AND (b = 1))
  Rows Removed by Filter: 9900
```

The planner estimates the selectivity for each condition individually, arriving at the same 1% estimates as above. Then it assumes that the conditions are independent, and so it multiplies their selectivities, producing a final selectivity estimate of just 0.01%. This is a significant underestimate, as the actual number of rows matching the conditions (100) is two orders of magnitude higher.

This problem can be fixed by creating a statistics object that directs ANALYZE to calculate functional-dependency multivariate statistics on the two columns:

```
CREATE STATISTICS stts (dependencies) ON a, b FROM t;
ANALYZE t;
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
1;
          QUERY PLAN
```

```
-----
Seq Scan on t  (cost=0.00..195.00 rows=100 width=8) (actual
rows=100 loops=1)
  Filter: ((a = 1) AND (b = 1))
  Rows Removed by Filter: 9900
```

70.2.2. Multivariate N-Distinct Counts

A similar problem occurs with estimation of the cardinality of sets of multiple columns, such as the number of groups that would be generated by a `GROUP BY` clause. When `GROUP BY` lists a single column, the n-distinct estimate (which is visible as the estimated number of rows returned by the `HashAggregate` node) is very accurate:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT COUNT(*) FROM t GROUP BY a;
                                QUERY PLAN
```

```
-----
HashAggregate (cost=195.00..196.00 rows=100 width=12) (actual
rows=100 loops=1)
  Group Key: a
    -> Seq Scan on t (cost=0.00..145.00 rows=10000 width=4)
        (actual rows=10000 loops=1)
```

But without multivariate statistics, the estimate for the number of groups in a query with two columns in `GROUP BY`, as in the following example, is off by an order of magnitude:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT COUNT(*) FROM t GROUP BY a, b;
                                QUERY PLAN
```

```
-----
HashAggregate (cost=220.00..230.00 rows=1000 width=16) (actual
rows=100 loops=1)
  Group Key: a, b
    -> Seq Scan on t (cost=0.00..145.00 rows=10000 width=8)
        (actual rows=10000 loops=1)
```

By redefining the statistics object to include n-distinct counts for the two columns, the estimate is much improved:

```
DROP STATISTICS stts;
CREATE STATISTICS stts (dependencies, ndistinct) ON a, b FROM t;
ANALYZE t;
EXPLAIN (ANALYZE, TIMING OFF) SELECT COUNT(*) FROM t GROUP BY a, b;
                                QUERY PLAN
```

```
-----
HashAggregate (cost=220.00..221.00 rows=100 width=16) (actual
rows=100 loops=1)
  Group Key: a, b
    -> Seq Scan on t (cost=0.00..145.00 rows=10000 width=8)
        (actual rows=10000 loops=1)
```

70.2.3. MCV Lists

As explained in Section 70.2.1, functional dependencies are very cheap and efficient type of statistics, but their main limitation is their global nature (only tracking dependencies at the column level, not between individual column values).

This section introduces multivariate variant of MCV (most-common values) lists, a straightforward extension of the per-column statistics described in Section 70.1. These statistics address the limitation by storing individual values, but it is naturally more expensive, both in terms of building the statistics in `ANALYZE`, storage and planning time.

Let's look at the query from Section 70.2.1 again, but this time with a MCV list created on the same set of columns (be sure to drop the functional dependencies, to make sure the planner uses the newly created statistics).

```
DROP STATISTICS stts;
CREATE STATISTICS stts2 (mcv) ON a, b FROM t;
ANALYZE t;
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
1;
```

QUERY PLAN

```
-----
Seq Scan on t (cost=0.00..195.00 rows=100 width=8) (actual
rows=100 loops=1)
  Filter: ((a = 1) AND (b = 1))
  Rows Removed by Filter: 9900
```

The estimate is as accurate as with the functional dependencies, mostly thanks to the table being fairly small and having a simple distribution with a low number of distinct values. Before looking at the second query, which was not handled by functional dependencies particularly well, let's inspect the MCV list a bit.

Inspecting the MCV list is possible using `pg_mcv_list_items` set-returning function.

```
SELECT m.* FROM pg_statistic_ext join pg_statistic_ext_data on (oid
= stxoid),
       pg_mcv_list_items(stxdmcv) m WHERE stxname =
```

```
'stts2';
 index | values | nulls | frequency | base_frequency
-----+-----+-----+-----+-----
      0 | {0, 0} | {f,f} | 0.01 | 0.0001
      1 | {1, 1} | {f,f} | 0.01 | 0.0001
    ...
     49 | {49, 49} | {f,f} | 0.01 | 0.0001
     50 | {50, 50} | {f,f} | 0.01 | 0.0001
    ...
     97 | {97, 97} | {f,f} | 0.01 | 0.0001
     98 | {98, 98} | {f,f} | 0.01 | 0.0001
     99 | {99, 99} | {f,f} | 0.01 | 0.0001
```

(100 rows)

This confirms there are 100 distinct combinations in the two columns, and all of them are about equally likely (1% frequency for each one). The base frequency is the frequency computed from per-column statistics, as if there were no multi-column statistics. Had there been any null values in either of the columns, this would be identified in the `nulls` column.

When estimating the selectivity, the planner applies all the conditions on items in the MCV list, and then sums the frequencies of the matching ones. See `mcv_clause_list_selectivity` in `src/backend/statistics/mcv.c` for details.

Compared to functional dependencies, MCV lists have two major advantages. Firstly, the list stores actual values, making it possible to decide which combinations are compatible.

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a = 1 AND b =
10;
```

QUERY PLAN

```
Seq Scan on t (cost=0.00..195.00 rows=1 width=8) (actual rows=0
loops=1)
  Filter: ((a = 1) AND (b = 10))
  Rows Removed by Filter: 10000
```

Secondly, MCV lists handle a wider range of clause types, not just equality clauses like functional dependencies. For example, consider the following range query for the same table:

```
EXPLAIN (ANALYZE, TIMING OFF) SELECT * FROM t WHERE a <= 49 AND b >
49;
```

QUERY PLAN

```
-----
Seq Scan on t (cost=0.00..195.00 rows=1 width=8) (actual rows=0
loops=1)
  Filter: ((a <= 49) AND (b > 49))
  Rows Removed by Filter: 10000
```

70.3. Planner Statistics and Security

Access to the table `pg_statistic` is restricted to superusers, so that ordinary users cannot learn about the contents of the tables of other users from it. Some selectivity estimation functions will use a user-provided operator (either the operator appearing in the query or a related operator) to analyze the stored statistics. For example, in order to determine whether a stored most common value is applicable, the selectivity estimator will have to run the appropriate `=` operator to compare the constant in the query to the stored value. Thus the data in `pg_statistic` is potentially passed to user-defined operators. An appropriately crafted operator can intentionally leak the passed operands (for example, by logging them or writing them to a different table), or accidentally leak them by showing their values in error messages, in either case possibly exposing data from `pg_statistic` to a user who should not be able to see it.

In order to prevent this, the following applies to all built-in selectivity estimation functions. When planning a query, in order to be able to use stored statistics, the current user must either have `SELECT` privilege on the table or the involved columns, or the operator used must be `LEAKPROOF` (more accurately, the function that the operator is based on). If not, then the selectivity estimator will behave as if no statistics are available, and the planner will proceed with default or fall-back assumptions.

If a user does not have the required privilege on the table or columns, then in many cases the query will ultimately receive a permission-denied error, in which case this mechanism is invisible in practice. But if the user is reading from a security-barrier view, then the planner might wish to check the statistics of an underlying table that is otherwise inaccessible to the user. In that case, the operator should be leak-proof or the statistics will not be used. There is no direct feedback about that, except that the plan might be suboptimal. If one suspects that this is the case, one could try running the query as a more privileged user, to see if a different plan results.

This restriction applies only to cases where the planner would need to execute a user-defined operator on one or more values from `pg_statistic`. Thus the planner is permitted to use generic statistical information, such as the fraction of null values or the number of distinct values in a column, regardless of access privileges.

Selectivity estimation functions contained in third-party extensions that potentially operate on statistics with user-defined operators should follow the same security rules. Consult the PostgreSQL source code for guidance.

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Appendix A. PostgreSQL Error Codes

All messages emitted by the PostgreSQL server are assigned five-character error codes that follow the SQL standard's conventions for "SQLSTATE" codes. Applications that need to know which error condition has occurred should usually test the error code, rather than looking at the textual error message. The error codes are less likely to change across PostgreSQL releases, and also are not subject to change due to localization of error messages. Note that some, but not all, of the error codes produced by PostgreSQL are defined by the SQL standard; some additional error codes for conditions not defined by the standard have been invented or borrowed from other databases.

According to the standard, the first two characters of an error code denote a class of errors, while the last three characters indicate a specific condition within that class. Thus, an application that does not recognize the specific error code might still be able to infer what to do from the error class.

Table A.1 lists all the error codes defined in PostgreSQL 12.1. (Some are not actually used at present, but are defined by the SQL standard.) The error classes are also shown. For each error class there is a "standard" error code having the last three characters 000. This code is used only for error conditions that fall within the class but do not have any more-specific code assigned.

The symbol shown in the column "Condition Name" is the condition name to use in PL/pgSQL. Condition names can be written in either upper or lower case. (Note that PL/pgSQL does not recognize warning, as opposed to error, condition names; those are classes 00, 01, and 02.)

For some types of errors, the server reports the name of a database object (a table, table column, data type, or constraint) associated with the error; for example, the name of the unique constraint that caused a `unique_violation` error. Such names are supplied in separate fields of the error report message so that applications need not try to extract them from the possibly-localized human-readable text of the message. As of PostgreSQL 9.3, complete coverage for this feature exists only for errors in SQLSTATE class 23 (integrity constraint violation), but this is likely to be expanded in future.

Table A.1. PostgreSQL Error Codes

Error Code	Condition Name
Class 00 — Successful Completion	
00000	successful_completion
Class 01 — Warning	
01000	warning
0100C	dynamic_result_sets_returned
01008	implicit_zero_bit_padding
01003	null_value_eliminated_in_set_function
01007	privilege_not_granted
01006	privilege_not_revoked
01004	string_data_right_truncation
01P01	deprecated_feature
Class 02 — No Data (this is also a warning class per the SQL standard)	
02000	no_data
02001	no_additional_dynamic_result_sets_returned
Class 03 — SQL Statement Not Yet Complete	
03000	sql_statement_not_yet_complete
Class 08 — Connection Exception	

Error Code	Condition Name
08000	connection_exception
08003	connection_does_not_exist
08006	connection_failure
08001	sqlclient_unable_to_establish_sqlconnection
08004	sqlserver_rejected_establishment_of_sqlconnection
08007	transaction_resolution_unknown
08P01	protocol_violation
Class 09 — Triggered Action Exception	
09000	triggered_action_exception
Class 0A — Feature Not Supported	
0A000	feature_not_supported
Class 0B — Invalid Transaction Initiation	
0B000	invalid_transaction_initiation
Class 0F — Locator Exception	
0F000	locator_exception
0F001	invalid_locator_specification
Class 0L — Invalid Grantor	
0L000	invalid_grantor
0LP01	invalid_grant_operation
Class 0P — Invalid Role Specification	
0P000	invalid_role_specification
Class 0Z — Diagnostics Exception	
0Z000	diagnostics_exception
0Z002	stacked_diagnostics_accessed_without_active_handler
Class 20 — Case Not Found	
20000	case_not_found
Class 21 — Cardinality Violation	
21000	cardinality_violation
Class 22 — Data Exception	
22000	data_exception
2202E	array_subscript_error
22021	character_not_in_repertoire
22008	datetime_field_overflow
22012	division_by_zero
22005	error_in_assignment
2200B	escape_character_conflict
22022	indicator_overflow
22015	interval_field_overflow
2201E	invalid_argument_for_logarithm

Error Code	Condition Name
22014	invalid_argument_for_ntile_function
22016	invalid_argument_for_nth_value_function
2201F	invalid_argument_for_power_function
2201G	invalid_argument_for_width_bucket_function
22018	invalid_character_value_for_cast
22007	invalid_datetime_format
22019	invalid_escape_character
2200D	invalid_escape_octet
22025	invalid_escape_sequence
22P06	nonstandard_use_of_escape_character
22010	invalid_indicator_parameter_value
22023	invalid_parameter_value
22013	invalid_preceding_or_following_size
2201B	invalid_regular_expression
2201W	invalid_row_count_in_limit_clause
2201X	invalid_row_count_in_result_offset_clause
2202H	invalid_tablesample_argument
2202G	invalid_tablesample_repeat
22009	invalid_time_zone_displacement_value
2200C	invalid_use_of_escape_character
2200G	most_specific_type_mismatch
22004	null_value_not_allowed
22002	null_value_no_indicator_parameter
22003	numeric_value_out_of_range
2200H	sequence_generator_limit_exceeded
22026	string_data_length_mismatch
22001	string_data_right_truncation
22011	substring_error
22027	trim_error
22024	unterminated_c_string
2200F	zero_length_character_string
22P01	floating_point_exception

Error Code	Condition Name
22P02	invalid_text_representation
22P03	invalid_binary_representation
22P04	bad_copy_file_format
22P05	untranslatable_character
2200L	not_an_xml_document
2200M	invalid_xml_document
2200N	invalid_xml_content
2200S	invalid_xml_comment
2200T	invalid_xml_processing_instruc- tion
22030	duplicate_json_object_key_value
22032	invalid_json_text
22033	invalid_sql_json_subscript
22034	more_than_one_sql_json_item
22035	no_sql_json_item
22036	non_numeric_sql_json_item
22037	non_unique_keys_in_a_json_object
22038	singleton_sql_json_item_required
22039	sql_json_array_not_found
2203A	sql_json_member_not_found
2203B	sql_json_number_not_found
2203C	sql_json_object_not_found
2203D	too_many_json_array_elements
2203E	too_many_json_object_members
2203F	sql_json_scalar_required
Class 23 — Integrity Constraint Violation	
23000	integrity_constraint_violation
23001	restrict_violation
23502	not_null_violation
23503	foreign_key_violation
23505	unique_violation
23514	check_violation
23P01	exclusion_violation
Class 24 — Invalid Cursor State	
24000	invalid_cursor_state
Class 25 — Invalid Transaction State	
25000	invalid_transaction_state
25001	active_sql_transaction
25002	branch_transaction_already_ac- tive
25008	held_cursor_requires_same_isola- tion_level

Error Code	Condition Name
25003	inappropriate_access_mode_for_branch_transaction
25004	inappropriate_isolation_level_for_branch_transaction
25005	no_active_sql_transaction_for_branch_transaction
25006	read_only_sql_transaction
25007	schema_and_data_statement_mixing_not_supported
25P01	no_active_sql_transaction
25P02	in_failed_sql_transaction
25P03	idle_in_transaction_session_timeout
Class 26 — Invalid SQL Statement Name	
26000	invalid_sql_statement_name
Class 27 — Triggered Data Change Violation	
27000	triggered_data_change_violation
Class 28 — Invalid Authorization Specification	
28000	invalid_authorization_specification
28P01	invalid_password
Class 2B — Dependent Privilege Descriptors Still Exist	
2B000	dependent_privilege_descriptors_still_exist
2BP01	dependent_objects_still_exist
Class 2D — Invalid Transaction Termination	
2D000	invalid_transaction_termination
Class 2F — SQL Routine Exception	
2F000	sql_routine_exception
2F005	function_executed_no_return_statement
2F002	modifying_sql_data_not_permitted
2F003	prohibited_sql_statement_attempted
2F004	reading_sql_data_not_permitted
Class 34 — Invalid Cursor Name	
34000	invalid_cursor_name
Class 38 — External Routine Exception	
38000	external_routine_exception
38001	containing_sql_not_permitted
38002	modifying_sql_data_not_permitted
38003	prohibited_sql_statement_attempted
38004	reading_sql_data_not_permitted

Error Code	Condition Name
Class 39 — External Routine Invocation Exception	
39000	external_routine_invocation_exception
39001	invalid_sqlstate_returned
39004	null_value_not_allowed
39P01	trigger_protocol_violated
39P02	srf_protocol_violated
39P03	event_trigger_protocol_violated
Class 3B — Savepoint Exception	
3B000	savepoint_exception
3B001	invalid_savepoint_specification
Class 3D — Invalid Catalog Name	
3D000	invalid_catalog_name
Class 3F — Invalid Schema Name	
3F000	invalid_schema_name
Class 40 — Transaction Rollback	
40000	transaction_rollback
40002	transaction_integrity_constraint_violation
40001	serialization_failure
40003	statement_completion_unknown
40P01	deadlock_detected
Class 42 — Syntax Error or Access Rule Violation	
42000	syntax_error_or_access_rule_violation
42601	syntax_error
42501	insufficient_privilege
42846	cannot_coerce
42803	grouping_error
42P20	windowing_error
42P19	invalid_recursion
42830	invalid_foreign_key
42602	invalid_name
42622	name_too_long
42939	reserved_name
42804	datatype_mismatch
42P18	indeterminate_datatype
42P21	collation_mismatch
42P22	indeterminate_collation
42809	wrong_object_type
428C9	generated_always
42703	undefined_column

Error Code	Condition Name
42883	undefined_function
42P01	undefined_table
42P02	undefined_parameter
42704	undefined_object
42701	duplicate_column
42P03	duplicate_cursor
42P04	duplicate_database
42723	duplicate_function
42P05	duplicate_prepared_statement
42P06	duplicate_schema
42P07	duplicate_table
42712	duplicate_alias
42710	duplicate_object
42702	ambiguous_column
42725	ambiguous_function
42P08	ambiguous_parameter
42P09	ambiguous_alias
42P10	invalid_column_reference
42611	invalid_column_definition
42P11	invalid_cursor_definition
42P12	invalid_database_definition
42P13	invalid_function_definition
42P14	invalid_prepared_statement_definition
42P15	invalid_schema_definition
42P16	invalid_table_definition
42P17	invalid_object_definition
Class 44 — WITH CHECK OPTION Violation	
44000	with_check_option_violation
Class 53 — Insufficient Resources	
53000	insufficient_resources
53100	disk_full
53200	out_of_memory
53300	too_many_connections
53400	configuration_limit_exceeded
Class 54 — Program Limit Exceeded	
54000	program_limit_exceeded
54001	statement_too_complex
54011	too_many_columns
54023	too_many_arguments
Class 55 — Object Not In Prerequisite State	

Error Code	Condition Name
55000	object_not_in_prerequisite_state
55006	object_in_use
55P02	cant_change_runtime_param
55P03	lock_not_available
55P04	unsafe_new_enum_value_usage
Class 57 — Operator Intervention	
57000	operator_intervention
57014	query_canceled
57P01	admin_shutdown
57P02	crash_shutdown
57P03	cannot_connect_now
57P04	database_dropped
Class 58 — System Error (errors external to PostgreSQL itself)	
58000	system_error
58030	io_error
58P01	undefined_file
58P02	duplicate_file
Class 72 — Snapshot Failure	
72000	snapshot_too_old
Class F0 — Configuration File Error	
F0000	config_file_error
F0001	lock_file_exists
Class HV — Foreign Data Wrapper Error (SQL/MED)	
HV000	fdw_error
HV005	fdw_column_name_not_found
HV002	fdw_dynamic_parameter_value_needed
HV010	fdw_function_sequence_error
HV021	fdw_inconsistent_descriptor_information
HV024	fdw_invalid_attribute_value
HV007	fdw_invalid_column_name
HV008	fdw_invalid_column_number
HV004	fdw_invalid_data_type
HV006	fdw_invalid_data_type_descriptors
HV091	fdw_invalid_descriptor_field_identifier
HV00B	fdw_invalid_handle
HV00C	fdw_invalid_option_index
HV00D	fdw_invalid_option_name

Error Code	Condition Name
HV090	fdw_in- valid_string_length_or_buffer_length
HV00A	fdw_invalid_string_format
HV009	fdw_invalid_use_of_null_pointer
HV014	fdw_too_many_handles
HV001	fdw_out_of_memory
HV00P	fdw_no_schemas
HV00J	fdw_option_name_not_found
HV00K	fdw_reply_handle
HV00Q	fdw_schema_not_found
HV00R	fdw_table_not_found
HV00L	fdw_unable_to_create_execution
HV00M	fdw_unable_to_create_reply
HV00N	fdw_unable_to_establish_conne- ction
Class P0 — PL/pgSQL Error	
P0000	plpgsql_error
P0001	raise_exception
P0002	no_data_found
P0003	too_many_rows
P0004	assert_failure
Class XX — Internal Error	
XX000	internal_error
XX001	data_corrupted
XX002	index_corrupted

Appendix B. Date/Time Support

PostgreSQL uses an internal heuristic parser for all date/time input support. Dates and times are input as strings, and are broken up into distinct fields with a preliminary determination of what kind of information can be in the field. Each field is interpreted and either assigned a numeric value, ignored, or rejected. The parser contains internal lookup tables for all textual fields, including months, days of the week, and time zones.

This appendix includes information on the content of these lookup tables and describes the steps used by the parser to decode dates and times.

B.1. Date/Time Input Interpretation

Date/time input strings are decoded using the following procedure.

1. Break the input string into tokens and categorize each token as a string, time, time zone, or number.
 - a. If the numeric token contains a colon (:), this is a time string. Include all subsequent digits and colons.
 - b. If the numeric token contains a dash (-), slash (/), or two or more dots (.), this is a date string which might have a text month. If a date token has already been seen, it is instead interpreted as a time zone name (e.g., `America/New_York`).
 - c. If the token is numeric only, then it is either a single field or an ISO 8601 concatenated date (e.g., `19990113` for January 13, 1999) or time (e.g., `141516` for 14:15:16).
 - d. If the token starts with a plus (+) or minus (-), then it is either a numeric time zone or a special field.
2. If the token is an alphabetic string, match up with possible strings:
 - a. See if the token matches any known time zone abbreviation. These abbreviations are supplied by the configuration file described in Section B.4.
 - b. If not found, search an internal table to match the token as either a special string (e.g., `today`), day (e.g., `Thursday`), month (e.g., `January`), or noise word (e.g., `at`, `on`).
 - c. If still not found, throw an error.
3. When the token is a number or number field:
 - a. If there are eight or six digits, and if no other date fields have been previously read, then interpret as a “concatenated date” (e.g., `19990118` or `990118`). The interpretation is `YYYYM-MDD` or `YYMMDD`.
 - b. If the token is three digits and a year has already been read, then interpret as day of year.
 - c. If four or six digits and a year has already been read, then interpret as a time (`HHMM` or `HHMMSS`).
 - d. If three or more digits and no date fields have yet been found, interpret as a year (this forces `yy-mm-dd` ordering of the remaining date fields).
 - e. Otherwise the date field ordering is assumed to follow the `DateStyle` setting: `mm-dd-yy`, `dd-mm-yy`, or `yy-mm-dd`. Throw an error if a month or day field is found to be out of range.
4. If BC has been specified, negate the year and add one for internal storage. (There is no year zero in the Gregorian calendar, so numerically 1 BC becomes year zero.)

- If BC was not specified, and if the year field was two digits in length, then adjust the year to four digits. If the field is less than 70, then add 2000, otherwise add 1900.

Tip

Gregorian years AD 1-99 can be entered by using 4 digits with leading zeros (e.g., 0099 is AD 99).

B.2. Handling of Invalid or Ambiguous Time-stamps

Ordinarily, if a date/time string is syntactically valid but contains out-of-range field values, an error will be thrown. For example, input specifying the 31st of February will be rejected.

During a daylight-savings-time transition, it is possible for a seemingly valid timestamp string to represent a nonexistent or ambiguous timestamp. Such cases are not rejected; the ambiguity is resolved by determining which UTC offset to apply. For example, supposing that the `TimeZone` parameter is set to `America/New_York`, consider

```
=> SELECT '2018-03-11 02:30'::timestampz;
       timestampz
-----
2018-03-11 03:30:00-04
(1 row)
```

Because that day was a spring-forward transition date in that time zone, there was no civil time instant 2:30AM; clocks jumped forward from 2AM EST to 3AM EDT. PostgreSQL interprets the given time as if it were standard time (UTC-5), which then renders as 3:30AM EDT (UTC-4).

Conversely, consider the behavior during a fall-back transition:

```
=> SELECT '2018-11-04 02:30'::timestampz;
       timestampz
-----
2018-11-04 02:30:00-05
(1 row)
```

On that date, there were two possible interpretations of 2:30AM; there was 2:30AM EDT, and then an hour later after the reversion to standard time, there was 2:30AM EST. Again, PostgreSQL interprets the given time as if it were standard time (UTC-5). We can force the matter by specifying daylight-savings time:

```
=> SELECT '2018-11-04 02:30 EDT'::timestampz;
       timestampz
-----
2018-11-04 01:30:00-05
(1 row)
```

This timestamp could validly be rendered as either 2:30 UTC-4 or 1:30 UTC-5; the timestamp output code chooses the latter.

The precise rule that is applied in such cases is that an invalid timestamp that appears to fall within a jump-forward daylight savings transition is assigned the UTC offset that prevailed in the time zone

just before the transition, while an ambiguous timestamp that could fall on either side of a jump-back transition is assigned the UTC offset that prevailed just after the transition. In most time zones this is equivalent to saying that “the standard-time interpretation is preferred when in doubt”.

In all cases, the UTC offset associated with a timestamp can be specified explicitly, using either a numeric UTC offset or a time zone abbreviation that corresponds to a fixed UTC offset. The rule just given applies only when it is necessary to infer a UTC offset for a time zone in which the offset varies.

B.3. Date/Time Key Words

Table B.1 shows the tokens that are recognized as names of months.

Table B.1. Month Names

Month	Abbreviations
January	Jan
February	Feb
March	Mar
April	Apr
May	
June	Jun
July	Jul
August	Aug
September	Sep, Sept
October	Oct
November	Nov
December	Dec

Table B.2 shows the tokens that are recognized as names of days of the week.

Table B.2. Day of the Week Names

Day	Abbreviations
Sunday	Sun
Monday	Mon
Tuesday	Tue, Tues
Wednesday	Wed, Weds
Thursday	Thu, Thur, Thurs
Friday	Fri
Saturday	Sat

Table B.3 shows the tokens that serve various modifier purposes.

Table B.3. Date/Time Field Modifiers

Identifier	Description
AM	Time is before 12:00
AT	Ignored
JULIAN, JD, J	Next field is Julian Date

Identifier	Description
ON	Ignored
PM	Time is on or after 12:00
T	Next field is time

B.4. Date/Time Configuration Files

Since timezone abbreviations are not well standardized, PostgreSQL provides a means to customize the set of abbreviations accepted by the server. The `timezone_abbreviations` run-time parameter determines the active set of abbreviations. While this parameter can be altered by any database user, the possible values for it are under the control of the database administrator — they are in fact names of configuration files stored in `.../share/timezonesets/` of the installation directory. By adding or altering files in that directory, the administrator can set local policy for timezone abbreviations.

`timezone_abbreviations` can be set to any file name found in `.../share/timezonesets/`, if the file's name is entirely alphabetic. (The prohibition against non-alphabetic characters in `timezone_abbreviations` prevents reading files outside the intended directory, as well as reading editor backup files and other extraneous files.)

A timezone abbreviation file can contain blank lines and comments beginning with `#`. Non-comment lines must have one of these formats:

```
zone_abbreviation offset
zone_abbreviation offset D
zone_abbreviation time_zone_name
@INCLUDE file_name
@OVERRIDE
```

A *zone_abbreviation* is just the abbreviation being defined. An *offset* is an integer giving the equivalent offset in seconds from UTC, positive being east from Greenwich and negative being west. For example, `-18000` would be five hours west of Greenwich, or North American east coast standard time. `D` indicates that the zone name represents local daylight-savings time rather than standard time.

Alternatively, a *time_zone_name* can be given, referencing a zone name defined in the IANA timezone database. The zone's definition is consulted to see whether the abbreviation is or has been in use in that zone, and if so, the appropriate meaning is used — that is, the meaning that was currently in use at the timestamp whose value is being determined, or the meaning in use immediately before that if it wasn't current at that time, or the oldest meaning if it was used only after that time. This behavior is essential for dealing with abbreviations whose meaning has historically varied. It is also allowed to define an abbreviation in terms of a zone name in which that abbreviation does not appear; then using the abbreviation is just equivalent to writing out the zone name.

Tip

Using a simple integer *offset* is preferred when defining an abbreviation whose offset from UTC has never changed, as such abbreviations are much cheaper to process than those that require consulting a time zone definition.

The `@INCLUDE` syntax allows inclusion of another file in the `.../share/timezonesets/` directory. Inclusion can be nested, to a limited depth.

The `@OVERRIDE` syntax indicates that subsequent entries in the file can override previous entries (typically, entries obtained from included files). Without this, conflicting definitions of the same timezone abbreviation are considered an error.

In an unmodified installation, the file `Default` contains all the non-conflicting time zone abbreviations for most of the world. Additional files `Australia` and `India` are provided for those regions: these files first include the `Default` file and then add or modify abbreviations as needed.

For reference purposes, a standard installation also contains files `Africa.txt`, `America.txt`, etc, containing information about every time zone abbreviation known to be in use according to the IANA timezone database. The zone name definitions found in these files can be copied and pasted into a custom configuration file as needed. Note that these files cannot be directly referenced as `time-zone_abbreviations` settings, because of the dot embedded in their names.

Note

If an error occurs while reading the time zone abbreviation set, no new value is applied and the old set is kept. If the error occurs while starting the database, startup fails.

Caution

Time zone abbreviations defined in the configuration file override non-timezone meanings built into PostgreSQL. For example, the `Australia` configuration file defines `SAT` (for South Australian Standard Time). When this file is active, `SAT` will not be recognized as an abbreviation for Saturday.

Caution

If you modify files in `.../share/timezonesets/`, it is up to you to make backups — a normal database dump will not include this directory.

B.5. History of Units

The SQL standard states that “Within the definition of a ‘datetime literal’, the ‘datetime values’ are constrained by the natural rules for dates and times according to the Gregorian calendar”. PostgreSQL follows the SQL standard’s lead by counting dates exclusively in the Gregorian calendar, even for years before that calendar was in use. This rule is known as the *proleptic Gregorian calendar*.

The Julian calendar was introduced by Julius Caesar in 45 BC. It was in common use in the Western world until the year 1582, when countries started changing to the Gregorian calendar. In the Julian calendar, the tropical year is approximated as $365 \frac{1}{4}$ days = 365.25 days. This gives an error of about 1 day in 128 years.

The accumulating calendar error prompted Pope Gregory XIII to reform the calendar in accordance with instructions from the Council of Trent. In the Gregorian calendar, the tropical year is approximated as $365 + 97 / 400$ days = 365.2425 days. Thus it takes approximately 3300 years for the tropical year to shift one day with respect to the Gregorian calendar.

The approximation $365+97/400$ is achieved by having 97 leap years every 400 years, using the following rules:

Every year divisible by 4 is a leap year.

However, every year divisible by 100 is not a leap year.

However, every year divisible by 400 is a leap year after all.

So, 1700, 1800, 1900, 2100, and 2200 are not leap years. But 1600, 2000, and 2400 are leap years. By contrast, in the older Julian calendar all years divisible by 4 are leap years.

The papal bull of February 1582 decreed that 10 days should be dropped from October 1582 so that 15 October should follow immediately after 4 October. This was observed in Italy, Poland, Portugal, and Spain. Other Catholic countries followed shortly after, but Protestant countries were reluctant to change, and the Greek Orthodox countries didn't change until the start of the 20th century. The reform was observed by Great Britain and its dominions (including what is now the USA) in 1752. Thus 2 September 1752 was followed by 14 September 1752. This is why Unix systems that have the `cal` program produce the following:

```
$ cal 9 1752
   September 1752
  S  M Tu  W Th  F  S
                1  2 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30
```

But, of course, this calendar is only valid for Great Britain and dominions, not other places. Since it would be difficult and confusing to try to track the actual calendars that were in use in various places at various times, PostgreSQL does not try, but rather follows the Gregorian calendar rules for all dates, even though this method is not historically accurate.

Different calendars have been developed in various parts of the world, many predating the Gregorian system. For example, the beginnings of the Chinese calendar can be traced back to the 14th century BC. Legend has it that the Emperor Huangdi invented that calendar in 2637 BC. The People's Republic of China uses the Gregorian calendar for civil purposes. The Chinese calendar is used for determining festivals.

The *Julian Date* system is another type of calendar, unrelated to the Julian calendar though it is confusingly named similarly to that calendar. The Julian Date system was invented by the French scholar Joseph Justus Scaliger (1540-1609) and probably takes its name from Scaliger's father, the Italian scholar Julius Caesar Scaliger (1484-1558). In the Julian Date system, each day has a sequential number, starting from JD 0 (which is sometimes called *the* Julian Date). JD 0 corresponds to 1 January 4713 BC in the Julian calendar, or 24 November 4714 BC in the Gregorian calendar. Julian Date counting is most often used by astronomers for labeling their nightly observations, and therefore a date runs from noon UTC to the next noon UTC, rather than from midnight to midnight: JD 0 designates the 24 hours from noon UTC on 24 November 4714 BC to noon UTC on 25 November 4714 BC.

Although PostgreSQL supports Julian Date notation for input and output of dates (and also uses Julian dates for some internal datetime calculations), it does not observe the nicety of having dates run from noon to noon. PostgreSQL treats a Julian Date as running from midnight to midnight.

Appendix C. SQL Key Words

Table C.1 lists all tokens that are key words in the SQL standard and in PostgreSQL 12.1. Background information can be found in Section 4.1.1. (For space reasons, only the latest two versions of the SQL standard, and SQL-92 for historical comparison, are included. The differences between those and the other intermediate standard versions are small.)

SQL distinguishes between *reserved* and *non-reserved* key words. According to the standard, reserved key words are the only real key words; they are never allowed as identifiers. Non-reserved key words only have a special meaning in particular contexts and can be used as identifiers in other contexts. Most non-reserved key words are actually the names of built-in tables and functions specified by SQL. The concept of non-reserved key words essentially only exists to declare that some predefined meaning is attached to a word in some contexts.

In the PostgreSQL parser life is a bit more complicated. There are several different classes of tokens ranging from those that can never be used as an identifier to those that have absolutely no special status in the parser as compared to an ordinary identifier. (The latter is usually the case for functions specified by SQL.) Even reserved key words are not completely reserved in PostgreSQL, but can be used as column labels (for example, `SELECT 55 AS CHECK`, even though `CHECK` is a reserved key word).

In Table C.1 in the column for PostgreSQL we classify as “non-reserved” those key words that are explicitly known to the parser but are allowed as column or table names. Some key words that are otherwise non-reserved cannot be used as function or data type names and are marked accordingly. (Most of these words represent built-in functions or data types with special syntax. The function or type is still available but it cannot be redefined by the user.) Labeled “reserved” are those tokens that are not allowed as column or table names. Some reserved key words are allowable as names for functions or data types; this is also shown in the table. If not so marked, a reserved key word is only allowed as an “AS” column label name.

As a general rule, if you get spurious parser errors for commands that contain any of the listed key words as an identifier you should try to quote the identifier to see if the problem goes away.

It is important to understand before studying Table C.1 that the fact that a key word is not reserved in PostgreSQL does not mean that the feature related to the word is not implemented. Conversely, the presence of a key word does not indicate the existence of a feature.

Table C.1. SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
A		non-reserved	non-reserved	
ABORT	non-reserved			
ABS		reserved	reserved	
ABSENT		non-reserved	non-reserved	
ABSOLUTE	non-reserved	non-reserved	non-reserved	reserved
ACCESS	non-reserved			
ACCORDING		non-reserved	non-reserved	
ACOS		reserved		
ACTION	non-reserved	non-reserved	non-reserved	reserved
ADA		non-reserved	non-reserved	non-reserved
ADD	non-reserved	non-reserved	non-reserved	reserved
ADMIN	non-reserved	non-reserved	non-reserved	
AFTER	non-reserved	non-reserved	non-reserved	
AGGREGATE	non-reserved			

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
ALL	reserved	reserved	reserved	reserved
ALLOCATE		reserved	reserved	reserved
ALSO	non-reserved			
ALTER	non-reserved	reserved	reserved	reserved
ALWAYS	non-reserved	non-reserved	non-reserved	
ANALYSE	reserved			
ANALYZE	reserved			
AND	reserved	reserved	reserved	reserved
ANY	reserved	reserved	reserved	reserved
ARE		reserved	reserved	reserved
ARRAY	reserved	reserved	reserved	
ARRAY_AGG		reserved	reserved	
AR- RAY_MAX_CARDI- NALITY		reserved	reserved	
AS	reserved	reserved	reserved	reserved
ASC	reserved	non-reserved	non-reserved	reserved
ASENSITIVE		reserved	reserved	
ASIN		reserved		
ASSERTION	non-reserved	non-reserved	non-reserved	reserved
ASSIGNMENT	non-reserved	non-reserved	non-reserved	
ASYMMETRIC	reserved	reserved	reserved	
AT	non-reserved	reserved	reserved	reserved
ATAN		reserved		
ATOMIC		reserved	reserved	
ATTACH	non-reserved			
ATTRIBUTE	non-reserved	non-reserved	non-reserved	
ATTRIBUTES		non-reserved	non-reserved	
AUTHORIZA- TION	reserved (can be function or type)	reserved	reserved	reserved
AVG		reserved	reserved	reserved
BACKWARD	non-reserved			
BASE64		non-reserved	non-reserved	
BEFORE	non-reserved	non-reserved	non-reserved	
BEGIN	non-reserved	reserved	reserved	reserved
BEGIN_FRAME		reserved	reserved	
BEGIN_PARTITION		reserved	reserved	
BERNOULLI		non-reserved	non-reserved	
BETWEEN	non-reserved (can- not be function or type)	reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
BIGINT	non-reserved (cannot be function or type)	reserved	reserved	
BINARY	reserved (can be function or type)	reserved	reserved	
BIT	non-reserved (cannot be function or type)			reserved
BIT_LENGTH				reserved
BLOB		reserved	reserved	
BLOCKED		non-reserved	non-reserved	
BOM		non-reserved	non-reserved	
BOOLEAN	non-reserved (cannot be function or type)	reserved	reserved	
BOTH	reserved	reserved	reserved	reserved
BREADTH		non-reserved	non-reserved	
BY	non-reserved	reserved	reserved	reserved
C		non-reserved	non-reserved	non-reserved
CACHE	non-reserved			
CALL	non-reserved	reserved	reserved	
CALLED	non-reserved	reserved	reserved	
CARDINALITY		reserved	reserved	
CASCADE	non-reserved	non-reserved	non-reserved	reserved
CASCADED	non-reserved	reserved	reserved	reserved
CASE	reserved	reserved	reserved	reserved
CAST	reserved	reserved	reserved	reserved
CATALOG	non-reserved	non-reserved	non-reserved	reserved
CATALOG_NAME		non-reserved	non-reserved	non-reserved
CEIL		reserved	reserved	
CEILING		reserved	reserved	
CHAIN	non-reserved	non-reserved	non-reserved	
CHAINING		non-reserved		
CHAR	non-reserved (cannot be function or type)	reserved	reserved	reserved
CHARACTER	non-reserved (cannot be function or type)	reserved	reserved	reserved
CHARACTERISTICS	non-reserved	non-reserved	non-reserved	
CHARACTERS		non-reserved	non-reserved	
CHARACTER_LENGTH		reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
CHARACTER_SET_CATALOG		non-reserved	non-reserved	non-reserved
CHARACTER_SET_NAME		non-reserved	non-reserved	non-reserved
CHARACTER_SET_SCHEMA		non-reserved	non-reserved	non-reserved
CHAR_LENGTH		reserved	reserved	reserved
CHECK	reserved	reserved	reserved	reserved
CHECKPOINT	non-reserved			
CLASS	non-reserved			
CLASSIFIER		reserved		
CLASS_ORIGIN		non-reserved	non-reserved	non-reserved
CLOB		reserved	reserved	
CLOSE	non-reserved	reserved	reserved	reserved
CLUSTER	non-reserved			
COALESCE	non-reserved (cannot be function or type)	reserved	reserved	reserved
COBOL		non-reserved	non-reserved	non-reserved
COLLATE	reserved	reserved	reserved	reserved
COLLATION	reserved (can be function or type)	non-reserved	non-reserved	reserved
COLLATION_CATALOG		non-reserved	non-reserved	non-reserved
COLLATION_NAME		non-reserved	non-reserved	non-reserved
COLLATION_SCHEMA		non-reserved	non-reserved	non-reserved
COLLECT		reserved	reserved	
COLUMN	reserved	reserved	reserved	reserved
COLUMNS	non-reserved	non-reserved	non-reserved	
COLUMN_NAME		non-reserved	non-reserved	non-reserved
COMMAND_FUNCTION		non-reserved	non-reserved	non-reserved
COMMAND_FUNCTION_CODE		non-reserved	non-reserved	
COMMENT	non-reserved			
COMMENTS	non-reserved			
COMMIT	non-reserved	reserved	reserved	reserved
COMMITTED	non-reserved	non-reserved	non-reserved	non-reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
CONCURRENTLY	reserved (can be function or type)			
CONDITION		reserved	reserved	
CONDITIONAL		non-reserved		
CONDITION_NUMBER		non-reserved	non-reserved	non-reserved
CONFIGURATION	non-reserved			
CONFLICT	non-reserved			
CONNECT		reserved	reserved	reserved
CONNECTION	non-reserved	non-reserved	non-reserved	reserved
CONNECTION_NAME		non-reserved	non-reserved	non-reserved
CONSTRAINT	reserved	reserved	reserved	reserved
CONSTRAINTS	non-reserved	non-reserved	non-reserved	reserved
CONSTRAINT_CATALOG		non-reserved	non-reserved	non-reserved
CONSTRAINT_NAME		non-reserved	non-reserved	non-reserved
CONSTRAINT_SCHEMA		non-reserved	non-reserved	non-reserved
CONSTRUCTOR		non-reserved	non-reserved	
CONTAINS		reserved	reserved	
CONTENT	non-reserved	non-reserved	non-reserved	
CONTINUE	non-reserved	non-reserved	non-reserved	reserved
CONTROL		non-reserved	non-reserved	
CONVERSION	non-reserved			
CONVERT		reserved	reserved	reserved
COPY	non-reserved	reserved		
CORR		reserved	reserved	
CORRESPONDING		reserved	reserved	reserved
COS		reserved		
COSH		reserved		
COST	non-reserved			
COUNT		reserved	reserved	reserved
COVAR_POP		reserved	reserved	
COVAR_SAMP		reserved	reserved	
CREATE	reserved	reserved	reserved	reserved
CROSS	reserved (can be function or type)	reserved	reserved	reserved
CSV	non-reserved			
CUBE	non-reserved	reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
CUME_DIST		reserved	reserved	
CURRENT	non-reserved	reserved	reserved	reserved
CURRENT_CATALOG	reserved	reserved	reserved	
CURRENT_DATE	reserved	reserved	reserved	reserved
CURRENT_DEFAULT_TRANSFORM_GROUP		reserved	reserved	
CURRENT_PATH		reserved	reserved	
CURRENT_ROLE	reserved	reserved	reserved	
CURRENT_ROW		reserved	reserved	
CURRENT_SCHEMA	reserved (can be function or type)	reserved	reserved	
CURRENT_TIME	reserved	reserved	reserved	reserved
CURRENT_TIMESTAMP	reserved	reserved	reserved	reserved
CURRENT_TRANSFORM_GROUP_FOR_TYPE		reserved	reserved	
CURRENT_USER	reserved	reserved	reserved	reserved
CURSOR	non-reserved	reserved	reserved	reserved
CURSOR_NAME		non-reserved	non-reserved	non-reserved
CYCLE	non-reserved	reserved	reserved	
DATA	non-reserved	non-reserved	non-reserved	non-reserved
DATABASE	non-reserved			
DATALINK		reserved	reserved	
DATE		reserved	reserved	reserved
DATETIME_INTERVAL_CODE		non-reserved	non-reserved	non-reserved
DATETIME_INTERVAL_PRECISION		non-reserved	non-reserved	non-reserved
DAY	non-reserved	reserved	reserved	reserved
DB		non-reserved	non-reserved	
DEALLOCATE	non-reserved	reserved	reserved	reserved
DEC	non-reserved (cannot be function or type)	reserved	reserved	reserved
DECFLOAT		reserved		
DECIMAL	non-reserved (cannot be function or type)	reserved	reserved	reserved
DECLARE	non-reserved	reserved	reserved	reserved
DEFAULT	reserved	reserved	reserved	reserved
DEFAULTS	non-reserved	non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
DEFERRABLE	reserved	non-reserved	non-reserved	reserved
DEFERRED	non-reserved	non-reserved	non-reserved	reserved
DEFINE		reserved		
DEFINED		non-reserved	non-reserved	
DEFINER	non-reserved	non-reserved	non-reserved	
DEGREE		non-reserved	non-reserved	
DELETE	non-reserved	reserved	reserved	reserved
DELIMITER	non-reserved			
DELIMITERS	non-reserved			
DENSE_RANK		reserved	reserved	
DEPENDS	non-reserved			
DEPTH		non-reserved	non-reserved	
DEREF		reserved	reserved	
DERIVED		non-reserved	non-reserved	
DESC	reserved	non-reserved	non-reserved	reserved
DESCRIBE		reserved	reserved	reserved
DESCRIPTOR		non-reserved	non-reserved	reserved
DETACH	non-reserved			
DETERMINISTIC		reserved	reserved	
DIAGNOSTICS		non-reserved	non-reserved	reserved
DICTIONARY	non-reserved			
DISABLE	non-reserved			
DISCARD	non-reserved			
DISCONNECT		reserved	reserved	reserved
DISPATCH		non-reserved	non-reserved	
DISTINCT	reserved	reserved	reserved	reserved
DLNEWCOPY		reserved	reserved	
DLPREVIOUS-COPY		reserved	reserved	
DLURLCOMPLETE		reserved	reserved	
DLURLCOMPLETEONLY		reserved	reserved	
DLURLCOMPLETEWRITE		reserved	reserved	
DLURLPATH		reserved	reserved	
DLURLPATHONLY		reserved	reserved	
DLURLPATHWRITE		reserved	reserved	
DLURLSCHEME		reserved	reserved	
DLURLSERVER		reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
DLVALUE		reserved	reserved	
DO	reserved			
DOCUMENT	non-reserved	non-reserved	non-reserved	
DOMAIN	non-reserved	non-reserved	non-reserved	reserved
DOUBLE	non-reserved	reserved	reserved	reserved
DROP	non-reserved	reserved	reserved	reserved
DYNAMIC		reserved	reserved	
DY- NAMIC_FUNC- TION		non-reserved	non-reserved	non-reserved
DY- NAMIC_FUNC- TION_CODE		non-reserved	non-reserved	
EACH	non-reserved	reserved	reserved	
ELEMENT		reserved	reserved	
ELSE	reserved	reserved	reserved	reserved
EMPTY		reserved	non-reserved	
ENABLE	non-reserved			
ENCODING	non-reserved	non-reserved	non-reserved	
ENCRYPTED	non-reserved			
END	reserved	reserved	reserved	reserved
END-EXEC		reserved	reserved	reserved
END_FRAME		reserved	reserved	
END_PARTITION		reserved	reserved	
ENFORCED		non-reserved	non-reserved	
ENUM	non-reserved			
EQUALS		reserved	reserved	
ERROR		non-reserved		
ESCAPE	non-reserved	reserved	reserved	reserved
EVENT	non-reserved			
EVERY		reserved	reserved	
EXCEPT	reserved	reserved	reserved	reserved
EXCEPTION				reserved
EXCLUDE	non-reserved	non-reserved	non-reserved	
EXCLUDING	non-reserved	non-reserved	non-reserved	
EXCLUSIVE	non-reserved			
EXEC		reserved	reserved	reserved
EXECUTE	non-reserved	reserved	reserved	reserved
EXISTS	non-reserved (cannot be function or type)	reserved	reserved	reserved
EXP		reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
EXPLAIN	non-reserved			
EXPRESSION		non-reserved	non-reserved	
EXTENSION	non-reserved			
EXTERNAL	non-reserved	reserved	reserved	reserved
EXTRACT	non-reserved (cannot be function or type)	reserved	reserved	reserved
FALSE	reserved	reserved	reserved	reserved
FAMILY	non-reserved			
FETCH	reserved	reserved	reserved	reserved
FILE		non-reserved	non-reserved	
FILTER	non-reserved	reserved	reserved	
FINAL		non-reserved	non-reserved	
FINISH		non-reserved		
FIRST	non-reserved	non-reserved	non-reserved	reserved
FIRST_VALUE		reserved	reserved	
FLAG		non-reserved	non-reserved	
FLOAT	non-reserved (cannot be function or type)	reserved	reserved	reserved
FLOOR		reserved	reserved	
FOLLOWING	non-reserved	non-reserved	non-reserved	
FOR	reserved	reserved	reserved	reserved
FORCE	non-reserved			
FOREIGN	reserved	reserved	reserved	reserved
FORMAT		non-reserved		
FORTRAN		non-reserved	non-reserved	non-reserved
FORWARD	non-reserved			
FOUND		non-reserved	non-reserved	reserved
FRAME_ROW		reserved	reserved	
FREE		reserved	reserved	
FREEZE	reserved (can be function or type)			
FROM	reserved	reserved	reserved	reserved
FS		non-reserved	non-reserved	
FULFILL		non-reserved		
FULL	reserved (can be function or type)	reserved	reserved	reserved
FUNCTION	non-reserved	reserved	reserved	
FUNCTIONS	non-reserved			
FUSION		reserved	reserved	
G		non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
GENERAL		non-reserved	non-reserved	
GENERATED	non-reserved	non-reserved	non-reserved	
GET		reserved	reserved	reserved
GLOBAL	non-reserved	reserved	reserved	reserved
GO		non-reserved	non-reserved	reserved
GOTO		non-reserved	non-reserved	reserved
GRANT	reserved	reserved	reserved	reserved
GRANTED	non-reserved	non-reserved	non-reserved	
GREATEST	non-reserved (cannot be function or type)			
GROUP	reserved	reserved	reserved	reserved
GROUPING	non-reserved (cannot be function or type)	reserved	reserved	
GROUPS	non-reserved	reserved	reserved	
HANDLER	non-reserved			
HAVING	reserved	reserved	reserved	reserved
HEADER	non-reserved			
HEX		non-reserved	non-reserved	
HIERARCHY		non-reserved	non-reserved	
HOLD	non-reserved	reserved	reserved	
HOURL	non-reserved	reserved	reserved	reserved
ID		non-reserved	non-reserved	
IDENTITY	non-reserved	reserved	reserved	reserved
IF	non-reserved			
IGNORE		non-reserved	non-reserved	
ILIKE	reserved (can be function or type)			
IMMEDIATE	non-reserved	non-reserved	non-reserved	reserved
IMMEDIATELY		non-reserved	non-reserved	
IMMUTABLE	non-reserved			
IMPLEMENTATION		non-reserved	non-reserved	
IMPLICIT	non-reserved			
IMPORT	non-reserved	reserved	reserved	
IN	reserved	reserved	reserved	reserved
INCLUDE	non-reserved			
INCLUDING	non-reserved	non-reserved	non-reserved	
INCREMENT	non-reserved	non-reserved	non-reserved	
INDENT		non-reserved	non-reserved	
INDEX	non-reserved			

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
INDEXES	non-reserved			
INDICATOR		reserved	reserved	reserved
INHERIT	non-reserved			
INHERITS	non-reserved			
INITIAL		reserved		
INITIALLY	reserved	non-reserved	non-reserved	reserved
INLINE	non-reserved			
INNER	reserved (can be function or type)	reserved	reserved	reserved
INOUT	non-reserved (cannot be function or type)	reserved	reserved	
INPUT	non-reserved	non-reserved	non-reserved	reserved
INSENSITIVE	non-reserved	reserved	reserved	reserved
INSERT	non-reserved	reserved	reserved	reserved
INSTANCE		non-reserved	non-reserved	
INSTANTIABLE		non-reserved	non-reserved	
INSTEAD	non-reserved	non-reserved	non-reserved	
INT	non-reserved (cannot be function or type)	reserved	reserved	reserved
INTEGER	non-reserved (cannot be function or type)	reserved	reserved	reserved
INTEGRITY		non-reserved	non-reserved	
INTERSECT	reserved	reserved	reserved	reserved
INTERSECTION		reserved	reserved	
INTERVAL	non-reserved (cannot be function or type)	reserved	reserved	reserved
INTO	reserved	reserved	reserved	reserved
INVOKER	non-reserved	non-reserved	non-reserved	
IS	reserved (can be function or type)	reserved	reserved	reserved
ISNULL	reserved (can be function or type)			
ISOLATION	non-reserved	non-reserved	non-reserved	reserved
JOIN	reserved (can be function or type)	reserved	reserved	reserved
JSON		non-reserved		
JSON_ARRAY		reserved		
JSON_ARRAYAGG		reserved		
JSON_EXISTS		reserved		

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
JSON_OBJECT		reserved		
JSON_OBJECTAGG		reserved		
JSON_QUERY		reserved		
JSON_TABLE		reserved		
JSON_TABLE_PRIMITIVE		reserved		
JSON_VALUE		reserved		
K		non-reserved	non-reserved	
KEEP		non-reserved		
KEY	non-reserved	non-reserved	non-reserved	reserved
KEYS		non-reserved		
KEY_MEMBER		non-reserved	non-reserved	
KEY_TYPE		non-reserved	non-reserved	
LABEL	non-reserved			
LAG		reserved	reserved	
LANGUAGE	non-reserved	reserved	reserved	reserved
LARGE	non-reserved	reserved	reserved	
LAST	non-reserved	non-reserved	non-reserved	reserved
LAST_VALUE		reserved	reserved	
LATERAL	reserved	reserved	reserved	
LEAD		reserved	reserved	
LEADING	reserved	reserved	reserved	reserved
LEAKPROOF	non-reserved			
LEAST	non-reserved (cannot be function or type)			
LEFT	reserved (can be function or type)	reserved	reserved	reserved
LENGTH		non-reserved	non-reserved	non-reserved
LEVEL	non-reserved	non-reserved	non-reserved	reserved
LIBRARY		non-reserved	non-reserved	
LIKE	reserved (can be function or type)	reserved	reserved	reserved
LIKE_REGEX		reserved	reserved	
LIMIT	reserved	non-reserved	non-reserved	
LINK		non-reserved	non-reserved	
LISTAGG		reserved		
LISTEN	non-reserved			
LN		reserved	reserved	
LOAD	non-reserved			
LOCAL	non-reserved	reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
LOCALTIME	reserved	reserved	reserved	
LOCALTIMES-TAMP	reserved	reserved	reserved	
LOCATION	non-reserved	non-reserved	non-reserved	
LOCATOR		non-reserved	non-reserved	
LOCK	non-reserved			
LOCKED	non-reserved			
LOG		reserved		
LOG10		reserved		
LOGGED	non-reserved			
LOWER		reserved	reserved	reserved
M		non-reserved	non-reserved	
MAP		non-reserved	non-reserved	
MAPPING	non-reserved	non-reserved	non-reserved	
MATCH	non-reserved	reserved	reserved	reserved
MATCHED		non-reserved	non-reserved	
MATCHES		reserved		
MATCH_NUMBER		reserved		
MATCH_RECOGNIZE		reserved		
MATERIALIZED	non-reserved			
MAX		reserved	reserved	reserved
MAXVALUE	non-reserved	non-reserved	non-reserved	
MEASURES		reserved		
MEMBER		reserved	reserved	
MERGE		reserved	reserved	
MESSAGE_LENGTH		non-reserved	non-reserved	non-reserved
MESSAGE_OCTET_LENGTH		non-reserved	non-reserved	non-reserved
MESSAGE_TEXT		non-reserved	non-reserved	non-reserved
METHOD	non-reserved	reserved	reserved	
MIN		reserved	reserved	reserved
MINUTE	non-reserved	reserved	reserved	reserved
MINVALUE	non-reserved	non-reserved	non-reserved	
MOD		reserved	reserved	
MODE	non-reserved			
MODIFIES		reserved	reserved	
MODULE		reserved	reserved	reserved
MONTH	non-reserved	reserved	reserved	reserved
MORE		non-reserved	non-reserved	non-reserved
MOVE	non-reserved			
MULTISET		reserved	reserved	
MUMPS		non-reserved	non-reserved	non-reserved

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
NAME	non-reserved	non-reserved	non-reserved	non-reserved
NAMES	non-reserved	non-reserved	non-reserved	reserved
NAMESPACE		non-reserved	non-reserved	
NATIONAL	non-reserved (cannot be function or type)	reserved	reserved	reserved
NATURAL	reserved (can be function or type)	reserved	reserved	reserved
NCHAR	non-reserved (cannot be function or type)	reserved	reserved	reserved
NCLOB		reserved	reserved	
NESTED		non-reserved		
NESTING		non-reserved	non-reserved	
NEW	non-reserved	reserved	reserved	
NEXT	non-reserved	non-reserved	non-reserved	reserved
NFC		non-reserved	non-reserved	
NFD		non-reserved	non-reserved	
NFKC		non-reserved	non-reserved	
NFKD		non-reserved	non-reserved	
NIL		non-reserved	non-reserved	
NO	non-reserved	reserved	reserved	reserved
NONE	non-reserved (cannot be function or type)	reserved	reserved	
NORMALIZE		reserved	reserved	
NORMALIZED		non-reserved	non-reserved	
NOT	reserved	reserved	reserved	reserved
NOTHING	non-reserved			
NOTIFY	non-reserved			
NOTNULL	reserved (can be function or type)			
NOWAIT	non-reserved			
NTH_VALUE		reserved	reserved	
NTILE		reserved	reserved	
NULL	reserved	reserved	reserved	reserved
NULLABLE		non-reserved	non-reserved	non-reserved
NULLIF	non-reserved (cannot be function or type)	reserved	reserved	reserved
NULLS	non-reserved	non-reserved	non-reserved	
NUMBER		non-reserved	non-reserved	non-reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
NUMERIC	non-reserved (cannot be function or type)	reserved	reserved	reserved
OBJECT	non-reserved	non-reserved	non-reserved	
OCCURRENCES_REGEX		reserved	reserved	
OCTETS		non-reserved	non-reserved	
OCTET_LENGTH		reserved	reserved	reserved
OF	non-reserved	reserved	reserved	reserved
OFF	non-reserved	non-reserved	non-reserved	
OFFSET	reserved	reserved	reserved	
OIDS	non-reserved			
OLD	non-reserved	reserved	reserved	
OMIT		reserved		
ON	reserved	reserved	reserved	reserved
ONE		reserved		
ONLY	reserved	reserved	reserved	reserved
OPEN		reserved	reserved	reserved
OPERATOR	non-reserved			
OPTION	non-reserved	non-reserved	non-reserved	reserved
OPTIONS	non-reserved	non-reserved	non-reserved	
OR	reserved	reserved	reserved	reserved
ORDER	reserved	reserved	reserved	reserved
ORDERING		non-reserved	non-reserved	
ORDINALITY	non-reserved	non-reserved	non-reserved	
OTHERS	non-reserved	non-reserved	non-reserved	
OUT	non-reserved (cannot be function or type)	reserved	reserved	
OUTER	reserved (can be function or type)	reserved	reserved	reserved
OUTPUT		non-reserved	non-reserved	reserved
OVER	non-reserved	reserved	reserved	
OVERFLOW		non-reserved		
OVERLAPS	reserved (can be function or type)	reserved	reserved	reserved
OVERLAY	non-reserved (cannot be function or type)	reserved	reserved	
OVERRIDING	non-reserved	non-reserved	non-reserved	
OWNED	non-reserved			
OWNER	non-reserved			
P		non-reserved	non-reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
PAD		non-reserved	non-reserved	reserved
PARALLEL	non-reserved			
PARAMETER		reserved	reserved	
PARAMETER_MODE		non-reserved	non-reserved	
PARAMETER_NAME		non-reserved	non-reserved	
PARAMETER_ORDINAL_POSITION		non-reserved	non-reserved	
PARAMETER_SPECIFIC_CATALOG		non-reserved	non-reserved	
PARAMETER_SPECIFIC_NAME		non-reserved	non-reserved	
PARAMETER_SPECIFIC_SCHEMA		non-reserved	non-reserved	
PARSER	non-reserved			
PARTIAL	non-reserved	non-reserved	non-reserved	reserved
PARTITION	non-reserved	reserved	reserved	
PASCAL		non-reserved	non-reserved	non-reserved
PASS		non-reserved		
PASSING	non-reserved	non-reserved	non-reserved	
PASSTHROUGH		non-reserved	non-reserved	
PASSWORD	non-reserved			
PAST		non-reserved		
PATH		non-reserved	non-reserved	
PATTERN		reserved		
PER		reserved		
PERCENT		reserved	reserved	
PERCENTILE_CONT		reserved	reserved	
PERCENTILE_DISC		reserved	reserved	
PERCENT_RANK		reserved	reserved	
PERIOD		reserved	reserved	
PERMISSION		non-reserved	non-reserved	
PERMUTE		reserved		
PLACING	reserved	non-reserved	non-reserved	
PLAN		non-reserved		
PLANS	non-reserved			
PLI		non-reserved	non-reserved	non-reserved
POLICY	non-reserved			
PORTION		reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
POSITION	non-reserved (cannot be function or type)	reserved	reserved	reserved
POSITION_REGEX		reserved	reserved	
POWER		reserved	reserved	
PRECEDES		reserved	reserved	
PRECEDING	non-reserved	non-reserved	non-reserved	
PRECISION	non-reserved (cannot be function or type)	reserved	reserved	reserved
PREPARE	non-reserved	reserved	reserved	reserved
PREPARED	non-reserved			
PRESERVE	non-reserved	non-reserved	non-reserved	reserved
PRIMARY	reserved	reserved	reserved	reserved
PRIOR	non-reserved	non-reserved	non-reserved	reserved
PRIVATE		non-reserved		
PRIVILEGES	non-reserved	non-reserved	non-reserved	reserved
PROCEDURAL	non-reserved			
PROCEDURE	non-reserved	reserved	reserved	reserved
PROCEDURES	non-reserved			
PROGRAM	non-reserved			
PRUNE		non-reserved		
PTF		reserved		
PUBLIC		non-reserved	non-reserved	reserved
PUBLICATION	non-reserved			
QUOTE	non-reserved			
QUOTES		non-reserved		
RANGE	non-reserved	reserved	reserved	
RANK		reserved	reserved	
READ	non-reserved	non-reserved	non-reserved	reserved
READS		reserved	reserved	
REAL	non-reserved (cannot be function or type)	reserved	reserved	reserved
REASSIGN	non-reserved			
RECHECK	non-reserved			
RECOVERY		non-reserved	non-reserved	
RECURSIVE	non-reserved	reserved	reserved	
REF	non-reserved	reserved	reserved	
REFERENCES	reserved	reserved	reserved	reserved
REFERENCING	non-reserved	reserved	reserved	
REFRESH	non-reserved			

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
REGR_AVGX		reserved	reserved	
REGR_AVGY		reserved	reserved	
REGR_COUNT		reserved	reserved	
REGR_INTERCEPT		reserved	reserved	
REGR_R2		reserved	reserved	
REGR_SLOPE		reserved	reserved	
REGR_SXX		reserved	reserved	
REGR_SXY		reserved	reserved	
REGR_SYY		reserved	reserved	
REINDEX	non-reserved			
RELATIVE	non-reserved	non-reserved	non-reserved	reserved
RELEASE	non-reserved	reserved	reserved	
RENAME	non-reserved			
REPEATABLE	non-reserved	non-reserved	non-reserved	non-reserved
REPLACE	non-reserved			
REPLICA	non-reserved			
REQUIRING		non-reserved	non-reserved	
RESET	non-reserved			
RESPECT		non-reserved	non-reserved	
RESTART	non-reserved	non-reserved	non-reserved	
RESTORE		non-reserved	non-reserved	
RESTRICT	non-reserved	non-reserved	non-reserved	reserved
RESULT		reserved	reserved	
RETURN		reserved	reserved	
RE-TURNED_CARDINALITY		non-reserved	non-reserved	
RE-TURNED_LENGTH		non-reserved	non-reserved	non-reserved
RE-TURNED_OCTET_LENGTH		non-reserved	non-reserved	non-reserved
RE-TURNED_SQLSTATE		non-reserved	non-reserved	non-reserved
RETURNING	reserved	non-reserved	non-reserved	
RETURNS	non-reserved	reserved	reserved	
REVOKE	non-reserved	reserved	reserved	reserved
RIGHT	reserved (can be function or type)	reserved	reserved	reserved
ROLE	non-reserved	non-reserved	non-reserved	
ROLLBACK	non-reserved	reserved	reserved	reserved
ROLLUP	non-reserved	reserved	reserved	

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
ROUTINE	non-reserved	non-reserved	non-reserved	
ROUTINES	non-reserved			
ROUTINE_CATALOG		non-reserved	non-reserved	
ROUTINE_NAME		non-reserved	non-reserved	
ROUTINE_SCHEMA		non-reserved	non-reserved	
ROW	non-reserved (cannot be function or type)	reserved	reserved	
ROWS	non-reserved	reserved	reserved	reserved
ROW_COUNT		non-reserved	non-reserved	non-reserved
ROW_NUMBER		reserved	reserved	
RULE	non-reserved			
RUNNING		reserved		
SAVEPOINT	non-reserved	reserved	reserved	
SCALAR		non-reserved		
SCALE		non-reserved	non-reserved	non-reserved
SCHEMA	non-reserved	non-reserved	non-reserved	reserved
SCHEMAS	non-reserved			
SCHEMA_NAME		non-reserved	non-reserved	non-reserved
SCOPE		reserved	reserved	
SCOPE_CATALOG		non-reserved	non-reserved	
SCOPE_NAME		non-reserved	non-reserved	
SCOPE_SCHEMA		non-reserved	non-reserved	
SCROLL	non-reserved	reserved	reserved	reserved
SEARCH	non-reserved	reserved	reserved	
SECOND	non-reserved	reserved	reserved	reserved
SECTION		non-reserved	non-reserved	reserved
SECURITY	non-reserved	non-reserved	non-reserved	
SEEK		reserved		
SELECT	reserved	reserved	reserved	reserved
SELECTIVE		non-reserved	non-reserved	
SELF		non-reserved	non-reserved	
SENSITIVE		reserved	reserved	
SEQUENCE	non-reserved	non-reserved	non-reserved	
SEQUENCES	non-reserved			
SERIALIZABLE	non-reserved	non-reserved	non-reserved	non-reserved
SERVER	non-reserved	non-reserved	non-reserved	
SERVER_NAME		non-reserved	non-reserved	non-reserved
SESSION	non-reserved	non-reserved	non-reserved	reserved
SESSION_USER	reserved	reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
SET	non-reserved	reserved	reserved	reserved
SETOF	non-reserved (cannot be function or type)			
SETS	non-reserved	non-reserved	non-reserved	
SHARE	non-reserved			
SHOW	non-reserved	reserved		
SIMILAR	reserved (can be function or type)	reserved	reserved	
SIMPLE	non-reserved	non-reserved	non-reserved	
SIN		reserved		
SINH		reserved		
SIZE		non-reserved	non-reserved	reserved
SKIP	non-reserved	reserved		
SMALLINT	non-reserved (cannot be function or type)	reserved	reserved	reserved
SNAPSHOT	non-reserved			
SOME	reserved	reserved	reserved	reserved
SOURCE		non-reserved	non-reserved	
SPACE		non-reserved	non-reserved	reserved
SPECIFIC		reserved	reserved	
SPECIFICTYPE		reserved	reserved	
SPECIFIC_NAME		non-reserved	non-reserved	
SQL	non-reserved	reserved	reserved	reserved
SQLCODE				reserved
SQLERROR				reserved
SQLEXCEPTION		reserved	reserved	
SQLSTATE		reserved	reserved	reserved
SQLWARNING		reserved	reserved	
SQRT		reserved	reserved	
STABLE	non-reserved			
STANDALONE	non-reserved	non-reserved	non-reserved	
START	non-reserved	reserved	reserved	
STATE		non-reserved	non-reserved	
STATEMENT	non-reserved	non-reserved	non-reserved	
STATIC		reserved	reserved	
STATISTICS	non-reserved			
STDDEV_POP		reserved	reserved	
STDDEV_SAMP		reserved	reserved	
STDIN	non-reserved			
STDOUT	non-reserved			

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
STORAGE	non-reserved			
STORED	non-reserved			
STRICT	non-reserved			
STRING		non-reserved		
STRIP	non-reserved	non-reserved	non-reserved	
STRUCTURE		non-reserved	non-reserved	
STYLE		non-reserved	non-reserved	
SUB- CLASS_ORIGIN		non-reserved	non-reserved	non-reserved
SUBMULTISET		reserved	reserved	
SUBSCRIPTION	non-reserved			
SUBSET		reserved		
SUBSTRING	non-reserved (cannot be function or type)	reserved	reserved	reserved
SUBSTRING_REGEX		reserved	reserved	
SUCCEEDS		reserved	reserved	
SUM		reserved	reserved	reserved
SUPPORT	non-reserved			
SYMMETRIC	reserved	reserved	reserved	
SYSID	non-reserved			
SYSTEM	non-reserved	reserved	reserved	
SYSTEM_TIME		reserved	reserved	
SYSTEM_USER		reserved	reserved	reserved
T		non-reserved	non-reserved	
TABLE	reserved	reserved	reserved	reserved
TABLES	non-reserved			
TABLESAMPLE	reserved (can be function or type)	reserved	reserved	
TABLESPACE	non-reserved			
TABLE_NAME		non-reserved	non-reserved	non-reserved
TAN		reserved		
TANH		reserved		
TEMP	non-reserved			
TEMPLATE	non-reserved			
TEMPORARY	non-reserved	non-reserved	non-reserved	reserved
TEXT	non-reserved			
THEN	reserved	reserved	reserved	reserved
THROUGH		non-reserved		
TIES	non-reserved	non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
TIME	non-reserved (cannot be function or type)	reserved	reserved	reserved
TIMESTAMP	non-reserved (cannot be function or type)	reserved	reserved	reserved
TIME-ZONE_HOUR		reserved	reserved	reserved
TIME-ZONE_MINUTE		reserved	reserved	reserved
TO	reserved	reserved	reserved	reserved
TOKEN		non-reserved	non-reserved	
TOP_LEVEL_COUNT		non-reserved	non-reserved	
TRAILING	reserved	reserved	reserved	reserved
TRANSACTION	non-reserved	non-reserved	non-reserved	reserved
TRANSACTIONS_COMMITTED		non-reserved	non-reserved	
TRANSACTIONS_ROLLED_BACK		non-reserved	non-reserved	
TRANSACTION_ACTIVE		non-reserved	non-reserved	
TRANSFORM	non-reserved	non-reserved	non-reserved	
TRANSFORMS		non-reserved	non-reserved	
TRANSLATE		reserved	reserved	reserved
TRANSLATE_REGEX		reserved	reserved	
TRANSLATION		reserved	reserved	reserved
TREAT	non-reserved (cannot be function or type)	reserved	reserved	
TRIGGER	non-reserved	reserved	reserved	
TRIGGER_CATALOG		non-reserved	non-reserved	
TRIGGER_NAME		non-reserved	non-reserved	
TRIGGER_SCHEMA		non-reserved	non-reserved	
TRIM	non-reserved (cannot be function or type)	reserved	reserved	reserved
TRIM_ARRAY		reserved	reserved	
TRUE	reserved	reserved	reserved	reserved
TRUNCATE	non-reserved	reserved	reserved	
TRUSTED	non-reserved			
TYPE	non-reserved	non-reserved	non-reserved	non-reserved

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
TYPES	non-reserved			
UESCAPE		reserved	reserved	
UNBOUNDED	non-reserved	non-reserved	non-reserved	
UNCOMMITTED	non-reserved	non-reserved	non-reserved	non-reserved
UNCONDITION- AL		non-reserved		
UNDER		non-reserved	non-reserved	
UNENCRYPTED	non-reserved			
UNION	reserved	reserved	reserved	reserved
UNIQUE	reserved	reserved	reserved	reserved
UNKNOWN	non-reserved	reserved	reserved	reserved
UNLINK		non-reserved	non-reserved	
UNLISTEN	non-reserved			
UNLOGGED	non-reserved			
UNMATCHED		reserved		
UNNAMED		non-reserved	non-reserved	non-reserved
UNNEST		reserved	reserved	
UNTIL	non-reserved			
UNTYPED		non-reserved	non-reserved	
UPDATE	non-reserved	reserved	reserved	reserved
UPPER		reserved	reserved	reserved
URI		non-reserved	non-reserved	
USAGE		non-reserved	non-reserved	reserved
USER	reserved	reserved	reserved	reserved
USER_DE- FINED_TYPE_CAT- ALOG		non-reserved	non-reserved	
USER_DE- FINED_TYPE_CODE		non-reserved	non-reserved	
USER_DE- FINED_TYPE_NAME		non-reserved	non-reserved	
USER_DE- FINED_TYPE_SCHEMA		non-reserved	non-reserved	
USING	reserved	reserved	reserved	reserved
UTF16		non-reserved		
UTF32		non-reserved		
UTF8		non-reserved		
VACUUM	non-reserved			
VALID	non-reserved	non-reserved	non-reserved	
VALIDATE	non-reserved			
VALIDATOR	non-reserved			
VALUE	non-reserved	reserved	reserved	reserved

SQL Key Words

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
VALUES	non-reserved (cannot be function or type)	reserved	reserved	reserved
VALUE_OF		reserved	reserved	
VARBINARY		reserved	reserved	
VARCHAR	non-reserved (cannot be function or type)	reserved	reserved	reserved
VARIADIC	reserved			
VARYING	non-reserved	reserved	reserved	reserved
VAR_POP		reserved	reserved	
VAR_SAMP		reserved	reserved	
VERBOSE	reserved (can be function or type)			
VERSION	non-reserved	non-reserved	non-reserved	
VERSIONING		reserved	reserved	
VIEW	non-reserved	non-reserved	non-reserved	reserved
VIEWS	non-reserved			
VOLATILE	non-reserved			
WHEN	reserved	reserved	reserved	reserved
WHENEVER		reserved	reserved	reserved
WHERE	reserved	reserved	reserved	reserved
WHITESPACE	non-reserved	non-reserved	non-reserved	
WIDTH_BUCKET		reserved	reserved	
WINDOW	reserved	reserved	reserved	
WITH	reserved	reserved	reserved	reserved
WITHIN	non-reserved	reserved	reserved	
WITHOUT	non-reserved	reserved	reserved	
WORK	non-reserved	non-reserved	non-reserved	reserved
WRAPPER	non-reserved	non-reserved	non-reserved	
WRITE	non-reserved	non-reserved	non-reserved	reserved
XML	non-reserved	reserved	reserved	
XMLAGG		reserved	reserved	
XMLATTRIBUTES	non-reserved (cannot be function or type)	reserved	reserved	
XMLBINARY		reserved	reserved	
XMLCAST		reserved	reserved	
XMLCOMMENT		reserved	reserved	
XMLCONCAT	non-reserved (cannot be function or type)	reserved	reserved	
XMLDECLARATION		non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2016	SQL:2011	SQL-92
XMLDOCUMENT		reserved	reserved	
XMLELEMENT	non-reserved (cannot be function or type)	reserved	reserved	
XML EXISTS	non-reserved (cannot be function or type)	reserved	reserved	
XMLFOREST	non-reserved (cannot be function or type)	reserved	reserved	
XMLITERATE		reserved	reserved	
XMLNAMESPACES	non-reserved (cannot be function or type)	reserved	reserved	
XMLPARSE	non-reserved (cannot be function or type)	reserved	reserved	
XMLPI	non-reserved (cannot be function or type)	reserved	reserved	
XMLQUERY		reserved	reserved	
XMLROOT	non-reserved (cannot be function or type)			
XMLSCHEMA		non-reserved	non-reserved	
XMLSERIALIZE	non-reserved (cannot be function or type)	reserved	reserved	
XMLTABLE	non-reserved (cannot be function or type)	reserved	reserved	
XMLTEXT		reserved	reserved	
XMLVALIDATE		reserved	reserved	
YEAR	non-reserved	reserved	reserved	reserved
YES	non-reserved	non-reserved	non-reserved	
ZONE	non-reserved	non-reserved	non-reserved	reserved

Appendix D. SQL Conformance

This section attempts to outline to what extent PostgreSQL conforms to the current SQL standard. The following information is not a full statement of conformance, but it presents the main topics in as much detail as is both reasonable and useful for users.

The formal name of the SQL standard is ISO/IEC 9075 “Database Language SQL”. A revised version of the standard is released from time to time; the most recent update appearing in 2016. The 2016 version is referred to as ISO/IEC 9075:2016, or simply as SQL:2016. The versions prior to that were SQL:2011, SQL:2008, SQL:2006, SQL:2003, SQL:1999, and SQL-92. Each version replaces the previous one, so claims of conformance to earlier versions have no official merit. PostgreSQL development aims for conformance with the latest official version of the standard where such conformance does not contradict traditional features or common sense. Many of the features required by the SQL standard are supported, though sometimes with slightly differing syntax or function. Further moves towards conformance can be expected over time.

SQL-92 defined three feature sets for conformance: Entry, Intermediate, and Full. Most database management systems claiming SQL standard conformance were conforming at only the Entry level, since the entire set of features in the Intermediate and Full levels was either too voluminous or in conflict with legacy behaviors.

Starting with SQL:1999, the SQL standard defines a large set of individual features rather than the ineffectively broad three levels found in SQL-92. A large subset of these features represents the “Core” features, which every conforming SQL implementation must supply. The rest of the features are purely optional. Some optional features are grouped together to form “packages”, which SQL implementations can claim conformance to, thus claiming conformance to particular groups of features.

The standard versions beginning with SQL:2003 are also split into a number of parts. Each is known by a shorthand name. Note that these parts are not consecutively numbered.

- ISO/IEC 9075-1 Framework (SQL/Framework)
- ISO/IEC 9075-2 Foundation (SQL/Foundation)
- ISO/IEC 9075-3 Call Level Interface (SQL/CLI)
- ISO/IEC 9075-4 Persistent Stored Modules (SQL/PSM)
- ISO/IEC 9075-9 Management of External Data (SQL/MED)
- ISO/IEC 9075-10 Object Language Bindings (SQL/OLB)
- ISO/IEC 9075-11 Information and Definition Schemas (SQL/Schemata)
- ISO/IEC 9075-13 Routines and Types using the Java Language (SQL/JRT)
- ISO/IEC 9075-14 XML-related specifications (SQL/XML)

The PostgreSQL core covers parts 1, 2, 9, 11, and 14. Part 3 is covered by the ODBC driver, and part 13 is covered by the PL/Java plug-in, but exact conformance is currently not being verified for these components. There are currently no implementations of parts 4 and 10 for PostgreSQL.

PostgreSQL supports most of the major features of SQL:2016. Out of 179 mandatory features required for full Core conformance, PostgreSQL conforms to at least 160. In addition, there is a long list of

supported optional features. It might be worth noting that at the time of writing, no current version of any database management system claims full conformance to Core SQL:2016.

In the following two sections, we provide a list of those features that PostgreSQL supports, followed by a list of the features defined in SQL:2016 which are not yet supported in PostgreSQL. Both of these lists are approximate: There might be minor details that are nonconforming for a feature that is listed as supported, and large parts of an unsupported feature might in fact be implemented. The main body of the documentation always contains the most accurate information about what does and does not work.

Note

Feature codes containing a hyphen are subfeatures. Therefore, if a particular subfeature is not supported, the main feature is listed as unsupported even if some other subfeatures are supported.

D.1. Supported Features

Identifier	Package	Description	Comment
B012		Embedded C	
B021		Direct SQL	
E011	Core	Numeric data types	
E011-01	Core	INTEGER and SMALLINT data types	
E011-02	Core	REAL, DOUBLE PRECISION, and FLOAT data types	
E011-03	Core	DECIMAL and NUMERIC data types	
E011-04	Core	Arithmetic operators	
E011-05	Core	Numeric comparison	
E011-06	Core	Implicit casting among the numeric data types	
E021	Core	Character data types	
E021-01	Core	CHARACTER data type	
E021-02	Core	CHARACTER VARYING data type	
E021-03	Core	Character literals	
E021-04	Core	CHARACTER_LENGTH function	trims trailing spaces from CHARACTER values before counting
E021-05	Core	OCTET_LENGTH function	
E021-06	Core	SUBSTRING function	
E021-07	Core	Character concatenation	
E021-08	Core	UPPER and LOWER functions	
E021-09	Core	TRIM function	

Identifier	Package	Description	Comment
E021-10	Core	Implicit casting among the character string types	
E021-11	Core	POSITION function	
E021-12	Core	Character comparison	
E031	Core	Identifiers	
E031-01	Core	Delimited identifiers	
E031-02	Core	Lower case identifiers	
E031-03	Core	Trailing underscore	
E051	Core	Basic query specification	
E051-01	Core	SELECT DISTINCT	
E051-02	Core	GROUP BY clause	
E051-04	Core	GROUP BY can contain columns not in <select list>	
E051-05	Core	Select list items can be renamed	
E051-06	Core	HAVING clause	
E051-07	Core	Qualified * in select list	
E051-08	Core	Correlation names in the FROM clause	
E051-09	Core	Rename columns in the FROM clause	
E061	Core	Basic predicates and search conditions	
E061-01	Core	Comparison predicate	
E061-02	Core	BETWEEN predicate	
E061-03	Core	IN predicate with list of values	
E061-04	Core	LIKE predicate	
E061-05	Core	LIKE predicate ESCAPE clause	
E061-06	Core	NULL predicate	
E061-07	Core	Quantified comparison predicate	
E061-08	Core	EXISTS predicate	
E061-09	Core	Subqueries in comparison predicate	
E061-11	Core	Subqueries in IN predicate	
E061-12	Core	Subqueries in quantified comparison predicate	
E061-13	Core	Correlated subqueries	
E061-14	Core	Search condition	

Identifier	Package	Description	Comment
E071	Core	Basic query expressions	
E071-01	Core	UNION DISTINCT table operator	
E071-02	Core	UNION ALL table operator	
E071-03	Core	EXCEPT DISTINCT table operator	
E071-05	Core	Columns combined via table operators need not have exactly the same data type	
E071-06	Core	Table operators in subqueries	
E081	Core	Basic Privileges	
E081-01	Core	SELECT privilege	
E081-02	Core	DELETE privilege	
E081-03	Core	INSERT privilege at the table level	
E081-04	Core	UPDATE privilege at the table level	
E081-05	Core	UPDATE privilege at the column level	
E081-06	Core	REFERENCES privilege at the table level	
E081-07	Core	REFERENCES privilege at the column level	
E081-08	Core	WITH GRANT OPTION	
E081-09	Core	USAGE privilege	
E081-10	Core	EXECUTE privilege	
E091	Core	Set functions	
E091-01	Core	AVG	
E091-02	Core	COUNT	
E091-03	Core	MAX	
E091-04	Core	MIN	
E091-05	Core	SUM	
E091-06	Core	ALL quantifier	
E091-07	Core	DISTINCT quantifier	
E101	Core	Basic data manipulation	
E101-01	Core	INSERT statement	
E101-03	Core	Searched UPDATE statement	
E101-04	Core	Searched DELETE statement	

Identifier	Package	Description	Comment
E111	Core	Single row SELECT statement	
E121	Core	Basic cursor support	
E121-01	Core	DECLARE CURSOR	
E121-02	Core	ORDER BY columns need not be in select list	
E121-03	Core	Value expressions in ORDER BY clause	
E121-04	Core	OPEN statement	
E121-06	Core	Positioned UPDATE statement	
E121-07	Core	Positioned DELETE statement	
E121-08	Core	CLOSE statement	
E121-10	Core	FETCH statement implicit NEXT	
E121-17	Core	WITH HOLD cursors	
E131	Core	Null value support (nulls in lieu of values)	
E141	Core	Basic integrity constraints	
E141-01	Core	NOT NULL constraints	
E141-02	Core	UNIQUE constraints of NOT NULL columns	
E141-03	Core	PRIMARY KEY constraints	
E141-04	Core	Basic FOREIGN KEY constraint with the NO ACTION default for both referential delete action and referential update action	
E141-06	Core	CHECK constraints	
E141-07	Core	Column defaults	
E141-08	Core	NOT NULL inferred on PRIMARY KEY	
E141-10	Core	Names in a foreign key can be specified in any order	
E151	Core	Transaction support	
E151-01	Core	COMMIT statement	
E151-02	Core	ROLLBACK statement	
E152	Core	Basic SET TRANSACTION statement	
E152-01	Core	SET TRANSACTION statement: ISOLATION	

Identifier	Package	Description	Comment
		LEVEL SERIALIZABLE clause	
E152-02	Core	SET TRANSACTION statement: READ ONLY and READ WRITE clauses	
E153	Core	Updatable queries with subqueries	
E161	Core	SQL comments using leading double minus	
E171	Core	SQLSTATE support	
F021	Core	Basic information schema	
F021-01	Core	COLUMNS view	
F021-02	Core	TABLES view	
F021-03	Core	VIEWS view	
F021-04	Core	TABLE_CONSTRAINTS view	
F021-05	Core	REFERENTIAL_CONSTRAINTS view	
F021-06	Core	CHECK_CONSTRAINTS view	
F031	Core	Basic schema manipulation	
F031-01	Core	CREATE TABLE statement to create persistent base tables	
F031-02	Core	CREATE VIEW statement	
F031-03	Core	GRANT statement	
F031-04	Core	ALTER TABLE statement: ADD COLUMN clause	
F031-13	Core	DROP TABLE statement: RESTRICT clause	
F031-16	Core	DROP VIEW statement: RESTRICT clause	
F031-19	Core	REVOKE statement: RESTRICT clause	
F032		CASCADE drop behavior	
F033		ALTER TABLE statement: DROP COLUMN clause	

Identifier	Package	Description	Comment
F034		Extended REVOKE statement	
F034-01		REVOKE statement performed by other than the owner of a schema object	
F034-02		REVOKE statement: GRANT OPTION FOR clause	
F034-03		REVOKE statement to revoke a privilege that the grantee has WITH GRANT OPTION	
F041	Core	Basic joined table	
F041-01	Core	Inner join (but not necessarily the INNER keyword)	
F041-02	Core	INNER keyword	
F041-03	Core	LEFT OUTER JOIN	
F041-04	Core	RIGHT OUTER JOIN	
F041-05	Core	Outer joins can be nested	
F041-07	Core	The inner table in a left or right outer join can also be used in an inner join	
F041-08	Core	All comparison operators are supported (rather than just =)	
F051	Core	Basic date and time	
F051-01	Core	DATE data type (including support of DATE literal)	
F051-02	Core	TIME data type (including support of TIME literal) with fractional seconds precision of at least 0	
F051-03	Core	TIMESTAMP data type (including support of TIMESTAMP literal) with fractional seconds precision of at least 0 and 6	
F051-04	Core	Comparison predicate on DATE, TIME, and TIMESTAMP data types	

Identifier	Package	Description	Comment
F051-05	Core	Explicit CAST between datetime types and character string types	
F051-06	Core	CURRENT_DATE	
F051-07	Core	LOCALTIME	
F051-08	Core	LOCALTIMESTAMP	
F052	Enhanced datetime facilities	Intervals and datetime arithmetic	
F053		OVERLAPS predicate	
F081	Core	UNION and EXCEPT in views	
F111		Isolation levels other than SERIALIZABLE	
F111-01		READ UNCOMMITTED isolation level	
F111-02		READ COMMITTED isolation level	
F111-03		REPEATABLE READ isolation level	
F131	Core	Grouped operations	
F131-01	Core	WHERE, GROUP BY, and HAVING clauses supported in queries with grouped views	
F131-02	Core	Multiple tables supported in queries with grouped views	
F131-03	Core	Set functions supported in queries with grouped views	
F131-04	Core	Subqueries with GROUP BY and HAVING clauses and grouped views	
F131-05	Core	Single row SELECT with GROUP BY and HAVING clauses and grouped views	
F171		Multiple schemas per user	
F191	Enhanced integrity management	Referential delete actions	
F200		TRUNCATE TABLE statement	
F201	Core	CAST function	
F202		TRUNCATE TABLE: identity column restart option	

Identifier	Package	Description	Comment
F221	Core	Explicit defaults	
F222		INSERT statement: DEFAULT VALUES clause	
F231		Privilege tables	
F231-01		TABLE_PRIVILEGES view	
F231-02		COLUMN- PRIVILEGES view	
F231-03		USAGE_PRIVILEGES view	
F251		Domain support	
F261	Core	CASE expression	
F261-01	Core	Simple CASE	
F261-02	Core	Searched CASE	
F261-03	Core	NULLIF	
F261-04	Core	COALESCE	
F262		Extended CASE expres- sion	
F271		Compound character lit- erals	
F281		LIKE enhancements	
F302		INTERSECT table op- erator	
F302-01		INTERSECT DISTINCT table opera- tor	
F302-02		INTERSECT ALL table operator	
F304		EXCEPT ALL table op- erator	
F311-01	Core	CREATE SCHEMA	
F311-02	Core	CREATE TABLE for persistent base tables	
F311-03	Core	CREATE VIEW	
F311-04	Core	CREATE VIEW: WITH CHECK OP- TION	
F311-05	Core	GRANT statement	
F321		User authorization	
F361		Subprogram support	
F381		Extended schema ma- nipulation	
F381-01		ALTER TABLE state- ment: ALTER COL- UMN clause	

Identifier	Package	Description	Comment
F381-02		ALTER TABLE statement: ADD CONSTRAINT clause	
F381-03		ALTER TABLE statement: DROP CONSTRAINT clause	
F382		Alter column data type	
F383		Set column not null clause	
F384		Drop identity property clause	
F386		Set identity column generation clause	
F391		Long identifiers	
F392		Unicode escapes in identifiers	
F393		Unicode escapes in literals	
F401		Extended joined table	
F401-01		NATURAL JOIN	
F401-02		FULL OUTER JOIN	
F401-04		CROSS JOIN	
F402		Named column joins for LOBs, arrays, and multisets	
F411	Enhanced datetime facilities	Time zone specification	differences regarding literal interpretation
F421		National character	
F431		Read-only scrollable cursors	
F431-01		FETCH with explicit NEXT	
F431-02		FETCH FIRST	
F431-03		FETCH LAST	
F431-04		FETCH PRIOR	
F431-05		FETCH ABSOLUTE	
F431-06		FETCH RELATIVE	
F441		Extended set function support	
F442		Mixed column references in set functions	
F471	Core	Scalar subquery values	
F481	Core	Expanded NULL predicate	
F491	Enhanced integrity management	Constraint management	

Identifier	Package	Description	Comment
F501	Core	Features and conformance views	
F501-01	Core	SQL_FEATURES view	
F501-02	Core	SQL_SIZING view	
F501-03	Core	SQL_LANGUAGES view	
F502		Enhanced documentation tables	
F502-01		SQL_SIZING_PROFILES view	
F502-02		SQL_IMPLEMENTATION_INFO view	
F502-03		SQL_PACKAGES view	
F531		Temporary tables	
F555	Enhanced datetime facilities	Enhanced seconds precision	
F561		Full value expressions	
F571		Truth value tests	
F591		Derived tables	
F611		Indicator data types	
F641		Row and table constructors	
F651		Catalog name qualifiers	
F661		Simple tables	
F672		Retrospective check constraints	
F690		Collation support	but no character set support
F692		Extended collation support	
F701	Enhanced integrity management	Referential update actions	
F711		ALTER domain	
F731		INSERT column privileges	
F751		View CHECK enhancements	
F761		Session management	
F762		CURRENT_CATALOG	
F763		CURRENT_SCHEMA	
F771		Connection management	

Identifier	Package	Description	Comment
F781		Self-referencing operations	
F791		Insensitive cursors	
F801		Full set function	
F850		Top-level <order by clause> in <query expression>	
F851		<order by clause> in subqueries	
F852		Top-level <order by clause> in views	
F855		Nested <order by clause> in <query expression>	
F856		Nested <fetch first clause> in <query expression>	
F857		Top-level <fetch first clause> in <query expression>	
F858		<fetch first clause> in subqueries	
F859		Top-level <fetch first clause> in views	
F860		<fetch first row count> in <fetch first clause>	
F861		Top-level <result offset clause> in <query expression>	
F862		<result offset clause> in subqueries	
F863		Nested <result offset clause> in <query expression>	
F864		Top-level <result offset clause> in views	
F865		<offset row count> in <result offset clause>	
S071	Enhanced object support	SQL paths in function and type name resolution	
S092		Arrays of user-defined types	
S095		Array constructors by query	
S096		Optional array bounds	
S098		ARRAY_AGG	

Identifier	Package	Description	Comment
S111	Enhanced object support	ONLY in query expressions	
S201		SQL-invoked routines on arrays	
S201-01		Array parameters	
S201-02		Array as result type of functions	
S211	Enhanced object support	User-defined cast functions	
S301		Enhanced UNNEST	
T031		BOOLEAN data type	
T071		BIGINT data type	
T121		WITH (excluding RECURSIVE) in query expression	
T122		WITH (excluding RECURSIVE) in subquery	
T131		Recursive query	
T132		Recursive query in subquery	
T141		SIMILAR predicate	
T151		DISTINCT predicate	
T152		DISTINCT predicate with negation	
T171		LIKE clause in table definition	
T172		AS subquery clause in table definition	
T173		Extended LIKE clause in table definition	
T174		Identity columns	
T177		Sequence generator support: simple restart option	
T178		Identity columns: simple restart option	
T191	Enhanced integrity management	Referential action RESTRICT	
T201	Enhanced integrity management	Comparable data types for referential constraints	
T211-01	Active database, Enhanced integrity management	Triggers activated on UPDATE, INSERT, or DELETE of one base table	

Identifier	Package	Description	Comment
T211-02	Active database, Enhanced integrity management	BEFORE triggers	
T211-03	Active database, Enhanced integrity management	AFTER triggers	
T211-04	Active database, Enhanced integrity management	FOR EACH ROW triggers	
T211-05	Active database, Enhanced integrity management	Ability to specify a search condition that must be true before the trigger is invoked	
T211-07	Active database, Enhanced integrity management	TRIGGER privilege	
T212	Enhanced integrity management	Enhanced trigger capability	
T213		INSTEAD OF triggers	
T231		Sensitive cursors	
T241		START TRANSACTION statement	
T261		Chained transactions	
T271		Savepoints	
T281		SELECT privilege with column granularity	
T285		Enhanced derived column names	
T312		OVERLAY function	
T321-01	Core	User-defined functions with no overloading	
T321-02	Core	User-defined stored procedures with no overloading	
T321-03	Core	Function invocation	
T321-04	Core	CALL statement	
T321-06	Core	ROUTINES view	
T321-07	Core	PARAMETERS view	
T323		Explicit security for external routines	
T325		Qualified SQL parameter references	
T331		Basic roles	
T341		Overloading of SQL-invoked functions and procedures	

Identifier	Package	Description	Comment
T351		Bracketed SQL comments (/*...*/ comments)	
T431	OLAP	Extended grouping capabilities	
T432		Nested and concatenated GROUPING SETS	
T433		Multiargument GROUPING function	
T441		ABS and MOD functions	
T461		Symmetric BETWEEN predicate	
T491		LATERAL derived table	
T501		Enhanced EXISTS predicate	
T521		Named arguments in CALL statement	
T523		Default values for INOUT parameters of SQL-invoked procedures	
T524		Named arguments in routine invocations other than a CALL statement	
T525		Default values for parameters of SQL-invoked functions	
T551		Optional key words for default syntax	
T581		Regular expression substring function	
T591		UNIQUE constraints of possibly null columns	
T611	OLAP	Elementary OLAP operations	
T613		Sampling	
T614		NTILE function	
T615		LEAD and LAG functions	
T617		FIRST_VALUE and LAST_VALUE function	
T620		WINDOW clause: GROUPS option	

Identifier	Package	Description	Comment
T621		Enhanced numeric functions	
T622		Trigonometric functions	
T623		General logarithm functions	
T624		Common logarithm functions	
T631	Core	IN predicate with one list element	
T651		SQL-schema statements in SQL routines	
T655		Cyclically dependent routines	
T831		SQL/JSON path language: strict mode	
T833		SQL/JSON path language: multiple subscripts	
T834		SQL/JSON path language: wildcard member accessor	
T835		SQL/JSON path language: filter expressions	
T836		SQL/JSON path language: starts with predicate	
T837		SQL/JSON path language: regex_like predicate	
X010		XML type	
X011		Arrays of XML type	
X014		Attributes of XML type	
X016		Persistent XML values	
X020		XMLConcat	
X031		XMLElement	
X032		XMLForest	
X034		XMLAgg	
X035		XMLAgg: ORDER BY option	
X036		XMLComment	
X037		XMLPI	
X040		Basic table mapping	
X041		Basic table mapping: nulls absent	

Identifier	Package	Description	Comment
X042		Basic table mapping: null as nil	
X043		Basic table mapping: table as forest	
X044		Basic table mapping: table as element	
X045		Basic table mapping: with target namespace	
X046		Basic table mapping: data mapping	
X047		Basic table mapping: metadata mapping	
X048		Basic table mapping: base64 encoding of binary strings	
X049		Basic table mapping: hex encoding of binary strings	
X050		Advanced table mapping	
X051		Advanced table mapping: nulls absent	
X052		Advanced table mapping: null as nil	
X053		Advanced table mapping: table as forest	
X054		Advanced table mapping: table as element	
X055		Advanced table mapping: with target namespace	
X056		Advanced table mapping: data mapping	
X057		Advanced table mapping: metadata mapping	
X058		Advanced table mapping: base64 encoding of binary strings	
X059		Advanced table mapping: hex encoding of binary strings	
X060		XMLParse: character string input and CONTENT option	
X061		XMLParse: character string input and DOCUMENT option	

Identifier	Package	Description	Comment
X070		XMLSerialize: character string serialization and CONTENT option	
X071		XMLSerialize: character string serialization and DOCUMENT option	
X072		XMLSerialize: character string serialization	
X090		XML document predicate	
X120		XML parameters in SQL routines	
X121		XML parameters in external routines	
X221		XML passing mechanism BY VALUE	
X301		XMLTable: derived column list option	
X302		XMLTable: ordinality column option	
X303		XMLTable: column default option	
X304		XMLTable: passing a context item	must be XML DOCUMENT
X400		Name and identifier mapping	
X410		Alter column data type: XML type	

D.2. Unsupported Features

The following features defined in SQL:2016 are not implemented in this release of PostgreSQL. In a few cases, equivalent functionality is available.

Identifier	Package	Description	Comment
B011		Embedded Ada	
B013		Embedded COBOL	
B014		Embedded Fortran	
B015		Embedded MUMPS	
B016		Embedded Pascal	
B017		Embedded PL/I	
B031		Basic dynamic SQL	
B032		Extended dynamic SQL	
B032-01		<describe input statement>	

Identifier	Package	Description	Comment
B033		Untyped SQL-invoked function arguments	
B034		Dynamic specification of cursor attributes	
B035		Non-extended descriptor names	
B041		Extensions to embedded SQL exception declarations	
B051		Enhanced execution rights	
B111		Module language Ada	
B112		Module language C	
B113		Module language COBOL	
B114		Module language Fortran	
B115		Module language MUMPS	
B116		Module language Pascal	
B117		Module language PL/I	
B121		Routine language Ada	
B122		Routine language C	
B123		Routine language COBOL	
B124		Routine language Fortran	
B125		Routine language MUMPS	
B126		Routine language Pascal	
B127		Routine language PL/I	
B128		Routine language SQL	
B200		Polymorphic table functions	
B201		More than one PTF generic table parameter	
B202		PTF Copartitioning	
B203		More than one copartition specification	
B204		PRUNE WHEN EMPTY	
B205		Pass-through columns	
B206		PTF descriptor parameters	

Identifier	Package	Description	Comment
B207		Cross products of partitionings	
B208		PTF component procedure interface	
B209		PTF extended names	
B211		Module language Ada: VARCHAR and NUMERIC support	
B221		Routine language Ada: VARCHAR and NUMERIC support	
E182	Core	Module language	
F054		TIMESTAMP in DATE type precedence list	
F121		Basic diagnostics management	
F121-01		GET DIAGNOSTICS statement	
F121-02		SET TRANSACTION statement: DIAGNOSTICS SIZE clause	
F122		Enhanced diagnostics management	
F123		All diagnostics	
F181	Core	Multiple module support	
F263		Comma-separated predicates in simple CASE expression	
F291		UNIQUE predicate	
F301		CORRESPONDING in query expressions	
F311	Core	Schema definition statement	
F312		MERGE statement	consider INSERT ... ON CONFLICT DO UPDATE
F313		Enhanced MERGE statement	
F314		MERGE statement with DELETE branch	
F341		Usage tables	no ROUTINE_*_USAGE tables
F385		Drop column generation expression clause	
F394		Optional normal form specification	

Identifier	Package	Description	Comment
F403		Partitioned joined tables	
F404		Range variable for common column names	
F451		Character set definition	
F461		Named character sets	
F492		Optional table constraint enforcement	
F521	Enhanced integrity management	Assertions	
F671	Enhanced integrity management	Subqueries in CHECK	intentionally omitted
F673		Reads SQL-data routine invocations in CHECK constraints	
F693		SQL-session and client module collations	
F695		Translation support	
F696		Additional translation documentation	
F721		Deferrable constraints	foreign and unique keys only
F741		Referential MATCH types	no partial match yet
F812	Core	Basic flagging	
F813		Extended flagging	
F821		Local table references	
F831		Full cursor update	
F831-01		Updatable scrollable cursors	
F831-02		Updatable ordered cursors	
F841		LIKE_REGEX predicate	
F842		OCCURRENCES_REGEX function	
F843		POSITION_REGEX function	
F844		SUBSTRING_REGEX function	
F845		TRANSLATE_REGEX function	
F846		Octet support in regular expression operators	
F847		Nonconstant regular expressions	

Identifier	Package	Description	Comment
F866		FETCH FIRST clause: PERCENT option	
F867		FETCH FIRST clause: WITH TIES option	
R010		Row pattern recognition: FROM clause	
R020		Row pattern recognition: WINDOW clause	
R030		Row pattern recognition: full aggregate support	
S011	Core	Distinct data types	
S011-01	Core	USER_DEFINED_TYPES view	
S023	Basic object support	Basic structured types	
S024	Enhanced object support	Enhanced structured types	
S025		Final structured types	
S026		Self-referencing structured types	
S027		Create method by specific method name	
S028		Permutable UDT options list	
S041	Basic object support	Basic reference types	
S043	Enhanced object support	Enhanced reference types	
S051	Basic object support	Create table of type	partially supported
S081	Enhanced object support	Subtables	
S091		Basic array support	partially supported
S091-01		Arrays of built-in data types	
S091-02		Arrays of distinct types	
S091-03		Array expressions	
S094		Arrays of reference types	
S097		Array element assignment	
S151	Basic object support	Type predicate	
S161	Enhanced object support	Subtype treatment	
S162		Subtype treatment for references	
S202		SQL-invoked routines on multisets	

Identifier	Package	Description	Comment
S231	Enhanced object support	Structured type locators	
S232		Array locators	
S233		Multiset locators	
S241		Transform functions	
S242		Alter transform statement	
S251		User-defined orderings	
S261		Specific type method	
S271		Basic multiset support	
S272		Multisets of user-defined types	
S274		Multisets of reference types	
S275		Advanced multiset support	
S281		Nested collection types	
S291		Unique constraint on entire row	
S401		Distinct types based on array types	
S402		Distinct types based on distinct types	
S403		AR-RAY_MAX_CARDINALITY	
S404		TRIM_ARRAY	
T011		Timestamp in Information Schema	
T021		BINARY and VARBINARY data types	
T022		Advanced support for BINARY and VARBINARY data types	
T023		Compound binary literal	
T024		Spaces in binary literals	
T041	Basic object support	Basic LOB data type support	
T041-01	Basic object support	BLOB data type	
T041-02	Basic object support	CLOB data type	
T041-03	Basic object support	POSITION, LENGTH, LOWER, TRIM, UPPER, and SUBSTRING functions for LOB data types	

Identifier	Package	Description	Comment
T041-04	Basic object support	Concatenation of LOB data types	
T041-05	Basic object support	LOB locator: non-holdable	
T042		Extended LOB data type support	
T043		Multiplier T	
T044		Multiplier P	
T051		Row types	
T053		Explicit aliases for all-fields reference	
T061		UCS support	
T076		DECFLOAT data type	
T101		Enhanced nullability determination	
T111		Updatable joins, unions, and columns	
T175		Generated columns	
T176		Sequence generator support	
T180		System-versioned tables	
T181		Application-time period tables	
T211	Active database, Enhanced integrity management	Basic trigger capability	
T211-06	Active database, Enhanced integrity management	Support for run-time rules for the interaction of triggers and constraints	
T211-08	Active database, Enhanced integrity management	Multiple triggers for the same event are executed in the order in which they were created in the catalog	intentionally omitted
T251		SET TRANSACTION statement: LOCAL option	
T272		Enhanced savepoint management	
T301		Functional dependencies	partially supported
T321	Core	Basic SQL-invoked routines	
T321-05	Core	RETURN statement	

Identifier	Package	Description	Comment
T322	PSM	Declared data type attributes	
T324		Explicit security for SQL routines	
T326		Table functions	
T332		Extended roles	mostly supported
T434		GROUP BY DISTINCT	
T471		Result sets return value	
T472		DESCRIBE CURSOR	
T495		Combined data change and retrieval	different syntax
T502		Period predicates	
T511		Transaction counts	
T522		Default values for IN parameters of SQL-invoked procedures	supported except DEFALT key word in invocation
T561		Holdable locators	
T571		Array-returning external SQL-invoked functions	
T572		Multiset-returning external SQL-invoked functions	
T601		Local cursor references	
T612		Advanced OLAP operations	some forms supported
T616		Null treatment option for LEAD and LAG functions	
T618		NTH_VALUE function	function exists, but some options missing
T619		Nested window functions	
T625		LISTAGG	
T641		Multiple column assignment	only some syntax variants supported
T652		SQL-dynamic statements in SQL routines	
T653		SQL-schema statements in external routines	
T654		SQL-dynamic statements in external routines	
T811		Basic SQL/JSON constructor functions	

Identifier	Package	Description	Comment
T812		SQL/JSON: JSON_OBJECTAGG	
T813		SQL/JSON: JSON_ARRAYAGG with ORDER BY	
T814		Colon in JSON_OBJECT or JSON_OBJECTAGG	
T821		Basic SQL/JSON query operators	
T822		SQL/JSON: IS JSON WITH UNIQUE KEYS predicate	
T823		SQL/JSON: PASSING clause	
T824		JSON_TABLE: specific PLAN clause	
T825		SQL/JSON: ON EMPTY and ON ERROR clauses	
T826		General value expression in ON ERROR or ON EMPTY clauses	
T827		JSON_TABLE: sibling NESTED COLUMNS clauses	
T828		JSON_QUERY	
T829		JSON_QUERY: array wrapper options	
T830		Enforcing unique keys in SQL/JSON constructor functions	
T832		SQL/JSON path language: item method	datetime() not yet implemented
T838		JSON_TABLE: PLAN DEFAULT clause	
T839		Formatted cast of datetimes to/from character strings	
M001		Datalinks	
M002		Datalinks via SQL/CLI	
M003		Datalinks via Embedded SQL	
M004		Foreign data support	partially supported
M005		Foreign schema support	
M006		GetSQLString routine	
M007		TransmitRequest	

Identifier	Package	Description	Comment
M009		GetOpts and GetStatistics routines	
M010		Foreign data wrapper support	different API
M011		Datalinks via Ada	
M012		Datalinks via C	
M013		Datalinks via COBOL	
M014		Datalinks via Fortran	
M015		Datalinks via M	
M016		Datalinks via Pascal	
M017		Datalinks via PL/I	
M018		Foreign data wrapper interface routines in Ada	
M019		Foreign data wrapper interface routines in C	different API
M020		Foreign data wrapper interface routines in COBOL	
M021		Foreign data wrapper interface routines in Fortran	
M022		Foreign data wrapper interface routines in MUMPS	
M023		Foreign data wrapper interface routines in Pascal	
M024		Foreign data wrapper interface routines in PL/I	
M030		SQL-server foreign data support	
M031		Foreign data wrapper general routines	
X012		Multisets of XML type	
X013		Distinct types of XML type	
X015		Fields of XML type	
X025		XMLCast	
X030		XMLDocument	
X038		XMLText	
X065		XMLParse: BLOB input and CONTENT option	

Identifier	Package	Description	Comment
X066		XMLParse: BLOB input and DOCUMENT option	
X068		XMLSerialize: BOM	
X069		XMLSerialize: INDENT	
X073		XMLSerialize: BLOB serialization and CONTENT option	
X074		XMLSerialize: BLOB serialization and DOCUMENT option	
X075		XMLSerialize: BLOB serialization	
X076		XMLSerialize: VERSION	
X077		XMLSerialize: explicit ENCODING option	
X078		XMLSerialize: explicit XML declaration	
X080		Namespaces in XML publishing	
X081		Query-level XML namespace declarations	
X082		XML namespace declarations in DML	
X083		XML namespace declarations in DDL	
X084		XML namespace declarations in compound statements	
X085		Predefined namespace prefixes	
X086		XML namespace declarations in XMLTable	
X091		XML content predicate	
X096		XMlexists	XPath 1.0 only
X100		Host language support for XML: CONTENT option	
X101		Host language support for XML: DOCUMENT option	
X110		Host language support for XML: VARCHAR mapping	

Identifier	Package	Description	Comment
X111		Host language support for XML: CLOB mapping	
X112		Host language support for XML: BLOB mapping	
X113		Host language support for XML: STRIP WHITESPACE option	
X114		Host language support for XML: PRESERVE WHITESPACE option	
X131		Query-level XMLBINARY clause	
X132		XMLBINARY clause in DML	
X133		XMLBINARY clause in DDL	
X134		XMLBINARY clause in compound statements	
X135		XMLBINARY clause in subqueries	
X141		IS VALID predicate: data-driven case	
X142		IS VALID predicate: ACCORDING TO clause	
X143		IS VALID predicate: ELEMENT clause	
X144		IS VALID predicate: schema location	
X145		IS VALID predicate outside check constraints	
X151		IS VALID predicate with DOCUMENT option	
X152		IS VALID predicate with CONTENT option	
X153		IS VALID predicate with SEQUENCE option	
X155		IS VALID predicate: NAMESPACE without ELEMENT clause	
X157		IS VALID predicate: NONAMESPACE with ELEMENT clause	

Identifier	Package	Description	Comment
X160		Basic Information Schema for registered XML Schemas	
X161		Advanced Information Schema for registered XML Schemas	
X170		XML null handling options	
X171		NIL ON NO CONTENT option	
X181		XML(DOCUMENT(UNTYPED)) type	
X182		XML(DOCUMENT(ANY)) type	
X190		XML(SEQUENCE) type	
X191		XML(DOCUMENT(XMLSCHEMA)) type	
X192		XML(CONTENT(XMLSCHEMA)) type	
X200		XMLQuery	
X201		XMLQuery: RETURNING CONTENT	
X202		XMLQuery: RETURNING SEQUENCE	
X203		XMLQuery: passing a context item	
X204		XMLQuery: initializing an XQuery variable	
X205		XMLQuery: EMPTY ON EMPTY option	
X206		XMLQuery: NULL ON EMPTY option	
X211		XML 1.1 support	
X222		XML passing mechanism BY REF	parser accepts BY REF but ignores it; passing is always BY VALUE
X231		XML(CONTENT(UNTYPED)) type	
X232		XML(CONTENT(ANY)) type	
X241		RETURNING CONTENT in XML publishing	

Identifier	Package	Description	Comment
X242		RETURNING SEQUENCE in XML publishing	
X251		Persistent XML values of XML(DOCUMENT(UNTYPED)) type	
X252		Persistent XML values of XML(DOCUMENT(ANY)) type	
X253		Persistent XML values of XML(CONTENT(UNTYPED)) type	
X254		Persistent XML values of XML(CONTENT(ANY)) type	
X255		Persistent XML values of XML(SEQUENCE) type	
X256		Persistent XML values of XML(DOCUMENT(XMLSCHEMA)) type	
X257		Persistent XML values of XML(CONTENT(XMLSCHEMA)) type	
X260		XML type: ELEMENT clause	
X261		XML type: NAMESPACE without ELEMENT clause	
X263		XML type: NO NAMESPACE with ELEMENT clause	
X264		XML type: schema location	
X271		XMLValidate: data-driven case	
X272		XMLValidate: ACCORDING TO clause	
X273		XMLValidate: ELEMENT clause	
X274		XMLValidate: schema location	
X281		XMLValidate with DOCUMENT option	
X282		XMLValidate with CONTENT option	

Identifier	Package	Description	Comment
X283		XMLValidate with SEQUENCE option	
X284		XMLValidate: NAMESPACE without ELEMENT clause	
X286		XMLValidate: NAMESPACE with ELEMENT clause	NO
X300		XMLTable	XPath 1.0 only
X305		XMLTable: initializing an XQuery variable	

D.3. XML Limits and Conformance to SQL/XML

Significant revisions to the XML-related specifications in ISO/IEC 9075-14 (SQL/XML) were introduced with SQL:2006. PostgreSQL's implementation of the XML data type and related functions largely follows the earlier 2003 edition, with some borrowing from later editions. In particular:

- Where the current standard provides a family of XML data types to hold “document” or “content” in untyped or XML Schema-typed variants, and a type `XML (SEQUENCE)` to hold arbitrary pieces of XML content, PostgreSQL provides the single `xml` type, which can hold “document” or “content”. There is no equivalent of the standard's “sequence” type.
- PostgreSQL provides two functions introduced in SQL:2006, but in variants that use the XPath 1.0 language, rather than XML Query as specified for them in the standard.

This section presents some of the resulting differences you may encounter.

D.3.1. Queries Are Restricted to XPath 1.0

The PostgreSQL-specific functions `xpath()` and `xpath_exists()` query XML documents using the XPath language. PostgreSQL also provides XPath-only variants of the standard functions `XML EXISTS` and `XMLTABLE`, which officially use the XQuery language. For all of these functions, PostgreSQL relies on the `libxml2` library, which provides only XPath 1.0.

There is a strong connection between the XQuery language and XPath versions 2.0 and later: any expression that is syntactically valid and executes successfully in both produces the same result (with a minor exception for expressions containing numeric character references or predefined entity references, which XQuery replaces with the corresponding character while XPath leaves them alone). But there is no such connection between these languages and XPath 1.0; it was an earlier language and differs in many respects.

There are two categories of limitation to keep in mind: the restriction from XQuery to XPath for the functions specified in the SQL standard, and the restriction of XPath to version 1.0 for both the standard and the PostgreSQL-specific functions.

D.3.1.1. Restriction of XQuery to XPath

Features of XQuery beyond those of XPath include:

- XQuery expressions can construct and return new XML nodes, in addition to all possible XPath values. XPath can create and return values of the atomic types (numbers, strings, and so on) but can only return XML nodes that were already present in documents supplied as input to the expression.

- XQuery has control constructs for iteration, sorting, and grouping.
- XQuery allows declaration and use of local functions.

Recent XPath versions begin to offer capabilities overlapping with these (such as functional-style `for-each` and `sort`, anonymous functions, and `parse-xml` to create a node from a string), but such features were not available before XPath 3.0.

D.3.1.2. Restriction of XPath to 1.0

For developers familiar with XQuery and XPath 2.0 or later, XPath 1.0 presents a number of differences to contend with:

- The fundamental type of an XQuery/XPath expression, the `sequence`, which can contain XML nodes, atomic values, or both, does not exist in XPath 1.0. A 1.0 expression can only produce a node-set (containing zero or more XML nodes), or a single atomic value.
- Unlike an XQuery/XPath sequence, which can contain any desired items in any desired order, an XPath 1.0 node-set has no guaranteed order and, like any set, does not allow multiple appearances of the same item.

Note

The libxml2 library does seem to always return node-sets to PostgreSQL with their members in the same relative order they had in the input document. Its documentation does not commit to this behavior, and an XPath 1.0 expression cannot control it.

- While XQuery/XPath provides all of the types defined in XML Schema and many operators and functions over those types, XPath 1.0 has only node-sets and the three atomic types `boolean`, `double`, and `string`.
- XPath 1.0 has no conditional operator. An XQuery/XPath expression such as `if (hat) then hat/@size else "no hat"` has no XPath 1.0 equivalent.
- XPath 1.0 has no ordering comparison operator for strings. Both `"cat" < "dog"` and `"cat" > "dog"` are false, because each is a numeric comparison of two NaNs. In contrast, `=` and `!=` do compare the strings as strings.
- XPath 1.0 blurs the distinction between *value comparisons* and *general comparisons* as XQuery/XPath define them. Both `sale/@hatsize = 7` and `sale/@customer = "alice"` are existentially quantified comparisons, true if there is any `sale` with the given value for the attribute, but `sale/@taxable = false()` is a value comparison to the *effective boolean value* of a whole node-set. It is true only if no `sale` has a `taxable` attribute at all.
- In the XQuery/XPath data model, a *document node* can have either document form (i.e., exactly one top-level element, with only comments and processing instructions outside of it) or content form (with those constraints relaxed). Its equivalent in XPath 1.0, the *root node*, can only be in document form. This is part of the reason an `xml` value passed as the context item to any PostgreSQL XPath-based function must be in document form.

The differences highlighted here are not all of them. In XQuery and the 2.0 and later versions of XPath, there is an XPath 1.0 compatibility mode, and the W3C lists of function library changes¹ and language changes² applied in that mode offer a more complete (but still not exhaustive) account of the differences. The compatibility mode cannot make the later languages exactly equivalent to XPath 1.0.

¹ <https://www.w3.org/TR/2010/REC-xpath-functions-20101214/#xpath1-compatibility>

² <https://www.w3.org/TR/xpath20/#id-backwards-compatibility>

D.3.1.3. Mappings between SQL and XML Data Types and Values

In SQL:2006 and later, both directions of conversion between standard SQL data types and the XML Schema types are specified precisely. However, the rules are expressed using the types and semantics of XQuery/XPath, and have no direct application to the different data model of XPath 1.0.

When PostgreSQL maps SQL data values to XML (as in `xmlElement`), or XML to SQL (as in the output columns of `xmlTable`), except for a few cases treated specially, PostgreSQL simply assumes that the XML data type's XPath 1.0 string form will be valid as the text-input form of the SQL datatype, and conversely. This rule has the virtue of simplicity while producing, for many data types, results similar to the mappings specified in the standard.

Where interoperability with other systems is a concern, for some data types, it may be necessary to use data type formatting functions (such as those in Section 9.8) explicitly to produce the standard mappings.

D.3.2. Incidental limits of the implementation

This section concerns limits that are not inherent in the libxml2 library, but apply to the current implementation in PostgreSQL.

D.3.2.1. Only BY VALUE Passing Mechanism Is Supported

The SQL standard defines two *passing mechanisms* that apply when passing an XML argument from SQL to an XML function or receiving a result: `BY REF`, in which a particular XML value retains its node identity, and `BY VALUE`, in which the content of the XML is passed but node identity is not preserved. A mechanism can be specified before a list of parameters, as the default mechanism for all of them, or after any parameter, to override the default.

To illustrate the difference, if `x` is an XML value, these two queries in an SQL:2006 environment would produce true and false, respectively:

```
SELECT XMLQUERY('$a is $b' PASSING BY REF x AS a, x AS b NULL ON
EMPTY);
SELECT XMLQUERY('$a is $b' PASSING BY VALUE x AS a, x AS b NULL ON
EMPTY);
```

PostgreSQL will accept `BY VALUE` or `BY REF` in an `XML EXISTS` or `XML TABLE` construct, but it ignores them. The `xml` data type holds a character-string serialized representation, so there is no node identity to preserve, and passing is always effectively `BY VALUE`.

D.3.2.2. Cannot Pass Named Parameters to Queries

The XPath-based functions support passing one parameter to serve as the XPath expression's context item, but do not support passing additional values to be available to the expression as named parameters.

D.3.2.3. No XML (SEQUENCE) Type

The PostgreSQL `xml` data type can only hold a value in `DOCUMENT` or `CONTENT` form. An XQuery/XPath expression context item must be a single XML node or atomic value, but XPath 1.0 further restricts it to be only an XML node, and has no node type allowing `CONTENT`. The upshot is that a well-formed `DOCUMENT` is the only form of XML value that PostgreSQL can supply as an XPath context item.

Appendix E. Release Notes

The release notes contain the significant changes in each PostgreSQL release, with major features and migration issues listed at the top. The release notes do not contain changes that affect only a few users or changes that are internal and therefore not user-visible. For example, the optimizer is improved in almost every release, but the improvements are usually observed by users as simply faster queries.

A complete list of changes for each release can be obtained by viewing the Git logs for each release. The `pgsql-committers` email list¹ records all source code changes as well. There is also a web interface² that shows changes to specific files.

The name appearing next to each item represents the major developer for that item. Of course all changes involve community discussion and patch review, so each item is truly a community effort.

E.1. Release 12.1

Release date: 2019-11-14

This release contains a variety of fixes from 12.0. For information about new features in major release 12, see Section E.2.

E.1.1. Migration to Version 12.1

A dump/restore is not required for those running 12.X.

E.1.2. Changes

- Fix crash when `ALTER TABLE` adds a column without a default value along with making other changes that require a table rewrite (Andres Freund)
- Fix lock handling in `REINDEX CONCURRENTLY` (Michael Paquier)

`REINDEX CONCURRENTLY` neglected to take a session-level lock on the new index version, potentially allowing other sessions to manipulate it too soon. Also, a query-cancel or session-termination interrupt arriving at the wrong time could result in failure to release the session-level locks that `REINDEX CONCURRENTLY` does hold.

- Avoid crash due to race condition when reporting the progress of a `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY` command (Álvaro Herrera)
- Avoid creating duplicate dependency entries during `REINDEX CONCURRENTLY` (Michael Paquier)

This bug resulted in bloat in `pg_depend`, but no worse consequences than that.

- Prevent `VACUUM` from trying to freeze an old multixact ID involving a still-running transaction (Nathan Bossart, Jeremy Schneider)

This case would lead to `VACUUM` failing until the old transaction terminates.

- Fix “wrong type of slot” error when trying to `CLUSTER` on an expression index (Andres Freund)
- `SET CONSTRAINTS . . . DEFERRED` failed on partitioned tables, incorrectly complaining about lack of triggers (Álvaro Herrera)

¹ <https://www.postgresql.org/list/pgsql-committers/>

² <https://git.postgresql.org/gitweb/?p=postgresql.git;a=summary>

- Fix failure when creating indexes for a partition, if the parent partitioned table contains any dropped columns (Michael Paquier)

- Fix dropping of indexed columns in partitioned tables (Amit Langote, Michael Paquier)

Previously this might fail with an error message complaining about the dependencies of the indexes. It should automatically drop the indexes, instead.

- Ensure that a partition index can be dropped after a failure to reindex it concurrently (Michael Paquier)

The index's `pg_class.relispartition` flag was left in the wrong state in such a case, causing `DROP INDEX` to fail.

- Fix handling of equivalence class members for partition-wise joins (Amit Langote)

This oversight could lead either to failure to use a feasible partition-wise join plan, or to a “could not find pathkey item to sort” planner failure.

- Ensure that offset expressions in `WINDOW` clauses are processed when a query's expressions are manipulated (Andrew Gierth)

This oversight could result in assorted failures when the offsets are nontrivial expressions. One example is that a function parameter reference in such an expression would fail if the function was inlined.

- Avoid postmaster failure if a parallel query requests a background worker when no postmaster child process array slots remain free (Tom Lane)

- Fix crash triggered by an `EvalPlanQual` recheck on a table with a `BEFORE UPDATE` trigger (Andres Freund)

- Fix “unexpected rekind” error when a query tries to access a `TOAST` table (John Hsu, Michael Paquier, Tom Lane)

The error should say that permission is denied, but this case got broken during code refactoring.

- Provide a relevant error context line when an error occurs while setting GUC parameters during parallel worker startup (Thomas Munro)

- Ensure that `fsync()` is applied only to files that are opened read/write (Andres Freund, Michael Paquier)

Some code paths tried to do this after opening a file read-only, but on some platforms that causes “bad file descriptor” or similar errors.

- Allow encoding conversion to succeed on longer strings than before (Álvaro Herrera, Tom Lane)

Previously, there was a hard limit of 0.25GB on the input string, but now it will work as long as the converted output is not over 1GB.

- Avoid creating unnecessarily-bulky tuple stores for window functions (Andrew Gierth)

In some cases the tuple storage would include all columns of the source table(s), not just the ones that are needed by the query.

- Allow `repalloc()` to give back space when a large chunk is reduced in size (Tom Lane)

- Ensure that temporary WAL and history files are removed at the end of archive recovery (Sawada Masahiko)

- Avoid failure in archive recovery if `recovery_min_apply_delay` is enabled (Fujii Masao)

`recovery_min_apply_delay` is not typically used in this configuration, but it should work.

- Ignore `restore_command`, `recovery_end_command`, and `recovery_min_apply_delay` settings during crash recovery (Fujii Masao)

Now that these settings can be specified in `postgresql.conf`, they could be turned on during crash recovery, but honoring them then is undesirable. Ignore these settings until crash recovery is complete.

- Fix logical replication failure when publisher and subscriber have different ideas about a table's replica identity columns (Jehan-Guillaume de Rorthais, Peter Eisentraut)

Declaring a column as part of the replica identity on the subscriber, when it does not exist at all on the publisher, led to “negative bitmapset member not allowed” errors.

- Avoid unwanted delay during shutdown of a logical replication walsender (Craig Ringer, Álvaro Herrera)
- Fix timeout handling in logical replication walreceiver processes (Julien Rouhaud)

Erroneous logic prevented `wal_receiver_timeout` from working in logical replication deployments.

- Correctly time-stamp replication messages for logical decoding (Jeff Janes)

This oversight resulted, for example, in `pg_stat_subscription.last_msg_send_time` usually reading as NULL.

- Fix race condition during backend exit, when the backend process has previously waited for synchronous replication to occur (Dongming Liu)
- Avoid logging complaints about abandoned connections when using PAM authentication (Tom Lane)

libpq-based clients will typically make two connection attempts when a password is required, since they don't prompt their user for a password until their first connection attempt fails. Therefore the server is coded not to generate useless log spam when a client closes the connection upon being asked for a password. However, the PAM authentication code hadn't gotten that memo, and would generate several messages about a phantom authentication failure.

- Fix misbehavior of `bitshiftright()` (Tom Lane)

The bitstring right shift operator failed to zero out padding space that exists in the last byte of the result when the bitstring length is not a multiple of 8. While invisible to most operations, any nonzero bits there would result in unexpected comparison behavior, since bitstring comparisons don't bother to ignore the extra bits, expecting them to always be zero.

If you have inconsistent data as a result of saving the output of `bitshiftright()` in a table, it's possible to fix it with something like

```
UPDATE mytab SET bitcol = ~(~bitcol) WHERE bitcol != ~(~bitcol);
```

- Fix result of text `position()` function (also known as `strpos()`) for an empty search string (Tom Lane)

Historically, and per the SQL standard, the result should be one in such cases, but 12.0 returned zero.

- Fix detection of edge-case integer overflow in interval multiplication (Yuya Watari)
- Avoid crashes if `ispell` text search dictionaries contain wrong affix data (Arthur Zakirov)

- Avoid memory leak while vacuuming a GiST index (Dilip Kumar)
- On Windows, recognize additional spellings of the “Norwegian (Bokmål)” locale name (Tom Lane)
- Fix libpq to allow trailing whitespace in the string values of integer parameters (Michael Paquier)

Version 12 tightened libpq's validation of integer parameters, but disallowing trailing whitespace seems undesirable.

- In libpq, correctly report `CONNECTION_BAD` connection status after a failure caused by a syntactically invalid `connect_timeout` parameter value (Lars Kanis)
- Avoid compile failure if an ECPG client includes `ecpglib.h` while having `ENABLE_NLS` defined (Tom Lane)

This risk was created by a misplaced declaration: `ecpg_gettext()` should not be visible to client code.

- Fix scheduling of parallel restore of a foreign key constraint on a partitioned table (Álvaro Herrera)
- In `pg_dump`, ensure stable output order for similarly-named triggers and row-level-security policy objects (Benjie Gillam)

Previously, if two triggers on different tables had the same names, they would be sorted in OID-based order, which is less desirable than sorting them by table name. Likewise for RLS policies.

- In `pg_upgrade`, reject tables with columns of type `sql_identifier`, as that has changed representation in version 12 (Tomas Vondra)
- Improve `pg_upgrade`'s checks for the use of a data type that has changed representation, such as `line` (Tomas Vondra)

The previous coding could be fooled by cases where the data type of interest underlies a stored column of a domain or composite type.

- In `pg_rewind` with the `--dry-run` option, avoid updating `pg_control` (Alexey Kondratov)
- Fix failure in `pg_waldump` with the `-s` option, when a continuation WAL record ends exactly at a page boundary (Andrey Lepikhov)
- In `pg_waldump` with the `--bkp-details` option, avoid emitting extra newlines for WAL records involving full-page writes (Andres Freund)
- Fix small memory leak in `pg_waldump` (Andres Freund)
- Put back `pgsignal()` as an exported libpq symbol (Tom Lane)

This function was removed on the grounds that no clients should be using it, but that turns out to break usage of current libpq with very old versions of `psql`, and perhaps other applications.

- Fix `configure`'s test for presence of `libperl` so that it works on recent Red Hat releases (Tom Lane)

Previously, it could fail if the user sets `CFLAGS` to `-O0`.

- Ensure correct code generation for spinlocks on PowerPC (Noah Misch)

The previous spinlock coding allowed the compiler to select register zero for use with an assembly instruction that does not accept that register, causing a build failure. We have seen only one long-

ago report that matches this bug, but it could cause problems for people trying to build modified PostgreSQL code or use atypical compiler options.

- On AIX, don't use the compiler option `-qsrcmsg` (Noah Misch)

This avoids an internal compiler error with `xlc v16.1.0`, with little consequence other than changing the format of compiler error messages.

- Fix MSVC build process to cope with spaces in the file path of OpenSSL (Andrew Dunstan)

E.2. Release 12

Release date: 2019-10-03

E.2.1. Overview

Major enhancements in PostgreSQL 12 include:

- General performance improvements, including:
 - Optimizations to space utilization and read/write performance for B-tree indexes
 - Partitioning performance enhancements, including improved query performance on tables with thousands of partitions, improved insertion performance with `INSERT` and `COPY`, and the ability to execute `ALTER TABLE ATTACH PARTITION` without blocking queries
 - Automatic (but overridable) inlining of common table expressions (CTEs)
 - Reduction of WAL overhead for creation of GiST, GIN, and SP-GiST indexes
 - Support for covering GiST indexes, via the `INCLUDE` clause
 - Multi-column most-common-value (MCV) statistics can be defined via `CREATE STATISTICS`, to support better plans for queries that test several non-uniformly-distributed columns
- Enhancements to administrative functionality, including:
 - `REINDEX CONCURRENTLY` can rebuild an index without blocking writes to its table
 - `pg_checksums` can enable/disable page checksums (used for detecting data corruption) in an off-line cluster
 - Progress reporting statistics for `CREATE INDEX`, `REINDEX`, `CLUSTER`, `VACUUM FULL`, and `pg_checksums`
- Support for the SQL/JSON path language
- Stored generated columns
- Nondeterministic ICU collations, enabling case-insensitive and accent-insensitive grouping and ordering
- New authentication features, including:
 - Encryption of TCP/IP connections when using GSSAPI authentication
 - Discovery of LDAP servers using DNS SRV records
 - Multi-factor authentication, using the `clientcert=verify-full` option combined with an additional authentication method in `pg_hba.conf`

The above items are explained in more detail in the sections below.

E.2.2. Migration to Version 12

A dump/restore using `pg_dumpall`, or use of `pg_upgrade`, is required for those wishing to migrate data from any previous release.

Version 12 contains a number of changes that may affect compatibility with previous releases. Observe the following incompatibilities:

- Remove the special behavior of `oid` columns (Andres Freund, John Naylor)

Previously, a normally-invisible `oid` column could be specified during table creation using `WITH OIDS`; that ability has been removed. Columns can still be explicitly declared as type `oid`. Operations on tables that have columns created using `WITH OIDS` will need adjustment.

The system catalogs that previously had hidden `oid` columns now have ordinary `oid` columns. Hence, `SELECT *` will now output those columns, whereas previously they would be displayed only if selected explicitly.

- Remove data types `abstime`, `reltime`, and `tinterval` (Andres Freund)

These are obsoleted by SQL-standard types such as `timestamp`.

- Remove the `timetravel` extension (Andres Freund)

- Move `recovery.conf` settings into `postgresql.conf` (Masao Fujii, Simon Riggs, Abhijit Menon-Sen, Sergei Kornilov)

`recovery.conf` is no longer used, and the server will not start if that file exists. `recovery.signal` and `standby.signal` files are now used to switch into non-primary mode. The `trigger_file` setting has been renamed to `promote_trigger_file`. The `standby_mode` setting has been removed.

- Do not allow multiple conflicting `recovery_target*` specifications (Peter Eisentraut)

Specifically, only allow one of `recovery_target`, `recovery_target_lsn`, `recovery_target_name`, `recovery_target_time`, and `recovery_target_xid`. Previously, multiple different instances of these parameters could be specified, and the last one was honored. Now, only one can be specified, though the same one can be specified multiple times and the last specification is honored.

- Cause recovery to advance to the latest timeline by default (Peter Eisentraut)

Specifically, `recovery_target_timeline` now defaults to `latest`. Previously, it defaulted to `current`.

- Refactor code for geometric functions and operators (Emre Hasegeli)

This could lead to more accurate, but slightly different, results compared to previous releases. Notably, cases involving NaN, underflow, overflow, and division by zero are handled more consistently than before.

- Improve performance by using a new algorithm for output of `real` and `double precision` values (Andrew Gierth)

Previously, displayed floating-point values were rounded to 6 (for `real`) or 15 (for `double precision`) digits by default, adjusted by the value of `extra_float_digits`. Now, whenever `extra_float_digits` is more than zero (as it now is by default), only the minimum number of digits required to preserve the exact binary value are output. The behavior is the same as before when `extra_float_digits` is set to zero or less.

Also, formatting of floating-point exponents is now uniform across platforms: two digits are used unless three are necessary. In previous releases, Windows builds always printed three digits.

- `random()` and `setseed()` now behave uniformly across platforms (Tom Lane)

The sequence of `random()` values generated following a `setseed()` call with a particular seed value is likely to be different now than before. However, it will also be repeatable, which was not previously guaranteed because of interference from other uses of random numbers inside the server. The SQL `random()` function now has its own private per-session state to forestall that.

- Change SQL-style `substring()` to have standard-compliant greediness behavior (Tom Lane)

In cases where the pattern can be matched in more than one way, the initial sub-pattern is now treated as matching the least possible amount of text rather than the greatest; for example, a pattern such as `%#"aa*#"%` now selects the first group of a's from the input, not the last group.

- Do not pretty-print the result of `xpath()` or the `XMLTABLE` construct (Tom Lane)

In some cases, these functions would insert extra whitespace (newlines and/or spaces) in nodeset values. This is undesirable since depending on usage, the whitespace might be considered semantically significant.

- Rename command-line tool `pg_verify_checksums` to `pg_checksums` (Michaël Paquier)

- In `pg_restore`, require specification of `-f -` to send the dump contents to standard output (Euler Taveira)

Previously, this happened by default if no destination was specified, but that was deemed to be unfriendly.

- Disallow non-unique abbreviations in `psql`'s `\pset format` command (Daniel Vérité)

Previously, for example, `\pset format a` chose `aligned`; it will now fail since that could equally well mean `asciidoc`.

- In new btree indexes, the maximum index entry length is reduced by eight bytes, to improve handling of duplicate entries (Peter Geoghegan)

This means that a `REINDEX` operation on an index `pg_upgrade'd` from a previous release could potentially fail.

- Cause `DROP IF EXISTS FUNCTION/PROCEDURE/AGGREGATE/ROUTINE` to generate an error if no argument list is supplied and there are multiple matching objects (David Rowley)

Also improve the error message in such cases.

- Split the `pg_statistic_ext` catalog into two catalogs, and add the `pg_stats_ext` view of it (Dean Rasheed, Tomas Vondra)

This change supports hiding potentially-sensitive statistics data from unprivileged users.

- Remove obsolete `pg_constraint.consrc` column (Peter Eisentraut)

- Remove obsolete `pg_attrdef.adsrc` column (Peter Eisentraut)

- Mark table columns of type name as having "C" collation by default (Tom Lane, Daniel Vérité)

The comparison operators for data type name can now use any collation, rather than always using "C" collation. To preserve the previous semantics of queries, columns of type name are now explicitly marked as having "C" collation. A side effect of this is that regular-expression operators on name columns will now use the "C" collation by default, not the database collation, to determine the behavior of locale-dependent regular expression patterns (such as `\w`). If you want non-C behavior for a regular expression on a name column, attach an explicit `COLLATE` clause. (For user-defined name columns, another possibility is to specify a different collation at table creation time; but that just moves the non-backwards-compatibility to the comparison operators.)

- Treat object-name columns in the `information_schema` views as being of type name, not `varchar` (Tom Lane)

Per the SQL standard, object-name columns in the `information_schema` views are declared as being of domain type `sql_identifier`. In PostgreSQL, the underlying catalog columns are really of type name. This change makes `sql_identifier` be a domain over name, rather than `varchar` as before. This eliminates a semantic mismatch in comparison and sorting behavior, which can greatly improve the performance of queries on `information_schema` views that restrict an object-name column. Note however that inequality restrictions, for example

```
SELECT ... FROM information_schema.tables WHERE table_name <
    'foo';
```

will now use “C”-locale comparison semantics by default, rather than the database's default collation as before. Sorting on these columns will also follow “C” ordering rules. The previous behavior (and inefficiency) can be enforced by adding a `COLLATE "default"` clause.

- Remove the ability to disable dynamic shared memory (Kyotaro Horiguchi)

Specifically, `dynamic_shared_memory_type` can no longer be set to `none`.

- Parse libpq integer connection parameters more strictly (Fabien Coelho)

In previous releases, using an incorrect integer value for connection parameters `connect_timeout`, `keepalives`, `keepalives_count`, `keepalives_idle`, `keepalives_interval` and `port` resulted in libpq either ignoring those values or failing with incorrect error messages.

E.2.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 12 and the previous major release.

E.2.3.1. Server

E.2.3.1.1. Partitioning

- Improve performance of many operations on partitioned tables (Amit Langote, David Rowley, Tom Lane, Álvaro Herrera)

Allow tables with thousands of child partitions to be processed efficiently by operations that only affect a small number of partitions.

- Allow foreign keys to reference partitioned tables (Álvaro Herrera)
- Improve speed of `COPY` into partitioned tables (David Rowley)
- Allow partition bounds to be any expression (Kyotaro Horiguchi, Tom Lane, Amit Langote)

Such expressions are evaluated at partitioned-table creation time. Previously, only simple constants were allowed as partition bounds.

- Allow `CREATE TABLE`'s tablespace specification for a partitioned table to affect the tablespace of its children (David Rowley, Álvaro Herrera)
- Avoid sorting when partitions are already being scanned in the necessary order (David Rowley)
- `ALTER TABLE ATTACH PARTITION` is now performed with reduced locking requirements (Robert Haas)
- Add partition introspection functions (Michaël Paquier, Álvaro Herrera, Amit Langote)

The new function `pg_partition_root()` returns the top-most parent of a partition tree, `pg_partition_ancestors()` reports all ancestors of a partition, and `pg_partition_tree()` displays information about partitions.

- Include partitioned indexes in the system view `pg_indexes` (Suraj Kharage)
- Add `psql` command `\dP` to list partitioned tables and indexes (Pavel Stehule)
- Improve `psql \d` and `\z` display of partitioned tables (Pavel Stehule, Michaël Paquier, Álvaro Herrera)
- Fix bugs that could cause `ALTER TABLE DETACH PARTITION` to leave behind incorrect dependency state, allowing subsequent operations to misbehave, for example by not dropping a former partition child index when its table is dropped (Tom Lane)

E.2.3.1.2. Indexes

- Improve performance and space utilization of btree indexes with many duplicates (Peter Geoghegan, Heikki Linnakangas)

Previously, duplicate index entries were stored unordered within their duplicate groups. This caused overhead during index inserts, wasted space due to excessive page splits, and it reduced `VACUUM`'s ability to recycle entire pages. Duplicate index entries are now sorted in heap-storage order.

Indexes `pg_upgrade`'d from previous releases will not have these benefits.

- Allow multi-column btree indexes to be smaller (Peter Geoghegan, Heikki Linnakangas)

Internal pages and min/max leaf page indicators now only store index keys until the change key, rather than all indexed keys. This also improves the locality of index access.

Indexes `pg_upgrade`'d from previous releases will not have these benefits.

- Improve speed of btree index insertions by reducing locking overhead (Alexander Korotkov)
- Support `INCLUDE` columns in GiST indexes (Andrey Borodin)
- Add support for nearest-neighbor (KNN) searches of SP-GiST indexes (Nikita Glukhov, Alexander Korotkov, Vlad Sterzhanov)
- Reduce the WAL write overhead of GiST, GIN, and SP-GiST index creation (Anastasia Lubenikova, Andrey V. Lepikhov)
- Allow index-only scans to be more efficient on indexes with many columns (Konstantin Knizhnik)
- Improve the performance of vacuum scans of GiST indexes (Andrey Borodin, Konstantin Kuznetsov, Heikki Linnakangas)
- Delete empty leaf pages during GiST `VACUUM` (Andrey Borodin)
- Reduce locking requirements for index renaming (Peter Eisentraut)

E.2.3.1.3. Optimizer

- Allow `CREATE STATISTICS` to create most-common-value statistics for multiple columns (Tomas Vondra)

This improves optimization for queries that test several columns, requiring an estimate of the combined effect of several `WHERE` clauses. If the columns are correlated and have non-uniform distributions then multi-column statistics will allow much better estimates.

- Allow common table expressions (CTEs) to be inlined into the outer query (Andreas Karlsson, Andrew Gierth, David Fetter, Tom Lane)

Specifically, CTEs are automatically inlined if they have no side-effects, are not recursive, and are referenced only once in the query. Inlining can be prevented by specifying `MATERIALIZED`, or forced for multiply-referenced CTEs by specifying `NOT MATERIALIZED`. Previously, CTEs were never inlined and were always evaluated before the rest of the query.

- Allow control over when generic plans are used for prepared statements (Pavel Stehule)

This is controlled by the `plan_cache_mode` server parameter.

- Improve optimization of partition and `UNION ALL` queries that have only a single child (David Rowley)

- Improve processing of domains that have no check constraints (Tom Lane)

Domains that are being used purely as type aliases no longer cause optimization difficulties.

- Pre-evaluate calls of `LEAST` and `GREATEST` when their arguments are constants (Vik Fearing)

- Improve optimizer's ability to verify that partial indexes with `IS NOT NULL` conditions are usable in queries (Tom Lane, James Coleman)

Usability can now be recognized in more cases where the calling query involves casts or large `x IN (array)` clauses.

- Compute `ANALYZE` statistics using the collation defined for each column (Tom Lane)

Previously, the database's default collation was used for all statistics. This potentially gives better optimizer behavior for columns with non-default collations.

- Improve selectivity estimates for inequality comparisons on `ctid` columns (Edmund Horner)

- Improve optimization of joins on columns of type `tid` (Tom Lane)

These changes primarily improve the efficiency of self-joins on `ctid` columns.

- Fix the leakproofness designations of some btree comparison operators and support functions (Tom Lane)

This allows some optimizations that previously would not have been applied in the presence of security barrier views or row-level security.

E.2.3.1.4. General Performance

- Enable Just-in-Time (JIT) compilation by default, if the server has been built with support for it (Andres Freund)

Note that this support is not built by default, but has to be selected explicitly while configuring the build.

- Speed up keyword lookup (John Naylor, Joerg Sonnenberger, Tom Lane)

- Improve search performance for multi-byte characters in `position()` and related functions (Heikki Linnakangas)

- Allow toasted values to be minimally decompressed (Paul Ramsey)

This is useful for routines that only need to examine the initial portion of a toasted field.

- Allow `ALTER TABLE . . . SET NOT NULL` to avoid unnecessary table scans (Sergei Kornilov)

This can be optimized when the table's column constraints can be recognized as disallowing nulls.

- Allow `ALTER TABLE ... SET DATA TYPE` changing between `timestamp` and `timestampz` to avoid a table rewrite when the session time zone is UTC (Noah Misch)

In the UTC time zone, these two data types are binary compatible.

- Improve speed in converting strings to `int2` or `int4` integers (Andres Freund)
- Allow parallelized queries when in `SERIALIZABLE` isolation mode (Thomas Munro)
Previously, parallelism was disabled when in this mode.
- Use `pread()` and `pwrite()` for random I/O (Oskari Saarenmaa, Thomas Munro)
This reduces the number of system calls required for I/O.
- Improve the speed of setting the process title on FreeBSD (Thomas Munro)

E.2.3.1.5. Monitoring

- Allow logging of statements from only a percentage of transactions (Adrien Nayrat)
The parameter `log_transaction_sample_rate` controls this.
- Add progress reporting to `CREATE INDEX` and `REINDEX` operations (Álvaro Herrera, Peter Eisentraut)
Progress is reported in the `pg_stat_progress_create_index` system view.
- Add progress reporting to `CLUSTER` and `VACUUM FULL` (Tatsuro Yamada)
Progress is reported in the `pg_stat_progress_cluster` system view.
- Add progress reporting to `pg_checksums` (Michael Banck, Bernd Helmle)
This is enabled with the option `--progress`.
- Add counter of checksum failures to `pg_stat_database` (Magnus Hagander)
- Add tracking of global objects in system view `pg_stat_database` (Julien Rouhaud)
Global objects are shown with a `pg_stat_database.datid` value of zero.
- Add the ability to list the contents of the archive directory (Christoph Moench-Tegeder)
The function is `pg_ls_archive_statusdir()`.
- Add the ability to list the contents of temporary directories (Nathan Bossart)
The function, `pg_ls_tmpdir()`, optionally allows specification of a tablespace.
- Add information about the client certificate to the system view `pg_stat_ssl` (Peter Eisentraut)
The new columns are `client_serial` and `issuer_dn`. Column `clientdn` has been renamed to `client_dn` for clarity.
- Restrict visibility of rows in `pg_stat_ssl` for unprivileged users (Peter Eisentraut)
- At server start, emit a log message including the server version number (Christoph Berg)
- Prevent logging “incomplete startup packet” if a new connection is immediately closed (Tom Lane)
This avoids log spam from certain forms of monitoring.
- Include the `application_name`, if set, in `log_connections` log messages (Don Seiler)
- Make the walreceiver set its application name to the cluster name, if set (Peter Eisentraut)

- Add the timestamp of the last received standby message to `pg_stat_replication` (Lim Myungkyu)
- Add a wait event for fsync of WAL segments (Konstantin Knizhnik)

E.2.3.1.6. Authentication

- Add GSSAPI encryption support (Robbie Harwood, Stephen Frost)

This feature allows TCP/IP connections to be encrypted when using GSSAPI authentication, without having to set up a separate encryption facility such as SSL. In support of this, add `hostgssenc` and `hostnogssenc` record types in `pg_hba.conf` for selecting connections that do or do not use GSSAPI encryption, corresponding to the existing `hostssl` and `hostnossl` record types. There is also a new `gssencmode libpq` option, and a `pg_stat_gssapi` system view.

- Allow the `clientcert pg_hba.conf` option to check that the database user name matches the client certificate's common name (Julian Markwort, Marius Timmer)

This new check is enabled with `clientcert=verify-full`.

- Allow discovery of an LDAP server using DNS SRV records (Thomas Munro)

This avoids the requirement of specifying `ldapserver`. It is only supported if PostgreSQL is compiled with OpenLDAP.

E.2.3.1.7. Server Configuration

- Add ability to enable/disable cluster checksums using `pg_checksums` (Michael Banck, Michaël Paquier)

The cluster must be shut down for these operations.

- Reduce the default value of `autovacuum_vacuum_cost_delay` to 2ms (Tom Lane)

This allows autovacuum operations to proceed faster by default.

- Allow `vacuum_cost_delay` to specify sub-millisecond delays, by accepting fractional values (Tom Lane)

- Allow time-based server parameters to use units of microseconds (us) (Tom Lane)

- Allow fractional input for integer server parameters (Tom Lane)

For example, `SET work_mem = '30.1GB'` is now allowed, even though `work_mem` is an integer parameter. The value will be rounded to an integer after any required units conversion.

- Allow units to be defined for floating-point server parameters (Tom Lane)

- Add `wal_recycle` and `wal_init_zero` server parameters to control WAL file recycling (Jerry Jelinek)

Avoiding file recycling can be beneficial on copy-on-write file systems like ZFS.

- Add server parameter `tcp_user_timeout` to control the server's TCP timeout (Ryohei Nagaura)

- Allow control of the minimum and maximum SSL protocol versions (Peter Eisentraut)

The server parameters are `ssl_min_protocol_version` and `ssl_max_protocol_version`.

- Add server parameter `ssl_library` to report the SSL library version used by the server (Peter Eisentraut)

- Add server parameter `shared_memory_type` to control the type of shared memory to use (Andres Freund)

This allows selection of System V shared memory, if desired.

E.2.3.2. Streaming Replication and Recovery

- Allow some recovery parameters to be changed with reload (Peter Eisentraut)

These parameters are `archive_cleanup_command`, `promote_trigger_file`, `recovery_end_command`, and `recovery_min_apply_delay`.

- Allow the streaming replication timeout (`wal_sender_timeout`) to be set per connection (Takayuki Tsunakawa)

Previously, this could only be set cluster-wide.

- Add function `pg_promote()` to promote standbys to primaries (Laurenz Albe, Michaël Paquier)

Previously, this operation was only possible by using `pg_ctl` or creating a trigger file.

- Allow replication slots to be copied (Masahiko Sawada)

The functions for this are `pg_copy_physical_replication_slot()` and `pg_copy_logical_replication_slot()`.

- Make `max_wal_senders` not count as part of `max_connections` (Alexander Kukushkin)
- Add an explicit value of `current` for `recovery_target_timeline` (Peter Eisentraut)
- Make recovery fail if a two-phase transaction status file is corrupt (Michaël Paquier)

Previously, a warning was logged and recovery continued, allowing the transaction to be lost.

E.2.3.3. Utility Commands

- Add `REINDEX CONCURRENTLY` option to allow reindexing without locking out writes (Michaël Paquier, Andreas Karlsson, Peter Eisentraut)

This is also controlled by the `reindexdb` application's `--concurrently` option.

- Add support for generated columns (Peter Eisentraut)

The content of generated columns are computed from expressions (including references to other columns in the same table) rather than being specified by `INSERT` or `UPDATE` commands.

- Add a `WHERE` clause to `COPY FROM` to control which rows are accepted (Surafel Temesgen)

This provides a simple way to filter incoming data.

- Allow enumerated values to be added more flexibly (Andrew Dunstan, Tom Lane, Thomas Munro)

Previously, `ALTER TYPE ... ADD VALUE` could not be called in a transaction block, unless it was part of the same transaction that created the enumerated type. Now it can be called in a later transaction, so long as the new enumerated value is not referenced until after it is committed.

- Add commands to end a transaction and start a new one (Peter Eisentraut)

The commands are `COMMIT AND CHAIN` and `ROLLBACK AND CHAIN`.

- Add `VACUUM` and `CREATE TABLE` options to prevent `VACUUM` from truncating trailing empty pages (Takayuki Tsunakawa)

These options are `vacuum_truncate` and `toast.vacuum_truncate`. Use of these options reduces `VACUUM`'s locking requirements, but prevents returning disk space to the operating system.

- Allow `VACUUM` to skip index cleanup (Masahiko Sawada)

This change adds a `VACUUM` command option `INDEX_CLEANUP` as well as a table storage option `vacuum_index_cleanup`. Use of this option reduces the ability to reclaim space and can lead to index bloat, but it is helpful when the main goal is to freeze old tuples.

- Add the ability to skip `VACUUM` and `ANALYZE` operations on tables that cannot be locked immediately (Nathan Bossart)

This option is called `SKIP_LOCKED`.

- Allow `VACUUM` and `ANALYZE` to take optional Boolean argument specifications (Masahiko Sawada)
- Prevent `TRUNCATE`, `VACUUM` and `ANALYZE` from requesting a lock on tables for which the user lacks permission (Michaël Paquier)

This prevents unauthorized locking, which could interfere with user queries.

- Add `EXPLAIN` option `SETTINGS` to output non-default optimizer settings (Tomas Vondra)

This output can also be obtained when using `auto_explain` by setting `auto_explain.log_settings`.

- Add `OR REPLACE` option to `CREATE AGGREGATE` (Andrew Gierth)
- Allow modifications of system catalogs' options using `ALTER TABLE` (Peter Eisentraut)

Modifications of catalogs' `reloptions` and autovacuum settings are now supported. (Setting `allow_system_table_mods` is still required.)

- Use all key columns' names when selecting default constraint names for foreign keys (Peter Eisentraut)

Previously, only the first column name was included in the constraint name, resulting in ambiguity for multi-column foreign keys.

E.2.3.4. Data Types

- Update assorted knowledge about Unicode to match Unicode 12.1.0 (Peter Eisentraut)

This fixes, for example, cases where `psql` would misformat output involving combining characters.

- Update Snowball stemmer dictionaries with support for new languages (Arthur Zakirov)

This adds word stemming support for Arabic, Indonesian, Irish, Lithuanian, Nepali, and Tamil to full text search.

- Allow creation of collations that report string equality for strings that are not bit-wise equal (Peter Eisentraut)

This feature supports “nondeterministic” collations that can define case- and accent-agnostic equality comparisons. Thus, for example, a case-insensitive uniqueness constraint on a text column can be made more easily than before. This is only supported for ICU collations.

- Add support for ICU collation attributes on older ICU versions (Peter Eisentraut)

This allows customization of the collation rules in a consistent way across all ICU versions.

- Allow data type name to more seamlessly be compared to other text types (Tom Lane)

Type name now behaves much like a domain over type `text` that has default collation “C”. This allows cross-type comparisons to be processed more efficiently.

E.2.3.5. Functions

- Add support for the SQL/JSON path language (Nikita Glukhov, Teodor Sigaev, Alexander Korotkov, Oleg Bartunov, Liudmila Mantrova)

This allows execution of complex queries on JSON values using an SQL-standard language.

- Add support for hyperbolic functions (Lætitia Avrot)

Also add `log10()` as an alias for `log()`, for standards compliance.

- Improve the accuracy of statistical aggregates like `variance()` by using more precise algorithms (Dean Rasheed)
- Allow `date_trunc()` to have an additional argument to control the time zone (Vik Fearing, Tom Lane)

This is faster and simpler than using the `AT TIME ZONE` clause.

- Adjust `to_timestamp()/to_date()` functions to be more forgiving of template mismatches (Artur Zakirov, Alexander Korotkov, Liudmila Mantrova)

This new behavior more closely matches the Oracle functions of the same name.

- Fix assorted bugs in XML functions (Pavel Stehule, Markus Winand, Chapman Flack)

Specifically, in `XMLTABLE`, `xpath()`, and `xmlexists()`, fix some cases where nothing was output for a node, or an unexpected error was thrown, or necessary escaping of XML special characters was omitted.

- Allow the `BY VALUE` clause in `XMLEXISTS` and `XMLTABLE` (Chapman Flack)

This SQL-standard clause has no effect in PostgreSQL's implementation, but it was unnecessarily being rejected.

- Prevent `current_schema()` and `current_schemas()` from being run by parallel workers, as they are not parallel-safe (Michaël Paquier)
- Allow `RECORD` and `RECORD[]` to be used as column types in a query's column definition list for a table function that is declared to return `RECORD` (Elvis Pranskevichus)

E.2.3.6. PL/pgSQL

- Allow SQL commands and variables with the same names as those commands to be used in the same PL/pgSQL function (Tom Lane)

For example, allow a variable called `comment` to exist in a function that calls the `COMMENT SQL` command. Previously this combination caused a parse error.

- Add new optional warning and error checks to PL/pgSQL (Pavel Stehule)

The new checks allow for run-time validation of `INTO` column counts and single-row results.

E.2.3.7. Client Interfaces

- Add connection parameter `tcp_user_timeout` to control libpq's TCP timeout (Ryohei Nagaura)
- Allow libpq (and thus psql) to report only the `SQLSTATE` value in error messages (Didier Gautheron)
- Add libpq function `PQresultMemorySize()` to report the memory used by a query result (Lars Kanis, Tom Lane)

- Remove the `no-display/debug` flag from `libpq's options` connection parameter (Peter Eisentraut)
This allows this parameter to be set by `postgres_fdw`.
- Allow `ecpg` to create variables of data type `bytea` (Ryo Matsumura)
This allows ECPG clients to interact with `bytea` data directly, rather than using an encoded form.
- Add `PREPARE AS` support to ECPG (Ryo Matsumura)

E.2.3.8. Client Applications

- Allow `vacuumdb` to select tables for vacuum based on their wraparound horizon (Nathan Bossart)
The options are `--min-xid-age` and `--min-mxid-age`.
- Allow `vacuumdb` to disable waiting for locks or skipping all-visible pages (Nathan Bossart)
The options are `--skip-locked` and `--disable-page-skipping`.
- Add colorization to the output of command-line utilities (Peter Eisentraut)
This is enabled by setting the environment variable `PG_COLOR` to `always` or `auto`. The specific colors used can be adjusted by setting the environment variable `PG_COLORS`, using ANSI escape codes for colors. For example, the default behavior is equivalent to `PG_COLORS="error=01;31:warning=01;35:locus=01"`.

E.2.3.8.1. psql

- Add CSV table output mode in `psql` (Daniel Vérité)
This is controlled by `\pset format csv` or the command-line `--csv` option.
- Show the manual page URL in `psql's \help` output for a SQL command (Peter Eisentraut)
- Display the IP address in `psql's \conninfo` (Fabien Coelho)
- Improve tab completion of `CREATE TABLE`, `CREATE TRIGGER`, `CREATE EVENT TRIGGER`, `ANALYZE`, `EXPLAIN`, `VACUUM`, `ALTER TABLE`, `ALTER INDEX`, `ALTER DATABASE`, and `ALTER INDEX ALTER COLUMN` (Dagfinn Ilmari Mannsåker, Tatsuro Yamada, Michaël Paquier, Tom Lane, Justin Pryzby)

E.2.3.8.2. pgbench

- Allow values produced by queries to be assigned to `pgbench` variables (Fabien Coelho, Álvaro Herrera)
The command for this is `\gset`.
- Improve precision of `pgbench's --rate` option (Tom Lane)
- Improve `pgbench's` error reporting with clearer messages and return codes (Peter Eisentraut)

E.2.3.9. Server Applications

- Allow control of log file rotation via `pg_ctl` (Kyotaro Horiguchi, Alexander Kuzmenkov, Alexander Korotkov)
Previously, this was only possible via an SQL function or a process signal.
- Properly detach the new server process during `pg_ctl start` (Paul Guo)
This prevents the server from being shut down if the shell script that invoked `pg_ctl` is interrupted later.

- Allow `pg_upgrade` to use the file system's cloning feature, if there is one (Peter Eisentraut)

The `--clone` option has the advantages of `--link`, while preventing the old cluster from being changed after the new cluster has started.

- Allow specification of the socket directory to use in `pg_upgrade` (Daniel Gustafsson)

This is controlled by `--socketdir`; the default is the current directory.

- Allow `pg_checksums` to disable `fsync` operations (Michaël Paquier)

This is controlled by the `--no-sync` option.

- Allow `pg_rewind` to disable `fsync` operations (Michaël Paquier)

- Fix `pg_test_fsync` to report accurate `open_datasync` durations on Windows (Lorenz Albe)

E.2.3.9.1. `pg_dump`, `pg_dumpall`, `pg_restore`

- When `pg_dump` emits data with `INSERT` commands rather than `COPY`, allow more than one data row to be included in each `INSERT` (Surafel Temesgen, David Rowley)

The option controlling this is `--rows-per-insert`.

- Allow `pg_dump` to emit `INSERT ... ON CONFLICT DO NOTHING` (Surafel Temesgen)

This avoids conflict failures during restore. The option is `--on-conflict-do-nothing`.

- Decouple the order of operations in a parallel `pg_dump` from the order used by a subsequent parallel `pg_restore` (Tom Lane)

This allows `pg_restore` to perform more-fully-parallelized parallel restores, especially in cases where the original dump was not done in parallel. Scheduling of a parallel `pg_dump` is also somewhat improved.

- Allow the `extra_float_digits` setting to be specified for `pg_dump` and `pg_dumpall` (Andrew Dunstan)

This is primarily useful for making dumps that are exactly comparable across different source server versions. It is not recommended for normal use, as it may result in loss of precision when the dump is restored.

- Add `--exclude-database` option to `pg_dumpall` (Andrew Dunstan)

E.2.3.10. Source Code

- Add `CREATE ACCESS METHOD` command to create new table types (Andres Freund, Haribabu Kommi, Álvaro Herrera, Alexander Korotkov, Dmitry Dolgov)

This enables the development of new table access methods, which can optimize storage for different use cases. The existing `heap` access method remains the default.

- Add planner support function interfaces to improve optimizer estimates, inlining, and indexing for functions (Tom Lane)

This allows extensions to create planner support functions that can provide function-specific selectivity, cost, and row-count estimates that can depend on the function's arguments. Support functions can also supply simplified representations and index conditions, greatly expanding optimization possibilities.

- Simplify renumbering manually-assigned OIDs, and establish a new project policy for management of such OIDs (John Naylor, Tom Lane)

Patches that manually assign OIDs for new built-in objects (such as new functions) should now randomly choose OIDs in the range 8000—9999. At the end of a development cycle, the OIDs used by committed patches will be renumbered down to lower numbers, currently somewhere in the 4xxx range, using the new `renumber_oids.pl` script. This approach should greatly reduce the odds of OID collisions between different in-process patches.

While there is no specific policy reserving any OIDs for external use, it is recommended that forks and other projects needing private manually-assigned OIDs use numbers in the high 7xxx range. This will avoid conflicts with recently-merged patches, and it should be a long time before the core project reaches that range.

- Build Cygwin binaries using dynamic instead of static libraries (Marco Atzeri)
- Remove configure switch `--disable-strong-random` (Michaël Paquier)

A strong random-number source is now required.

- `printf`-family functions, as well as `strerror` and `strerror_r`, now behave uniformly across platforms within Postgres code (Tom Lane)

Notably, `printf` understands `%m` everywhere; on Windows, `strerror` copes with Winsock error codes (it used to do so in backend but not frontend code); and `strerror_r` always follows the GNU return convention.

- Require a C99-compliant compiler, and MSVC 2013 or later on Windows (Andres Freund)
- Use `pandoc`, not `lynx`, for generating plain-text documentation output files (Peter Eisentraut)

This affects only the `INSTALL` file generated during `make dist` and the seldom-used plain-text `postgres.txt` output file. `Pandoc` produces better output than `lynx` and avoids some locale/encoding issues. `Pandoc` version 1.13 or later is required.

- Support use of images in the PostgreSQL documentation (Jürgen Purtz)

E.2.3.11. Additional Modules

- Allow `ORDER BY` sorts and `LIMIT` clauses to be pushed to `postgres_fdw` foreign servers in more cases (Etsuro Fujita)
- Improve optimizer cost accounting for `postgres_fdw` queries (Etsuro Fujita)
- Properly honor `WITH CHECK OPTION` on views that reference `postgres_fdw` tables (Etsuro Fujita)

While `CHECK OPTIONS` on `postgres_fdw` tables are ignored (because the reference is foreign), views on such tables are considered local, so this change enforces `CHECK OPTIONS` on them. Previously, only `INSERTs` and `UPDATEs` with `RETURNING` clauses that returned `CHECK OPTION` values were validated.

- Allow `pg_stat_statements_reset()` to be more granular (Haribabu Kommi, Amit Kapila)

The function now allows reset of statistics for specific databases, users, and queries.

- Allow control of the `auto_explain` log level (Tom Dunstan, Andrew Dunstan)

The default is `LOG`.

- Update `unaccent` rules with new punctuation and symbols (Hugh Ranalli, Michaël Paquier)
- Allow `unaccent` to handle some accents encoded as combining characters (Hugh Ranalli)
- Allow `unaccent` to remove accents from Greek characters (Tasos Maschalidis)

- Add a parameter to `amcheck's bt_index_parent_check()` function to check each index tuple from the root of the tree (Peter Geoghegan)
- Improve `oid2name` and `vacuumlo` option handling to match other commands (Tatsuro Yamada)

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E.3. Prior Releases

Release notes for prior release branches can be found at <https://www.postgresql.org/docs/release/>

Appendix F. Additional Supplied Modules

This appendix and the next one contain information regarding the modules that can be found in the `contrib` directory of the PostgreSQL distribution. These include porting tools, analysis utilities, and plug-in features that are not part of the core PostgreSQL system, mainly because they address a limited audience or are too experimental to be part of the main source tree. This does not preclude their usefulness.

This appendix covers extensions and other server plug-in modules found in `contrib`. Appendix G covers utility programs.

When building from the source distribution, these components are not built automatically, unless you build the "world" target (see Step 2). You can build and install all of them by running:

```
make  
make install
```

in the `contrib` directory of a configured source tree; or to build and install just one selected module, do the same in that module's subdirectory. Many of the modules have regression tests, which can be executed by running:

```
make check
```

before installation or

```
make installcheck
```

once you have a PostgreSQL server running.

If you are using a pre-packaged version of PostgreSQL, these modules are typically made available as a separate subpackage, such as `postgresql-contrib`.

Many modules supply new user-defined functions, operators, or types. To make use of one of these modules, after you have installed the code you need to register the new SQL objects in the database system. In PostgreSQL 9.1 and later, this is done by executing a `CREATE EXTENSION` command. In a fresh database, you can simply do

```
CREATE EXTENSION module_name;
```

This command must be run by a database superuser. This registers the new SQL objects in the current database only, so you need to run this command in each database that you want the module's facilities to be available in. Alternatively, run it in database `template1` so that the extension will be copied into subsequently-created databases by default.

Many modules allow you to install their objects in a schema of your choice. To do that, add `SCHEMA schema_name` to the `CREATE EXTENSION` command. By default, the objects will be placed in your current creation target schema, which in turn defaults to `public`.

If your database was brought forward by dump and reload from a pre-9.1 version of PostgreSQL, and you had been using the pre-9.1 version of the module in it, you should instead do

```
CREATE EXTENSION module_name FROM unpackaged;
```

This will update the pre-9.1 objects of the module into a proper *extension* object. Future updates to the module will be managed by ALTER EXTENSION. For more information about extension updates, see Section 37.17.

Note, however, that some of these modules are not “extensions” in this sense, but are loaded into the server in some other way, for instance by way of `shared_preload_libraries`. See the documentation of each module for details.

F.1. adminpack

`adminpack` provides a number of support functions which `pgAdmin` and other administration and management tools can use to provide additional functionality, such as remote management of server log files. Use of all these functions is only allowed to the superuser by default but may be allowed to other users by using the GRANT command.

The functions shown in Table F.1 provide write access to files on the machine hosting the server. (See also the functions in Table 9.94, which provide read-only access.) Only files within the database cluster directory can be accessed, unless the user is a superuser or given one of the `pg_read_server_files`, or `pg_write_server_files` roles, as appropriate for the function, but either a relative or absolute path is allowable.

Table F.1. adminpack Functions

Name	Return Type	Description
<code>pg_catalog.pg_file_write(filename text, data text, append boolean)</code>	bigint	Write, or append to, a text file
<code>pg_catalog.pg_file_rename(oldname text, newname text [, archivename text])</code>	boolean	Rename a file
<code>pg_catalog.pg_file_unlink(filename text)</code>	boolean	Remove a file
<code>pg_catalog.pg_logdir_ls()</code>	setof record	List the log files in the <code>log_directory</code> directory

`pg_file_write` writes the specified *data* into the file named by *filename*. If *append* is false, the file must not already exist. If *append* is true, the file can already exist, and will be appended to if so. Returns the number of bytes written.

`pg_file_rename` renames a file. If *archivename* is omitted or NULL, it simply renames *oldname* to *newname* (which must not already exist). If *archivename* is provided, it first renames *newname* to *archivename* (which must not already exist), and then renames *oldname* to *newname*. In event of failure of the second rename step, it will try to rename *archivename* back to *newname* before reporting the error. Returns true on success, false if the source file(s) are not present or not writable; other cases throw errors.

`pg_file_unlink` removes the specified file. Returns true on success, false if the specified file is not present or the `unlink()` call fails; other cases throw errors.

`pg_logdir_ls` returns the start timestamps and path names of all the log files in the `log_directory` directory. The `log_filename` parameter must have its default setting (`postgresql-%Y-%m-%d_%H%M%S.log`) to use this function.

F.2. amcheck

The `amcheck` module provides functions that allow you to verify the logical consistency of the structure of relations. If the structure appears to be valid, no error is raised.

The functions verify various *invariants* in the structure of the representation of particular relations. The correctness of the access method functions behind index scans and other important operations relies on these invariants always holding. For example, certain functions verify, among other things, that all B-Tree pages have items in “logical” order (e.g., for B-Tree indexes on `text`, index tuples should be in collated lexical order). If that particular invariant somehow fails to hold, we can expect binary searches on the affected page to incorrectly guide index scans, resulting in wrong answers to SQL queries.

Verification is performed using the same procedures as those used by index scans themselves, which may be user-defined operator class code. For example, B-Tree index verification relies on comparisons made with one or more B-Tree support function 1 routines. See Section 37.16.3 for details of operator class support functions.

`amcheck` functions may only be used by superusers.

F.2.1. Functions

`bt_index_check(index regclass, heapallindexed boolean)` returns void

`bt_index_check` tests that its target, a B-Tree index, respects a variety of invariants. Example usage:

```
test=# SELECT bt_index_check(index => c.oid, heapallindexed =>
      i.indisunique),
      c.relname,
      c.relpages
FROM pg_index i
JOIN pg_opclass op ON i.indclass[0] = op.oid
JOIN pg_am am ON op.opcmethod = am.oid
JOIN pg_class c ON i.indexrelid = c.oid
JOIN pg_namespace n ON c.relnamespace = n.oid
WHERE am.amname = 'btree' AND n.nspname = 'pg_catalog'
-- Don't check temp tables, which may be from another session:
AND c.relpersistence != 't'
-- Function may throw an error when this is omitted:
AND c.relkind = 'i' AND i.indisready AND i.indisvalid
ORDER BY c.relpages DESC LIMIT 10;
```

<code>bt_index_check</code>	<code>relname</code>	<code>relpages</code>
	<code>pg_depend_reference_index</code>	43
	<code>pg_depend_depender_index</code>	40
	<code>pg_proc_proname_args_nsp_index</code>	31
	<code>pg_description_o_c_o_index</code>	21
	<code>pg_attribute_relid_attnam_index</code>	14
	<code>pg_proc_oid_index</code>	10
	<code>pg_attribute_relid_attnum_index</code>	9
	<code>pg_amproc_fam_proc_index</code>	5

	pg_amop_opr_fam_index	5
	pg_amop_fam_strat_index	5

(10 rows)

This example shows a session that performs verification of the 10 largest catalog indexes in the database “test”. Verification of the presence of heap tuples as index tuples is requested for the subset that are unique indexes. Since no error is raised, all indexes tested appear to be logically consistent. Naturally, this query could easily be changed to call `bt_index_check` for every index in the database where verification is supported.

`bt_index_check` acquires an `AccessShareLock` on the target index and the heap relation it belongs to. This lock mode is the same lock mode acquired on relations by simple `SELECT` statements. `bt_index_check` does not verify invariants that span child/parent relationships, but will verify the presence of all heap tuples as index tuples within the index when `heapallindexed` is `true`. When a routine, lightweight test for corruption is required in a live production environment, using `bt_index_check` often provides the best trade-off between thoroughness of verification and limiting the impact on application performance and availability.

`bt_index_parent_check(index regclass, heapallindexed boolean, rootdescend boolean)` returns void

`bt_index_parent_check` tests that its target, a B-Tree index, respects a variety of invariants. Optionally, when the `heapallindexed` argument is `true`, the function verifies the presence of all heap tuples that should be found within the index, and that there are no missing down-links in the index structure. When the optional `rootdescend` argument is `true`, verification re-finds tuples on the leaf level by performing a new search from the root page for each tuple. The checks that can be performed by `bt_index_parent_check` are a superset of the checks that can be performed by `bt_index_check`. `bt_index_parent_check` can be thought of as a more thorough variant of `bt_index_check`: unlike `bt_index_check`, `bt_index_parent_check` also checks invariants that span parent/child relationships. `bt_index_parent_check` follows the general convention of raising an error if it finds a logical inconsistency or other problem.

A `ShareLock` is required on the target index by `bt_index_parent_check` (a `ShareLock` is also acquired on the heap relation). These locks prevent concurrent data modification from `INSERT`, `UPDATE`, and `DELETE` commands. The locks also prevent the underlying relation from being concurrently processed by `VACUUM`, as well as all other utility commands. Note that the function holds locks only while running, not for the entire transaction.

`bt_index_parent_check`'s additional verification is more likely to detect various pathological cases. These cases may involve an incorrectly implemented B-Tree operator class used by the index that is checked, or, hypothetically, undiscovered bugs in the underlying B-Tree index access method code. Note that `bt_index_parent_check` cannot be used when Hot Standby mode is enabled (i.e., on read-only physical replicas), unlike `bt_index_check`.

F.2.2. Optional *heapallindexed* Verification

When the `heapallindexed` argument to verification functions is `true`, an additional phase of verification is performed against the table associated with the target index relation. This consists of a “dummy” `CREATE INDEX` operation, which checks for the presence of all hypothetical new index tuples against a temporary, in-memory summarizing structure (this is built when needed during the basic first phase of verification). The summarizing structure “fingerprints” every tuple found within the target index. The high level principle behind `heapallindexed` verification is that a new index that is equivalent to the existing, target index must only have entries that can be found in the existing structure.

The additional `heapallindexed` phase adds significant overhead: verification will typically take several times longer. However, there is no change to the relation-level locks acquired when `heapallindexed` verification is performed.

The summarizing structure is bound in size by `maintenance_work_mem`. In order to ensure that there is no more than a 2% probability of failure to detect an inconsistency for each heap tuple that should be represented in the index, approximately 2 bytes of memory are needed per tuple. As less memory is made available per tuple, the probability of missing an inconsistency slowly increases. This approach limits the overhead of verification significantly, while only slightly reducing the probability of detecting a problem, especially for installations where verification is treated as a routine maintenance task. Any single absent or malformed tuple has a new opportunity to be detected with each new verification attempt.

F.2.3. Using `amcheck` Effectively

`amcheck` can be effective at detecting various types of failure modes that data page checksums will always fail to catch. These include:

- Structural inconsistencies caused by incorrect operator class implementations.

This includes issues caused by the comparison rules of operating system collations changing. Comparisons of datums of a collatable type like `text` must be immutable (just as all comparisons used for B-Tree index scans must be immutable), which implies that operating system collation rules must never change. Though rare, updates to operating system collation rules can cause these issues. More commonly, an inconsistency in the collation order between a master server and a standby server is implicated, possibly because the *major* operating system version in use is inconsistent. Such inconsistencies will generally only arise on standby servers, and so can generally only be detected on standby servers.

If a problem like this arises, it may not affect each individual index that is ordered using an affected collation, simply because *indexed* values might happen to have the same absolute ordering regardless of the behavioral inconsistency. See Section 23.1 and Section 23.2 for further details about how PostgreSQL uses operating system locales and collations.

- Structural inconsistencies between indexes and the heap relations that are indexed (when *heapallindexed* verification is performed).

There is no cross-checking of indexes against their heap relation during normal operation. Symptoms of heap corruption can be subtle.

- Corruption caused by hypothetical undiscovered bugs in the underlying PostgreSQL access method code, sort code, or transaction management code.

Automatic verification of the structural integrity of indexes plays a role in the general testing of new or proposed PostgreSQL features that could plausibly allow a logical inconsistency to be introduced. Verification of table structure and associated visibility and transaction status information plays a similar role. One obvious testing strategy is to call `amcheck` functions continuously when running the standard regression tests. See Section 32.1 for details on running the tests.

- File system or storage subsystem faults where checksums happen to simply not be enabled.

Note that `amcheck` examines a page as represented in some shared memory buffer at the time of verification if there is only a shared buffer hit when accessing the block. Consequently, `amcheck` does not necessarily examine data read from the file system at the time of verification. Note that when checksums are enabled, `amcheck` may raise an error due to a checksum failure when a corrupt block is read into a buffer.

- Corruption caused by faulty RAM, or the broader memory subsystem.

PostgreSQL does not protect against correctable memory errors and it is assumed you will operate using RAM that uses industry standard Error Correcting Codes (ECC) or better protection. However, ECC memory is typically only immune to single-bit errors, and should not be assumed to provide *absolute* protection against failures that result in memory corruption.

When *heapallindexed* verification is performed, there is generally a greatly increased chance of detecting single-bit errors, since strict binary equality is tested, and the indexed attributes within the heap are tested.

In general, *amcheck* can only prove the presence of corruption; it cannot prove its absence.

F.2.4. Repairing Corruption

No error concerning corruption raised by *amcheck* should ever be a false positive. *amcheck* raises errors in the event of conditions that, by definition, should never happen, and so careful analysis of *amcheck* errors is often required.

There is no general method of repairing problems that *amcheck* detects. An explanation for the root cause of an invariant violation should be sought. *pageinspect* may play a useful role in diagnosing corruption that *amcheck* detects. A *REINDEX* may not be effective in repairing corruption.

F.3. *auth_delay*

auth_delay causes the server to pause briefly before reporting authentication failure, to make brute-force attacks on database passwords more difficult. Note that it does nothing to prevent denial-of-service attacks, and may even exacerbate them, since processes that are waiting before reporting authentication failure will still consume connection slots.

In order to function, this module must be loaded via *shared_preload_libraries* in *postgresql.conf*.

F.3.1. Configuration Parameters

auth_delay.milliseconds (int)

The number of milliseconds to wait before reporting an authentication failure. The default is 0.

These parameters must be set in *postgresql.conf*. Typical usage might be:

```
# postgresql.conf
shared_preload_libraries = 'auth_delay'

auth_delay.milliseconds = '500'
```

F.3.2. Author

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F.4. *auto_explain*

The *auto_explain* module provides a means for logging execution plans of slow statements automatically, without having to run *EXPLAIN* by hand. This is especially helpful for tracking down un-optimized queries in large applications.

The module provides no SQL-accessible functions. To use it, simply load it into the server. You can load it into an individual session:

```
LOAD 'auto_explain';
```

(You must be superuser to do that.) More typical usage is to preload it into some or all sessions by including `auto_explain` in `session_preload_libraries` or `shared_preload_libraries` in `postgresql.conf`. Then you can track unexpectedly slow queries no matter when they happen. Of course there is a price in overhead for that.

F.4.1. Configuration Parameters

There are several configuration parameters that control the behavior of `auto_explain`. Note that the default behavior is to do nothing, so you must set at least `auto_explain.log_min_duration` if you want any results.

`auto_explain.log_min_duration` (integer)

`auto_explain.log_min_duration` is the minimum statement execution time, in milliseconds, that will cause the statement's plan to be logged. Setting this to 0 logs all plans. -1 (the default) disables logging of plans. For example, if you set it to 250ms then all statements that run 250ms or longer will be logged. Only superusers can change this setting.

`auto_explain.log_analyze` (boolean)

`auto_explain.log_analyze` causes `EXPLAIN ANALYZE` output, rather than just `EXPLAIN` output, to be printed when an execution plan is logged. This parameter is off by default. Only superusers can change this setting.

Note

When this parameter is on, per-plan-node timing occurs for all statements executed, whether or not they run long enough to actually get logged. This can have an extremely negative impact on performance. Turning off `auto_explain.log_timing` ameliorates the performance cost, at the price of obtaining less information.

`auto_explain.log_buffers` (boolean)

`auto_explain.log_buffers` controls whether buffer usage statistics are printed when an execution plan is logged; it's equivalent to the `BUFFERS` option of `EXPLAIN`. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_timing` (boolean)

`auto_explain.log_timing` controls whether per-node timing information is printed when an execution plan is logged; it's equivalent to the `TIMING` option of `EXPLAIN`. The overhead of repeatedly reading the system clock can slow down queries significantly on some systems, so it may be useful to set this parameter to off when only actual row counts, and not exact times, are needed. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is on by default. Only superusers can change this setting.

`auto_explain.log_triggers` (boolean)

`auto_explain.log_triggers` causes trigger execution statistics to be included when an execution plan is logged. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_verbose` (boolean)

`auto_explain.log_verbose` controls whether verbose details are printed when an execution plan is logged; it's equivalent to the `VERBOSE` option of `EXPLAIN`. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_settings` (boolean)

`auto_explain.log_settings` controls whether information about modified configuration options are printed when execution plan is logged. Only options affecting query planning with value different from the built-in default value are included in the output. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_format` (enum)

`auto_explain.log_format` selects the EXPLAIN output format to be used. The allowed values are `text`, `xml`, `json`, and `yaml`. The default is `text`. Only superusers can change this setting.

`auto_explain.log_level` (enum)

`auto_explain.log_level` selects the log level at which `auto_explain` will log the query plan. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, `INFO`, `NOTICE`, `WARNING`, and `LOG`. The default is `LOG`. Only superusers can change this setting.

`auto_explain.log_nested_statements` (boolean)

`auto_explain.log_nested_statements` causes nested statements (statements executed inside a function) to be considered for logging. When it is off, only top-level query plans are logged. This parameter is off by default. Only superusers can change this setting.

`auto_explain.sample_rate` (real)

`auto_explain.sample_rate` causes `auto_explain` to only explain a fraction of the statements in each session. The default is 1, meaning explain all the queries. In case of nested statements, either all will be explained or none. Only superusers can change this setting.

In ordinary usage, these parameters are set in `postgresql.conf`, although superusers can alter them on-the-fly within their own sessions. Typical usage might be:

```
# postgresql.conf
session_preload_libraries = 'auto_explain'

auto_explain.log_min_duration = '3s'
```

F.4.2. Example

```
postgres=# LOAD 'auto_explain';
postgres=# SET auto_explain.log_min_duration = 0;
postgres=# SET auto_explain.log_analyze = true;
postgres=# SELECT count(*)
           FROM pg_class, pg_index
           WHERE oid = indrelid AND indisunique;
```

This might produce log output such as:

```
LOG:  duration: 3.651 ms  plan:
       Query Text: SELECT count(*)
                   FROM pg_class, pg_index
                   WHERE oid = indrelid AND indisunique;
       Aggregate  (cost=16.79..16.80 rows=1 width=0) (actual
time=3.626..3.627 rows=1 loops=1)
```

```
-> Hash Join (cost=4.17..16.55 rows=92 width=0) (actual
time=3.349..3.594 rows=92 loops=1)
  Hash Cond: (pg_class.oid = pg_index.indrelid)
  -> Seq Scan on pg_class (cost=0.00..9.55 rows=255
width=4) (actual time=0.016..0.140 rows=255 loops=1)
  -> Hash (cost=3.02..3.02 rows=92 width=4) (actual
time=3.238..3.238 rows=92 loops=1)
    Buckets: 1024 Batches: 1 Memory Usage: 4kB
  -> Seq Scan on pg_index (cost=0.00..3.02 rows=92
width=4) (actual time=0.008..3.187 rows=92 loops=1)
    Filter: indisunique
```

F.4.3. Author

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F.5. bloom

bloom provides an index access method based on Bloom filters¹.

A Bloom filter is a space-efficient data structure that is used to test whether an element is a member of a set. In the case of an index access method, it allows fast exclusion of non-matching tuples via signatures whose size is determined at index creation.

A signature is a lossy representation of the indexed attribute(s), and as such is prone to reporting false positives; that is, it may be reported that an element is in the set, when it is not. So index search results must always be rechecked using the actual attribute values from the heap entry. Larger signatures reduce the odds of a false positive and thus reduce the number of useless heap visits, but of course also make the index larger and hence slower to scan.

This type of index is most useful when a table has many attributes and queries test arbitrary combinations of them. A traditional btree index is faster than a bloom index, but it can require many btree indexes to support all possible queries where one needs only a single bloom index. Note however that bloom indexes only support equality queries, whereas btree indexes can also perform inequality and range searches.

F.5.1. Parameters

A bloom index accepts the following parameters in its WITH clause:

`length`

Length of each signature (index entry) in bits. It is rounded up to the nearest multiple of 16. The default is 80 bits and the maximum is 4096.

`coll - col32`

Number of bits generated for each index column. Each parameter's name refers to the number of the index column that it controls. The default is 2 bits and maximum is 4095. Parameters for index columns not actually used are ignored.

F.5.2. Examples

This is an example of creating a bloom index:

¹ https://en.wikipedia.org/wiki/Bloom_filter

```
CREATE INDEX bloomidx ON tbloom USING bloom (i1,i2,i3)
    WITH (length=80, coll=2, col2=2, col3=4);
```

The index is created with a signature length of 80 bits, with attributes i1 and i2 mapped to 2 bits, and attribute i3 mapped to 4 bits. We could have omitted the length, coll, and col2 specifications since those have the default values.

Here is a more complete example of bloom index definition and usage, as well as a comparison with equivalent btree indexes. The bloom index is considerably smaller than the btree index, and can perform better.

```
=# CREATE TABLE tbloom AS
  SELECT
    (random() * 1000000)::int as i1,
    (random() * 1000000)::int as i2,
    (random() * 1000000)::int as i3,
    (random() * 1000000)::int as i4,
    (random() * 1000000)::int as i5,
    (random() * 1000000)::int as i6
  FROM
    generate_series(1,10000000);
SELECT 10000000
=# CREATE INDEX bloomidx ON tbloom USING bloom (i1, i2, i3, i4, i5,
  i6);
CREATE INDEX
=# SELECT pg_size_pretty(pg_relation_size('bloomidx'));
  pg_size_pretty
-----
 153 MB
(1 row)
=# CREATE index btreeidx ON tbloom (i1, i2, i3, i4, i5, i6);
CREATE INDEX
=# SELECT pg_size_pretty(pg_relation_size('btreeidx'));
  pg_size_pretty
-----
 387 MB
(1 row)
```

A sequential scan over this large table takes a long time:

```
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
  123451;
                                     QUERY PLAN
-----
Seq Scan on tbloom (cost=0.00..213694.08 rows=1 width=24) (actual
time=1445.438..1445.438 rows=0 loops=1)
  Filter: ((i2 = 898732) AND (i5 = 123451))
  Rows Removed by Filter: 10000000
Planning time: 0.177 ms
Execution time: 1445.473 ms
(5 rows)
```

So the planner will usually select an index scan if possible. With a btree index, we get results like this:

```
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
  123451;
```

QUERY

PLAN

```
-----
Index Only Scan using btreeidx on tbloom (cost=0.56..298311.96
rows=1 width=24) (actual time=445.709..445.709 rows=0 loops=1)
  Index Cond: ((i2 = 898732) AND (i5 = 123451))
  Heap Fetches: 0
Planning time: 0.193 ms
Execution time: 445.770 ms
(5 rows)
```

Bloom is better than btree in handling this type of search:

```
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
123451;
```

QUERY PLAN

```
-----
Bitmap Heap Scan on tbloom (cost=178435.39..178439.41 rows=1
width=24) (actual time=76.698..76.698 rows=0 loops=1)
  Recheck Cond: ((i2 = 898732) AND (i5 = 123451))
  Rows Removed by Index Recheck: 2439
  Heap Blocks: exact=2408
  -> Bitmap Index Scan on bloomidx (cost=0.00..178435.39 rows=1
width=0) (actual time=72.455..72.455 rows=2439 loops=1)
    Index Cond: ((i2 = 898732) AND (i5 = 123451))
Planning time: 0.475 ms
Execution time: 76.778 ms
(8 rows)
```

Note the relatively large number of false positives: 2439 rows were selected to be visited in the heap, but none actually matched the query. We could reduce that by specifying a larger signature length. In this example, creating the index with `length=200` reduced the number of false positives to 55; but it doubled the index size (to 306 MB) and ended up being slower for this query (125 ms overall).

Now, the main problem with the btree search is that btree is inefficient when the search conditions do not constrain the leading index column(s). A better strategy for btree is to create a separate index on each column. Then the planner will choose something like this:

```
=# EXPLAIN ANALYZE SELECT * FROM tbloom WHERE i2 = 898732 AND i5 =
123451;
```

QUERY

PLAN

```
-----
Bitmap Heap Scan on tbloom (cost=9.29..13.30 rows=1 width=24)
(actual time=0.148..0.148 rows=0 loops=1)
  Recheck Cond: ((i5 = 123451) AND (i2 = 898732))
  -> BitmapAnd (cost=9.29..9.29 rows=1 width=0) (actual
time=0.145..0.145 rows=0 loops=1)
    -> Bitmap Index Scan on tbloom_i5_idx (cost=0.00..4.52
rows=11 width=0) (actual time=0.089..0.089 rows=10 loops=1)
      Index Cond: (i5 = 123451)
    -> Bitmap Index Scan on tbloom_i2_idx (cost=0.00..4.52
rows=11 width=0) (actual time=0.048..0.048 rows=8 loops=1)
      Index Cond: (i2 = 898732)
Planning time: 2.049 ms
Execution time: 0.280 ms
(9 rows)
```

Although this query runs much faster than with either of the single indexes, we pay a large penalty in index size. Each of the single-column btree indexes occupies 214 MB, so the total space needed is over 1.2GB, more than 8 times the space used by the bloom index.

F.5.3. Operator Class Interface

An operator class for bloom indexes requires only a hash function for the indexed data type and an equality operator for searching. This example shows the operator class definition for the `text` data type:

```
CREATE OPERATOR CLASS text_ops
DEFAULT FOR TYPE text USING bloom AS
    OPERATOR      1      =(text, text),
    FUNCTION      1      hashtext(text);
```

F.5.4. Limitations

- Only operator classes for `int4` and `text` are included with the module.
- Only the `=` operator is supported for search. But it is possible to add support for arrays with union and intersection operations in the future.
- bloom access method doesn't support `UNIQUE` indexes.
- bloom access method doesn't support searching for `NULL` values.

F.5.5. Authors

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F.6. btree_gin

`btree_gin` provides sample GIN operator classes that implement B-tree equivalent behavior for the data types `int2`, `int4`, `int8`, `float4`, `float8`, `timestamp with time zone`, `timestamp without time zone`, `time with time zone`, `time without time zone`, `date`, `interval`, `oid`, `money`, `"char"`, `varchar`, `text`, `bytea`, `bit`, `varbit`, `macaddr`, `macaddr8`, `inet`, `cidr`, `uuid`, `name`, `bool`, `bpchar`, and all enum types.

In general, these operator classes will not outperform the equivalent standard B-tree index methods, and they lack one major feature of the standard B-tree code: the ability to enforce uniqueness. However, they are useful for GIN testing and as a base for developing other GIN operator classes. Also, for queries that test both a GIN-indexable column and a B-tree-indexable column, it might be more efficient to create a multicolumn GIN index that uses one of these operator classes than to create two separate indexes that would have to be combined via bitmap ANDing.

F.6.1. Example Usage

```
CREATE TABLE test (a int4);
-- create index
CREATE INDEX testidx ON test USING GIN (a);
-- query
SELECT * FROM test WHERE a < 10;
```

F.6.2. Authors

Teodor Sigaev (<teodor@stack.net>) and Oleg Bartunov (<oleg@sai.msu.su>). See <http://www.sai.msu.su/~megera/oddmuse/index.cgi/Gin> for additional information.

F.7. btree_gist

`btree_gist` provides GiST index operator classes that implement B-tree equivalent behavior for the data types `int2`, `int4`, `int8`, `float4`, `float8`, `numeric`, `timestamp with time zone`, `timestamp without time zone`, `time with time zone`, `time without time zone`, `date`, `interval`, `oid`, `money`, `char`, `varchar`, `text`, `bytea`, `bit`, `varbit`, `macaddr`, `macaddr8`, `inet`, `cidr`, `uuid`, and all enum types.

In general, these operator classes will not outperform the equivalent standard B-tree index methods, and they lack one major feature of the standard B-tree code: the ability to enforce uniqueness. However, they provide some other features that are not available with a B-tree index, as described below. Also, these operator classes are useful when a multicolumn GiST index is needed, wherein some of the columns are of data types that are only indexable with GiST but other columns are just simple data types. Lastly, these operator classes are useful for GiST testing and as a base for developing other GiST operator classes.

In addition to the typical B-tree search operators, `btree_gist` also provides index support for `<>` (“not equals”). This may be useful in combination with an exclusion constraint, as described below.

Also, for data types for which there is a natural distance metric, `btree_gist` defines a distance operator `<->`, and provides GiST index support for nearest-neighbor searches using this operator. Distance operators are provided for `int2`, `int4`, `int8`, `float4`, `float8`, `timestamp with time zone`, `timestamp without time zone`, `time without time zone`, `date`, `interval`, `oid`, and `money`.

F.7.1. Example Usage

Simple example using `btree_gist` instead of `btree`:

```
CREATE TABLE test (a int4);
-- create index
CREATE INDEX testidx ON test USING GIST (a);
-- query
SELECT * FROM test WHERE a < 10;
-- nearest-neighbor search: find the ten entries closest to "42"
SELECT *, a <-> 42 AS dist FROM test ORDER BY a <-> 42 LIMIT 10;
```

Use an exclusion constraint to enforce the rule that a cage at a zoo can contain only one kind of animal:

```
=> CREATE TABLE zoo (
    cage INTEGER,
    animal TEXT,
    EXCLUDE USING GIST (cage WITH =, animal WITH <>)
);

=> INSERT INTO zoo VALUES(123, 'zebra');
INSERT 0 1
=> INSERT INTO zoo VALUES(123, 'zebra');
INSERT 0 1
=> INSERT INTO zoo VALUES(123, 'lion');
ERROR:  conflicting key value violates exclusion constraint
       "zoo_cage_animal_excl"
```

```
DETAIL:  Key (cage, animal)=(123, lion) conflicts with existing key
(cage, animal)=(123, zebra).
=> INSERT INTO zoo VALUES(124, 'lion');
INSERT 0 1
```

F.7.2. Authors

Teodor Sigaev (<teodor@stack.net>), Oleg Bartunov (<oleg@sai.msu.su>), Janko Richter (<jankorichter@yahoo.de>), and Paul Jungwirth (<pj@illuminatedcomputing.com>). See <http://www.sai.msu.su/~megera/postgres/gist/> for additional information.

F.8. citext

The `citext` module provides a case-insensitive character string type, `citext`. Essentially, it internally calls `lower` when comparing values. Otherwise, it behaves almost exactly like `text`.

Tip

Consider using *nondeterministic collations* (see Section 23.2.2.4) instead of this module. They can be used for case-insensitive comparisons, accent-insensitive comparisons, and other combinations, and they handle more Unicode special cases correctly.

F.8.1. Rationale

The standard approach to doing case-insensitive matches in PostgreSQL has been to use the `lower` function when comparing values, for example

```
SELECT * FROM tab WHERE lower(col) = LOWER(?);
```

This works reasonably well, but has a number of drawbacks:

- It makes your SQL statements verbose, and you always have to remember to use `lower` on both the column and the query value.
- It won't use an index, unless you create a functional index using `lower`.
- If you declare a column as `UNIQUE` or `PRIMARY KEY`, the implicitly generated index is case-sensitive. So it's useless for case-insensitive searches, and it won't enforce uniqueness case-insensitively.

The `citext` data type allows you to eliminate calls to `lower` in SQL queries, and allows a primary key to be case-insensitive. `citext` is locale-aware, just like `text`, which means that the matching of upper case and lower case characters is dependent on the rules of the database's `LC_CTYPE` setting. Again, this behavior is identical to the use of `lower` in queries. But because it's done transparently by the data type, you don't have to remember to do anything special in your queries.

F.8.2. How to Use It

Here's a simple example of usage:

```
CREATE TABLE users (
    nick CITEXT PRIMARY KEY,
    pass TEXT NOT NULL
);
```

```
INSERT INTO users VALUES ( 'larry',
    sha256(random()::text::bytea) );
INSERT INTO users VALUES ( 'Tom',
    sha256(random()::text::bytea) );
INSERT INTO users VALUES ( 'Damian',
    sha256(random()::text::bytea) );
INSERT INTO users VALUES ( 'NEAL',
    sha256(random()::text::bytea) );
INSERT INTO users VALUES ( 'Bjørn',
    sha256(random()::text::bytea) );

SELECT * FROM users WHERE nick = 'Larry';
```

The `SELECT` statement will return one tuple, even though the `nick` column was set to `larry` and the query was for `Larry`.

F.8.3. String Comparison Behavior

`citext` performs comparisons by converting each string to lower case (as though `lower` were called) and then comparing the results normally. Thus, for example, two strings are considered equal if `lower` would produce identical results for them.

In order to emulate a case-insensitive collation as closely as possible, there are `citext`-specific versions of a number of string-processing operators and functions. So, for example, the regular expression operators `~` and `~*` exhibit the same behavior when applied to `citext`: they both match case-insensitively. The same is true for `!~` and `!~*`, as well as for the `LIKE` operators `~~` and `~~*`, and `!~~` and `!~~*`. If you'd like to match case-sensitively, you can cast the operator's arguments to `text`.

Similarly, all of the following functions perform matching case-insensitively if their arguments are `citext`:

- `regexp_match()`
- `regexp_matches()`
- `regexp_replace()`
- `regexp_split_to_array()`
- `regexp_split_to_table()`
- `replace()`
- `split_part()`
- `strpos()`
- `translate()`

For the `regexp` functions, if you want to match case-sensitively, you can specify the “`c`” flag to force a case-sensitive match. Otherwise, you must cast to `text` before using one of these functions if you want case-sensitive behavior.

F.8.4. Limitations

- `citext`'s case-folding behavior depends on the `LC_CTYPE` setting of your database. How it compares values is therefore determined when the database is created. It is not truly case-insensitive in the terms defined by the Unicode standard. Effectively, what this means is that, as long as you're happy with your collation, you should be happy with `citext`'s comparisons. But if you have data in different languages stored in your database, users of one language may find their query results are not as expected if the collation is for another language.

- As of PostgreSQL 9.1, you can attach a `COLLATE` specification to `citext` columns or data values. Currently, `citext` operators will honor a non-default `COLLATE` specification while comparing case-folded strings, but the initial folding to lower case is always done according to the database's `LC_CTYPE` setting (that is, as though `COLLATE "default"` were given). This may be changed in a future release so that both steps follow the input `COLLATE` specification.
- `citext` is not as efficient as `text` because the operator functions and the B-tree comparison functions must make copies of the data and convert it to lower case for comparisons. It is, however, slightly more efficient than using `lower` to get case-insensitive matching.
- `citext` doesn't help much if you need data to compare case-sensitively in some contexts and case-insensitively in other contexts. The standard answer is to use the `text` type and manually use the `lower` function when you need to compare case-insensitively; this works all right if case-insensitive comparison is needed only infrequently. If you need case-insensitive behavior most of the time and case-sensitive infrequently, consider storing the data as `citext` and explicitly casting the column to `text` when you want case-sensitive comparison. In either situation, you will need two indexes if you want both types of searches to be fast.
- The schema containing the `citext` operators must be in the current `search_path` (typically `public`); if it is not, the normal case-sensitive `text` operators will be invoked instead.
- The approach of lower-casing strings for comparison does not handle some Unicode special cases correctly, for example when one upper-case letter has two lower-case letter equivalents. Unicode distinguishes between *case mapping* and *case folding* for this reason. Use nondeterministic collations instead of `citext` to handle that correctly.

F.8.5. Author

David E. Wheeler <david@kineticode.com>

Inspired by the original `citext` module by Donald Fraser.

F.9. cube

This module implements a data type `cube` for representing multidimensional cubes.

F.9.1. Syntax

Table F.2 shows the valid external representations for the `cube` type. `x`, `y`, etc. denote floating-point numbers.

Table F.2. Cube External Representations

External Syntax	Meaning
<code>x</code>	A one-dimensional point (or, zero-length one-dimensional interval)
<code>(x)</code>	Same as above
<code>x1, x2, . . . , xn</code>	A point in n-dimensional space, represented internally as a zero-volume cube
<code>(x1, x2, . . . , xn)</code>	Same as above
<code>(x), (y)</code>	A one-dimensional interval starting at <code>x</code> and ending at <code>y</code> or vice versa; the order does not matter
<code>[(x), (y)]</code>	Same as above
<code>(x1, . . . , xn), (y1, . . . , yn)</code>	An n-dimensional cube represented by a pair of its diagonally opposite corners
<code>[(x1, . . . , xn), (y1, . . . , yn)]</code>	Same as above

It does not matter which order the opposite corners of a cube are entered in. The `cube` functions automatically swap values if needed to create a uniform “lower left — upper right” internal representation. When the corners coincide, `cube` stores only one corner along with an “is point” flag to avoid wasting space.

White space is ignored on input, so `[(x) , (y)]` is the same as `[(x) , (y)]`.

F.9.2. Precision

Values are stored internally as 64-bit floating point numbers. This means that numbers with more than about 16 significant digits will be truncated.

F.9.3. Usage

Table F.3 shows the operators provided for type `cube`.

Table F.3. Cube Operators

Operator	Result	Description
<code>a = b</code>	boolean	The cubes <code>a</code> and <code>b</code> are identical.
<code>a && b</code>	boolean	The cubes <code>a</code> and <code>b</code> overlap.
<code>a @> b</code>	boolean	The cube <code>a</code> contains the cube <code>b</code> .
<code>a <@ b</code>	boolean	The cube <code>a</code> is contained in the cube <code>b</code> .
<code>a < b</code>	boolean	The cube <code>a</code> is less than the cube <code>b</code> .
<code>a <= b</code>	boolean	The cube <code>a</code> is less than or equal to the cube <code>b</code> .
<code>a > b</code>	boolean	The cube <code>a</code> is greater than the cube <code>b</code> .
<code>a >= b</code>	boolean	The cube <code>a</code> is greater than or equal to the cube <code>b</code> .
<code>a <> b</code>	boolean	The cube <code>a</code> is not equal to the cube <code>b</code> .
<code>a -> n</code>	float8	Get n -th coordinate of cube (counting from 1).
<code>a ~> n</code>	float8	Get n -th coordinate of cube in following way: $n = 2 * k - 1$ means lower bound of k -th dimension, $n = 2 * k$ means upper bound of k -th dimension. Negative n denotes the inverse value of the corresponding positive coordinate. This operator is designed for KNN-GiST support.
<code>a <-> b</code>	float8	Euclidean distance between <code>a</code> and <code>b</code> .
<code>a <#> b</code>	float8	Taxicab (L-1 metric) distance between <code>a</code> and <code>b</code> .
<code>a <=> b</code>	float8	Chebyshev (L-inf metric) distance between <code>a</code> and <code>b</code> .

(Before PostgreSQL 8.2, the containment operators @> and <@ were respectively called @ and ~. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The scalar ordering operators (<, >=, etc) do not make a lot of sense for any practical purpose but sorting. These operators first compare the first coordinates, and if those are equal, compare the second coordinates, etc. They exist mainly to support the b-tree index operator class for cube, which can be useful for example if you would like a UNIQUE constraint on a cube column.

The cube module also provides a GiST index operator class for cube values. A cube GiST index can be used to search for values using the =, &&, @>, and <@ operators in WHERE clauses.

In addition, a cube GiST index can be used to find nearest neighbors using the metric operators <->, <#>, and <=#> in ORDER BY clauses. For example, the nearest neighbor of the 3-D point (0.5, 0.5, 0.5) could be found efficiently with:

```
SELECT c FROM test ORDER BY c <-> cube(array[0.5,0.5,0.5]) LIMIT 1;
```

The ~> operator can also be used in this way to efficiently retrieve the first few values sorted by a selected coordinate. For example, to get the first few cubes ordered by the first coordinate (lower left corner) ascending one could use the following query:

```
SELECT c FROM test ORDER BY c ~> 1 LIMIT 5;
```

And to get 2-D cubes ordered by the first coordinate of the upper right corner descending:

```
SELECT c FROM test ORDER BY c ~> 3 DESC LIMIT 5;
```

Table F.4 shows the available functions.

Table F.4. Cube Functions

Function	Result	Description	Example
cube(float8)	cube	Makes a one dimensional cube with both coordinates the same.	cube(1) == '(1)'
cube(float8, float8)	cube	Makes a one dimensional cube.	cube(1,2) == '(1),(2)'
cube(float8[])	cube	Makes a zero-volume cube using the coordinates defined by the array.	cube(ARRAY[1,2]) == '(1,2)'
cube(float8[], float8[])	cube	Makes a cube with upper right and lower left coordinates as defined by the two arrays, which must be of the same length.	cube(ARRAY[1,2], ARRAY[3,4]) == '(1,2),(3,4)'
cube(cube, float8)	cube	Makes a new cube by adding a dimension on to an existing cube, with the same values for both endpoints of the new coordinate. This is useful for building cubes piece	cube('(1,2),(3,4)::cube, 5) == '(1,2,5),(3,4,5)'

Function	Result	Description	Example
		by piece from calculated values.	
<code>cube(cube, float8, float8)</code>	cube	Makes a new cube by adding a dimension on to an existing cube. This is useful for building cubes piece by piece from calculated values.	<code>cube(' (1,2), (3,4) '::cube, 5, 6) == ' (1,2,5), (3,4,6) '</code>
<code>cube_dim(cube)</code>	integer	Returns the number of dimensions of the cube.	<code>cube_dim(' (1,2), (3,4) ') == '2'</code>
<code>cube_ll_coord(cube, integer)</code>	float8	Returns the <i>n</i> -th coordinate value for the lower left corner of the cube.	<code>cube_ll_coord(' (1,2), (3,4) ', 2) == '2'</code>
<code>cube_ur_coord(cube, integer)</code>	float8	Returns the <i>n</i> -th coordinate value for the upper right corner of the cube.	<code>cube_ur_coord(' (1,2), (3,4) ', 2) == '4'</code>
<code>cube_is_point(cube)</code>	boolean	Returns true if the cube is a point, that is, the two defining corners are the same.	
<code>cube_distance(cube, cube)</code>	float8	Returns the distance between two cubes. If both cubes are points, this is the normal distance function.	
<code>cube_subset(cube, integer[])</code>	cube	Makes a new cube from an existing cube, using a list of dimension indexes from an array. Can be used to extract the endpoints of a single dimension, or to drop dimensions, or to reorder them as desired.	<code>cube_subset(cube(' (1,3,5), (6,7,8) '), ARRAY[2]) == ' (3), (7) '</code> <code>cube_subset(cube(' (1,3,5), (6,7,8) '), ARRAY[3,2,1,1]) == ' (5,3,1,1), (8,7,6,6) '</code>
<code>cube_union(cube, cube)</code>	cube	Produces the union of two cubes.	
<code>cube_inter(cube, cube)</code>	cube	Produces the intersection of two cubes.	
<code>cube_enlarge(cube, r double, n integer)</code>	cube	Increases the size of the cube by the specified radius <i>r</i> in at least <i>n</i> dimensions. If the radius is negative the cube is shrunk instead. All defined dimensions are changed by the radius <i>r</i> . Lower-left coordinates are decreased by <i>r</i> and upper-right coordinates are increased by <i>r</i> . If a lower-left coordinate is increased to more than the cor-	<code>cube_enlarge(' (1,2), (3,4) ', 0.5, 3) == ' (0.5,1.5,-0.5), (3.5,4.5,0.5) '</code>

Function	Result	Description	Example
		<p>responding upper-right coordinate (this can only happen when $r < 0$) than both coordinates are set to their average. If n is greater than the number of defined dimensions and the cube is being enlarged ($r > 0$), then extra dimensions are added to make n altogether; 0 is used as the initial value for the extra coordinates. This function is useful for creating bounding boxes around a point for searching for nearby points.</p>	

F.9.4. Defaults

I believe this union:

```
select cube_union('(0,5,2),(2,3,1)', '0');
cube_union
-----
(0, 0, 0),(2, 5, 2)
(1 row)
```

does not contradict common sense, neither does the intersection

```
select cube_inter('(0,-1),(1,1)', '(-2),(2)');
cube_inter
-----
(0, 0),(1, 0)
(1 row)
```

In all binary operations on differently-dimensional cubes, I assume the lower-dimensional one to be a Cartesian projection, i. e., having zeroes in place of coordinates omitted in the string representation. The above examples are equivalent to:

```
cube_union('(0,5,2),(2,3,1)', '(0,0,0),(0,0,0)');
cube_inter('(0,-1),(1,1)', '(-2,0),(2,0)');
```

The following containment predicate uses the point syntax, while in fact the second argument is internally represented by a box. This syntax makes it unnecessary to define a separate point type and functions for (box,point) predicates.

```
select cube_contains('(0,0),(1,1)', '0.5,0.5');
cube_contains
-----
t
```

(1 row)

F.9.5. Notes

For examples of usage, see the regression test `sql/cube.sql`.

To make it harder for people to break things, there is a limit of 100 on the number of dimensions of cubes. This is set in `cubedata.h` if you need something bigger.

F.9.6. Credits

Original author: Gene Selkov, Jr. <selkovjr@mcs.anl.gov>, Mathematics and Computer Science Division, Argonne National Laboratory.

My thanks are primarily to Prof. Joe Hellerstein (<http://db.cs.berkeley.edu/jmh/>) for elucidating the gist of the GiST (<http://gist.cs.berkeley.edu/>), and to his former student Andy Dong for his example written for `Illustra`. I am also grateful to all Postgres developers, present and past, for enabling myself to create my own world and live undisturbed in it. And I would like to acknowledge my gratitude to Argonne Lab and to the U.S. Department of Energy for the years of faithful support of my database research.

Minor updates to this package were made by Bruno Wolff III <bruno@wolff.to> in August/September of 2002. These include changing the precision from single precision to double precision and adding some new functions.

Additional updates were made by Joshua Reich <josh@root.net> in July 2006. These include `cube(float8[], float8[])` and cleaning up the code to use the V1 call protocol instead of the deprecated V0 protocol.

F.10. dblink

`dblink` is a module that supports connections to other PostgreSQL databases from within a database session.

See also `postgres_fdw`, which provides roughly the same functionality using a more modern and standards-compliant infrastructure.

dblink_connect

`dblink_connect` — opens a persistent connection to a remote database

Synopsis

```
dblink_connect(text connstr) returns text
dblink_connect(text connname, text connstr) returns text
```

Description

`dblink_connect()` establishes a connection to a remote PostgreSQL database. The server and database to be contacted are identified through a standard libpq connection string. Optionally, a name can be assigned to the connection. Multiple named connections can be open at once, but only one unnamed connection is permitted at a time. The connection will persist until closed or until the database session is ended.

The connection string may also be the name of an existing foreign server. It is recommended to use the foreign-data wrapper `dblink_fdw` when defining the foreign server. See the example below, as well as `CREATE SERVER` and `CREATE USER MAPPING`.

Arguments

connname

The name to use for this connection; if omitted, an unnamed connection is opened, replacing any existing unnamed connection.

connstr

libpq-style connection info string, for example `hostaddr=127.0.0.1 port=5432 dbname=mydb user=postgres password=mypasswd options=-csearch_path=`. For details see Section 33.1.1. Alternatively, the name of a foreign server.

Return Value

Returns status, which is always OK (since any error causes the function to throw an error instead of returning).

Notes

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin each session by removing publicly-writable schemas from `search_path`. One could, for example, add `options=-csearch_path=` to *connstr*. This consideration is not specific to `dblink`; it applies to every interface for executing arbitrary SQL commands.

Only superusers may use `dblink_connect` to create non-password-authenticated connections. If non-superusers need this capability, use `dblink_connect_u` instead.

It is unwise to choose connection names that contain equal signs, as this opens a risk of confusion with connection info strings in other `dblink` functions.

Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
 dblink_connect
-----
```

```
OK
(1 row)
```

```
SELECT dblink_connect('myconn', 'dbname=postgres options=-
csearch_path=');
dblink_connect
```

```
-----
OK
(1 row)
```

```
-- FOREIGN DATA WRAPPER functionality
-- Note: local connection must require password authentication for
-- this to work properly
-- Otherwise, you will receive the following error from
-- dblink_connect():
--
```

```
-----
-- ERROR: password is required
-- DETAIL: Non-superuser cannot connect if the server does
-- not request a password.
-- HINT: Target server's authentication method must be
-- changed.
```

```
CREATE SERVER fdtest FOREIGN DATA WRAPPER dblink_fdw OPTIONS
(hostaddr '127.0.0.1', dbname 'contrib_regression');
```

```
CREATE USER regress_dblink_user WITH PASSWORD 'secret';
CREATE USER MAPPING FOR regress_dblink_user SERVER fdtest OPTIONS
(user 'regress_dblink_user', password 'secret');
GRANT USAGE ON FOREIGN SERVER fdtest TO regress_dblink_user;
GRANT SELECT ON TABLE foo TO regress_dblink_user;
```

```
\set ORIGINAL_USER :USER
\c - regress_dblink_user
SELECT dblink_connect('myconn', 'fdtest');
dblink_connect
```

```
-----
OK
(1 row)
```

```
SELECT * FROM dblink('myconn', 'SELECT * FROM foo') AS t(a int, b
text, c text[]);
```

```
 a | b | c
-----+-----
 0 | a | {a0,b0,c0}
 1 | b | {a1,b1,c1}
 2 | c | {a2,b2,c2}
 3 | d | {a3,b3,c3}
 4 | e | {a4,b4,c4}
 5 | f | {a5,b5,c5}
 6 | g | {a6,b6,c6}
 7 | h | {a7,b7,c7}
 8 | i | {a8,b8,c8}
 9 | j | {a9,b9,c9}
10 | k | {a10,b10,c10}
(11 rows)
```

```
\c - :ORIGINAL_USER
```

```
REVOKE USAGE ON FOREIGN SERVER fdtest FROM regress_dblink_user;  
REVOKE SELECT ON TABLE foo FROM regress_dblink_user;  
DROP USER MAPPING FOR regress_dblink_user SERVER fdtest;  
DROP USER regress_dblink_user;  
DROP SERVER fdtest;
```

dblink_connect_u

`dblink_connect_u` — opens a persistent connection to a remote database, insecurely

Synopsis

```
dblink_connect_u(text connstr) returns text  
dblink_connect_u(text connname, text connstr) returns text
```

Description

`dblink_connect_u()` is identical to `dblink_connect()`, except that it will allow non-superusers to connect using any authentication method.

If the remote server selects an authentication method that does not involve a password, then impersonation and subsequent escalation of privileges can occur, because the session will appear to have originated from the user as which the local PostgreSQL server runs. Also, even if the remote server does demand a password, it is possible for the password to be supplied from the server environment, such as a `~/ .pgpass` file belonging to the server's user. This opens not only a risk of impersonation, but the possibility of exposing a password to an untrustworthy remote server. Therefore, `dblink_connect_u()` is initially installed with all privileges revoked from `PUBLIC`, making it un-callable except by superusers. In some situations it may be appropriate to grant `EXECUTE` permission for `dblink_connect_u()` to specific users who are considered trustworthy, but this should be done with care. It is also recommended that any `~/ .pgpass` file belonging to the server's user *not* contain any records specifying a wildcard host name.

For further details see `dblink_connect()`.

dblink_disconnect

`dblink_disconnect` — closes a persistent connection to a remote database

Synopsis

```
dblink_disconnect() returns text
dblink_disconnect(text connname) returns text
```

Description

`dblink_disconnect()` closes a connection previously opened by `dblink_connect()`. The form with no arguments closes an unnamed connection.

Arguments

connname

The name of a named connection to be closed.

Return Value

Returns status, which is always OK (since any error causes the function to throw an error instead of returning).

Examples

```
SELECT dblink_disconnect();
 dblink_disconnect
-----
      OK
(1 row)

SELECT dblink_disconnect('myconn');
 dblink_disconnect
-----
      OK
(1 row)
```

dblink

`dblink` — executes a query in a remote database

Synopsis

```
dblink(text connname, text sql [, bool fail_on_error]) returns
  setof record
dblink(text connstr, text sql [, bool fail_on_error]) returns setof
  record
dblink(text sql [, bool fail_on_error]) returns setof record
```

Description

`dblink` executes a query (usually a `SELECT`, but it can be any SQL statement that returns rows) in a remote database.

When two `text` arguments are given, the first one is first looked up as a persistent connection's name; if found, the command is executed on that connection. If not found, the first argument is treated as a connection info string as for `dblink_connect`, and the indicated connection is made just for the duration of this command.

Arguments

connname

Name of the connection to use; omit this parameter to use the unnamed connection.

connstr

A connection info string, as previously described for `dblink_connect`.

sql

The SQL query that you wish to execute in the remote database, for example `select * from foo`.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a `NOTICE`, and the function returns no rows.

Return Value

The function returns the row(s) produced by the query. Since `dblink` can be used with any query, it is declared to return `record`, rather than specifying any particular set of columns. This means that you must specify the expected set of columns in the calling query — otherwise PostgreSQL would not know what to expect. Here is an example:

```
SELECT *
FROM dblink('dbname=mydb options=-csearch_path=',
            'select proname, prosrc from pg_proc')
AS t1(proname name, prosrc text)
WHERE proname LIKE 'bytea%';
```

The “alias” part of the FROM clause must specify the column names and types that the function will return. (Specifying column names in an alias is actually standard SQL syntax, but specifying column types is a PostgreSQL extension.) This allows the system to understand what * should expand to, and what pronom in the WHERE clause refers to, in advance of trying to execute the function. At run time, an error will be thrown if the actual query result from the remote database does not have the same number of columns shown in the FROM clause. The column names need not match, however, and dblink does not insist on exact type matches either. It will succeed so long as the returned data strings are valid input for the column type declared in the FROM clause.

Notes

A convenient way to use dblink with predetermined queries is to create a view. This allows the column type information to be buried in the view, instead of having to spell it out in every query. For example,

```
CREATE VIEW myremote_pg_proc AS
  SELECT *
    FROM dblink('dbname=postgres options=-csearch_path=',
                'select pronom, prosrc from pg_proc')
    AS t1(pronom name, prosrc text);

SELECT * FROM myremote_pg_proc WHERE pronom LIKE 'bytea%';
```

Examples

```
SELECT * FROM dblink('dbname=postgres options=-csearch_path=',
                    'select pronom, prosrc from pg_proc')
  AS t1(pronom name, prosrc text) WHERE pronom LIKE 'bytea%';
 pronom      |   prosrc
-----+-----
 byteacat    | byteacat
 byteaeq     | byteaeq
 bytealt     | bytealt
 byteale     | byteale
 byteagt     | byteagt
 byteage     | byteage
 byteane     | byteane
 byteacmp    | byteacmp
 bytealike   | bytealike
 byteanlike  | byteanlike
 byteain     | byteain
 byteaout    | byteaout
(12 rows)
```

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
 dblink_connect
-----
 OK
(1 row)
```

```
SELECT * FROM dblink('select pronom, prosrc from pg_proc')
  AS t1(pronom name, prosrc text) WHERE pronom LIKE 'bytea%';
 pronom      |   prosrc
-----+-----
 byteacat    | byteacat
 byteaeq     | byteaeq
```

```

bytealt      | bytealt
byteale      | byteale
byteagt      | byteagt
byteage      | byteage
byteane      | byteane
byteacmp     | byteacmp
bytealike    | bytealike
byteanlike   | byteanlike
byteain      | byteain
byteaout     | byteaout
(12 rows)

```

```

SELECT dblink_connect('myconn', 'dbname=regression options=-
csearch_path=');
 dblink_connect
-----
OK
(1 row)

```

```

SELECT * FROM dblink('myconn', 'select proname, prosrc from
pg_proc')
 AS t1(proname name, prosrc text) WHERE proname LIKE 'bytea%';
 proname      |   prosrc
-----+-----
bytearecv     | bytearecv
byteasend     | byteasend
byteale       | byteale
byteagt       | byteagt
byteage       | byteage
byteane       | byteane
byteacmp      | byteacmp
bytealike     | bytealike
byteanlike    | byteanlike
byteacat      | byteacat
byteaeq       | byteaeq
bytealt       | bytealt
byteain       | byteain
byteaout      | byteaout
(14 rows)

```

dblink_exec

`dblink_exec` — executes a command in a remote database

Synopsis

```
dblink_exec(text connname, text sql [, bool fail_on_error]) returns
  text
dblink_exec(text connstr, text sql [, bool fail_on_error]) returns
  text
dblink_exec(text sql [, bool fail_on_error]) returns text
```

Description

`dblink_exec` executes a command (that is, any SQL statement that doesn't return rows) in a remote database.

When two `text` arguments are given, the first one is first looked up as a persistent connection's name; if found, the command is executed on that connection. If not found, the first argument is treated as a connection info string as for `dblink_connect`, and the indicated connection is made just for the duration of this command.

Arguments

connname

Name of the connection to use; omit this parameter to use the unnamed connection.

connstr

A connection info string, as previously described for `dblink_connect`.

sql

The SQL command that you wish to execute in the remote database, for example `insert into foo values(0, 'a', '{ "a0", "b0", "c0" }')`.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to `ERROR`.

Return Value

Returns status, either the command's status string or `ERROR`.

Examples

```
SELECT dblink_connect('dbname=dblink_test_standby');
 dblink_connect
-----
OK
(1 row)
```

```
SELECT dblink_exec('insert into foo
values(21, 'z', '{a0,b0,c0}');');
dblink_exec
```

```
-----
INSERT 943366 1
(1 row)
```

```
SELECT dblink_connect('myconn', 'dbname=regression');
dblink_connect
```

```
-----
OK
(1 row)
```

```
SELECT dblink_exec('myconn', 'insert into foo
values(21, 'z', '{a0,b0,c0}');');
dblink_exec
```

```
-----
INSERT 6432584 1
(1 row)
```

```
SELECT dblink_exec('myconn', 'insert into pg_class values
('foo'),false);
NOTICE: sql error
DETAIL: ERROR: null value in column "relnamespace" violates not-
null constraint
```

```
dblink_exec
-----
ERROR
(1 row)
```

dblink_open

`dblink_open` — opens a cursor in a remote database

Synopsis

```
dblink_open(text cursorname, text sql [, bool fail_on_error])
  returns text
dblink_open(text connname, text cursorname, text sql [, bool
  fail_on_error]) returns text
```

Description

`dblink_open()` opens a cursor in a remote database. The cursor can subsequently be manipulated with `dblink_fetch()` and `dblink_close()`.

Arguments

connname

Name of the connection to use; omit this parameter to use the unnamed connection.

cursorname

The name to assign to this cursor.

sql

The `SELECT` statement that you wish to execute in the remote database, for example `select * from pg_class`.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a `NOTICE`, and the function's return value is set to `ERROR`.

Return Value

Returns status, either `OK` or `ERROR`.

Notes

Since a cursor can only persist within a transaction, `dblink_open` starts an explicit transaction block (`BEGIN`) on the remote side, if the remote side was not already within a transaction. This transaction will be closed again when the matching `dblink_close` is executed. Note that if you use `dblink_exec` to change data between `dblink_open` and `dblink_close`, and then an error occurs or you use `dblink_disconnect` before `dblink_close`, your change *will be lost* because the transaction will be aborted.

Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
dblink_connect
```

OK
(1 row)

```
SELECT dblink_open('foo', 'select proname, prosrc from pg_proc');  
dblink_open
```

OK
(1 row)

dblink_fetch

`dblink_fetch` — returns rows from an open cursor in a remote database

Synopsis

```
dblink_fetch(text cursorname, int howmany [, bool fail_on_error])
  returns setof record
dblink_fetch(text connname, text cursorname, int howmany [, bool
  fail_on_error]) returns setof record
```

Description

`dblink_fetch` fetches rows from a cursor previously established by `dblink_open`.

Arguments

connname

Name of the connection to use; omit this parameter to use the unnamed connection.

cursorname

The name of the cursor to fetch from.

howmany

The maximum number of rows to retrieve. The next *howmany* rows are fetched, starting at the current cursor position, moving forward. Once the cursor has reached its end, no more rows are produced.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

Return Value

The function returns the row(s) fetched from the cursor. To use this function, you will need to specify the expected set of columns, as previously discussed for `dblink`.

Notes

On a mismatch between the number of return columns specified in the FROM clause, and the actual number of columns returned by the remote cursor, an error will be thrown. In this event, the remote cursor is still advanced by as many rows as it would have been if the error had not occurred. The same is true for any other error occurring in the local query after the remote FETCH has been done.

Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
dblink_connect
-----
```

OK
(1 row)

```
SELECT dblink_open('foo', 'select proname, prosrc from pg_proc
where proname like ''bytea%'');
dblink_open
```

OK
(1 row)

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

funcname	source
byteacat	byteacat
byteacmp	byteacmp
byteaeq	byteaeq
byteage	byteage
byteagt	byteagt

(5 rows)

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

funcname	source
byteain	byteain
byteale	byteale
bytealike	bytealike
bytealt	bytealt
byteane	byteane

(5 rows)

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

funcname	source
byteanlike	byteanlike
byteaout	byteaout

(2 rows)

```
SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source
text);
```

funcname	source
----------	--------

(0 rows)

dblink_close

`dblink_close` — closes a cursor in a remote database

Synopsis

```
dblink_close(text cursorname [, bool fail_on_error]) returns text
dblink_close(text connname, text cursorname [, bool fail_on_error])
returns text
```

Description

`dblink_close` closes a cursor previously opened with `dblink_open`.

Arguments

connname

Name of the connection to use; omit this parameter to use the unnamed connection.

cursorname

The name of the cursor to close.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to ERROR.

Return Value

Returns status, either OK or ERROR.

Notes

If `dblink_open` started an explicit transaction block, and this is the last remaining open cursor in this connection, `dblink_close` will issue the matching COMMIT.

Examples

```
SELECT dblink_connect('dbname=postgres options=-csearch_path=');
 dblink_connect
-----
 OK
(1 row)

SELECT dblink_open('foo', 'select proname, prosrc from pg_proc');
 dblink_open
-----
 OK
(1 row)

SELECT dblink_close('foo');
```

dblink_close

OK
(1 row)

dblink_get_connections

`dblink_get_connections` — returns the names of all open named dblink connections

Synopsis

```
dblink_get_connections() returns text[]
```

Description

`dblink_get_connections` returns an array of the names of all open named dblink connections.

Return Value

Returns a text array of connection names, or NULL if none.

Examples

```
SELECT dblink_get_connections();
```

dblink_error_message

`dblink_error_message` — gets last error message on the named connection

Synopsis

```
dblink_error_message(text connname) returns text
```

Description

`dblink_error_message` fetches the most recent remote error message for a given connection.

Arguments

connname

Name of the connection to use.

Return Value

Returns last error message, or OK if there has been no error in this connection.

Notes

When asynchronous queries are initiated by `dblink_send_query`, the error message associated with the connection might not get updated until the server's response message is consumed. This typically means that `dblink_is_busy` or `dblink_get_result` should be called prior to `dblink_error_message`, so that any error generated by the asynchronous query will be visible.

Examples

```
SELECT dblink_error_message('dtest1');
```

dblink_send_query

`dblink_send_query` — sends an async query to a remote database

Synopsis

```
dblink_send_query(text connname, text sql) returns int
```

Description

`dblink_send_query` sends a query to be executed asynchronously, that is, without immediately waiting for the result. There must not be an async query already in progress on the connection.

After successfully dispatching an async query, completion status can be checked with `dblink_is_busy`, and the results are ultimately collected with `dblink_get_result`. It is also possible to attempt to cancel an active async query using `dblink_cancel_query`.

Arguments

connname

Name of the connection to use.

sql

The SQL statement that you wish to execute in the remote database, for example `select * from pg_class`.

Return Value

Returns 1 if the query was successfully dispatched, 0 otherwise.

Examples

```
SELECT dblink_send_query('dtest1', 'SELECT * FROM foo WHERE f1 < 3');
```

dblink_is_busy

`dblink_is_busy` — checks if connection is busy with an async query

Synopsis

```
dblink_is_busy(text connname) returns int
```

Description

`dblink_is_busy` tests whether an async query is in progress.

Arguments

connname

Name of the connection to check.

Return Value

Returns 1 if connection is busy, 0 if it is not busy. If this function returns 0, it is guaranteed that `dblink_get_result` will not block.

Examples

```
SELECT dblink_is_busy('dtest1');
```

dblink_get_notify

dblink_get_notify — retrieve async notifications on a connection

Synopsis

```
dblink_get_notify() returns setof (notify_name text, be_pid int,
  extra text)
dblink_get_notify(text connname) returns setof (notify_name text,
  be_pid int, extra text)
```

Description

dblink_get_notify retrieves notifications on either the unnamed connection, or on a named connection if specified. To receive notifications via dblink, LISTEN must first be issued, using dblink_exec. For details see LISTEN and NOTIFY.

Arguments

connname

The name of a named connection to get notifications on.

Return Value

Returns setof (notify_name text, be_pid int, extra text), or an empty set if none.

Examples

```
SELECT dblink_exec('LISTEN virtual');
dblink_exec
-----
LISTEN
(1 row)

SELECT * FROM dblink_get_notify();
 notify_name | be_pid | extra
-----+-----+-----
(0 rows)

NOTIFY virtual;
NOTIFY

SELECT * FROM dblink_get_notify();
 notify_name | be_pid | extra
-----+-----+-----
 virtual    | 1229   |
(1 row)
```

dblink_get_result

`dblink_get_result` — gets an async query result

Synopsis

```
dblink_get_result(text connname [, bool fail_on_error]) returns
  setof record
```

Description

`dblink_get_result` collects the results of an asynchronous query previously sent with `dblink_send_query`. If the query is not already completed, `dblink_get_result` will wait until it is.

Arguments

connname

Name of the connection to use.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

Return Value

For an async query (that is, a SQL statement returning rows), the function returns the row(s) produced by the query. To use this function, you will need to specify the expected set of columns, as previously discussed for `dblink`.

For an async command (that is, a SQL statement not returning rows), the function returns a single row with a single text column containing the command's status string. It is still necessary to specify that the result will have a single text column in the calling FROM clause.

Notes

This function *must* be called if `dblink_send_query` returned 1. It must be called once for each query sent, and one additional time to obtain an empty set result, before the connection can be used again.

When using `dblink_send_query` and `dblink_get_result`, `dblink` fetches the entire remote query result before returning any of it to the local query processor. If the query returns a large number of rows, this can result in transient memory bloat in the local session. It may be better to open such a query as a cursor with `dblink_open` and then fetch a manageable number of rows at a time. Alternatively, use plain `dblink()`, which avoids memory bloat by spooling large result sets to disk.

Examples

```
contrib_regression=# SELECT dblink_connect('dtest1',
  'dbname=contrib_regression');
dblink_connect
-----
```

```

OK
(1 row)

contrib_regression=# SELECT * FROM
contrib_regression=# dblink_send_query('dtest1', 'select * from foo
  where f1 < 3') AS t1;
 t1
----
  1
(1 row)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
 t1(f1 int, f2 text, f3 text[]);
 f1 | f2 |      f3
----+-----+-----
  0 | a  | {a0,b0,c0}
  1 | b  | {a1,b1,c1}
  2 | c  | {a2,b2,c2}
(3 rows)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
 t1(f1 int, f2 text, f3 text[]);
 f1 | f2 | f3
----+-----+-----
(0 rows)

contrib_regression=# SELECT * FROM
contrib_regression=# dblink_send_query('dtest1', 'select * from foo
  where f1 < 3; select * from foo where f1 > 6') AS t1;
 t1
----
  1
(1 row)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
 t1(f1 int, f2 text, f3 text[]);
 f1 | f2 |      f3
----+-----+-----
  0 | a  | {a0,b0,c0}
  1 | b  | {a1,b1,c1}
  2 | c  | {a2,b2,c2}
(3 rows)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
 t1(f1 int, f2 text, f3 text[]);
 f1 | f2 |      f3
----+-----+-----
  7 | h  | {a7,b7,c7}
  8 | i  | {a8,b8,c8}
  9 | j  | {a9,b9,c9}
 10 | k  | {a10,b10,c10}
(4 rows)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS
 t1(f1 int, f2 text, f3 text[]);
 f1 | f2 | f3
----+-----+-----
(0 rows)

```

dblink_cancel_query

`dblink_cancel_query` — cancels any active query on the named connection

Synopsis

```
dblink_cancel_query(text connname) returns text
```

Description

`dblink_cancel_query` attempts to cancel any query that is in progress on the named connection. Note that this is not certain to succeed (since, for example, the remote query might already have finished). A cancel request simply improves the odds that the query will fail soon. You must still complete the normal query protocol, for example by calling `dblink_get_result`.

Arguments

connname

Name of the connection to use.

Return Value

Returns OK if the cancel request has been sent, or the text of an error message on failure.

Examples

```
SELECT dblink_cancel_query('dtest1');
```

dblink_get_pkey

`dblink_get_pkey` — returns the positions and field names of a relation's primary key fields

Synopsis

```
dblink_get_pkey(text relname) returns setof dblink_pkey_results
```

Description

`dblink_get_pkey` provides information about the primary key of a relation in the local database. This is sometimes useful in generating queries to be sent to remote databases.

Arguments

relname

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

Return Value

Returns one row for each primary key field, or no rows if the relation has no primary key. The result row type is defined as

```
CREATE TYPE dblink_pkey_results AS (position int, colname text);
```

The `position` column simply runs from 1 to *N*; it is the number of the field within the primary key, not the number within the table's columns.

Examples

```
CREATE TABLE foobar (  
    f1 int,  
    f2 int,  
    f3 int,  
    PRIMARY KEY (f1, f2, f3)  
);  
CREATE TABLE  
  
SELECT * FROM dblink_get_pkey('foobar');  
 position | colname  
-----+-----  
         1 | f1  
         2 | f2  
         3 | f3  
(3 rows)
```

dblink_build_sql_insert

`dblink_build_sql_insert` — builds an INSERT statement using a local tuple, replacing the primary key field values with alternative supplied values

Synopsis

```
dblink_build_sql_insert(text relname,  
                        int2vector primary_key_attnums,  
                        integer num_primary_key_atts,  
                        text[] src_pk_att_vals_array,  
                        text[] tgt_pk_att_vals_array) returns text
```

Description

`dblink_build_sql_insert` can be useful in doing selective replication of a local table to a remote database. It selects a row from the local table based on primary key, and then builds a SQL INSERT command that will duplicate that row, but with the primary key values replaced by the values in the last argument. (To make an exact copy of the row, just specify the same values for the last two arguments.)

Arguments

relname

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

primary_key_attnums

Attribute numbers (1-based) of the primary key fields, for example `1 2`.

num_primary_key_atts

The number of primary key fields.

src_pk_att_vals_array

Values of the primary key fields to be used to look up the local tuple. Each field is represented in text form. An error is thrown if there is no local row with these primary key values.

tgt_pk_att_vals_array

Values of the primary key fields to be placed in the resulting INSERT command. Each field is represented in text form.

Return Value

Returns the requested SQL statement as text.

Notes

As of PostgreSQL 9.0, the attribute numbers in *primary_key_attnums* are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous

versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

Examples

```
SELECT dblink_build_sql_insert('foo', '1 2', 2, '{"1", "a"}',
    '{"1", "b'a"}');
          dblink_build_sql_insert
-----
INSERT INTO foo(f1,f2,f3) VALUES('1','b'a','1')
(1 row)
```

dblink_build_sql_delete

`dblink_build_sql_delete` — builds a DELETE statement using supplied values for primary key field values

Synopsis

```
dblink_build_sql_delete(text relname,  
                        int2vector primary_key_attnums,  
                        integer num_primary_key_atts,  
                        text[] tgt_pk_att_vals_array) returns text
```

Description

`dblink_build_sql_delete` can be useful in doing selective replication of a local table to a remote database. It builds a SQL DELETE command that will delete the row with the given primary key values.

Arguments

relname

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

primary_key_attnums

Attribute numbers (1-based) of the primary key fields, for example `1 2`.

num_primary_key_atts

The number of primary key fields.

tgt_pk_att_vals_array

Values of the primary key fields to be used in the resulting DELETE command. Each field is represented in text form.

Return Value

Returns the requested SQL statement as text.

Notes

As of PostgreSQL 9.0, the attribute numbers in *primary_key_attnums* are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

Examples

```
SELECT dblink_build_sql_delete('"MyFoo"', '1 2', 2, '{"1", "b"}');  
       dblink_build_sql_delete
```

```
-----  
DELETE FROM "MyFoo" WHERE f1='1' AND f2='b'  
(1 row)
```

dblink_build_sql_update

`dblink_build_sql_update` — builds an UPDATE statement using a local tuple, replacing the primary key field values with alternative supplied values

Synopsis

```
dblink_build_sql_update(text relname,  
                        int2vector primary_key_attnums,  
                        integer num_primary_key_atts,  
                        text[] src_pk_att_vals_array,  
                        text[] tgt_pk_att_vals_array) returns text
```

Description

`dblink_build_sql_update` can be useful in doing selective replication of a local table to a remote database. It selects a row from the local table based on primary key, and then builds a SQL UPDATE command that will duplicate that row, but with the primary key values replaced by the values in the last argument. (To make an exact copy of the row, just specify the same values for the last two arguments.) The UPDATE command always assigns all fields of the row — the main difference between this and `dblink_build_sql_insert` is that it's assumed that the target row already exists in the remote table.

Arguments

relname

Name of a local relation, for example `foo` or `myschema.mytab`. Include double quotes if the name is mixed-case or contains special characters, for example `"FooBar"`; without quotes, the string will be folded to lower case.

primary_key_attnums

Attribute numbers (1-based) of the primary key fields, for example `1 2`.

num_primary_key_atts

The number of primary key fields.

src_pk_att_vals_array

Values of the primary key fields to be used to look up the local tuple. Each field is represented in text form. An error is thrown if there is no local row with these primary key values.

tgt_pk_att_vals_array

Values of the primary key fields to be placed in the resulting UPDATE command. Each field is represented in text form.

Return Value

Returns the requested SQL statement as text.

Notes

As of PostgreSQL 9.0, the attribute numbers in *primary_key_attnums* are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous

versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

Examples

```
SELECT dblink_build_sql_update('foo', '1 2', 2, '{"1", "a"}',
    '{"1", "b"}');
          dblink_build_sql_update
-----
UPDATE foo SET f1='1',f2='b',f3='1' WHERE f1='1' AND f2='b'
(1 row)
```

F.11. dict_int

`dict_int` is an example of an add-on dictionary template for full-text search. The motivation for this example dictionary is to control the indexing of integers (signed and unsigned), allowing such numbers to be indexed while preventing excessive growth in the number of unique words, which greatly affects the performance of searching.

F.11.1. Configuration

The dictionary accepts two options:

- The `maxlen` parameter specifies the maximum number of digits allowed in an integer word. The default value is 6.
- The `rejectlong` parameter specifies whether an overlength integer should be truncated or ignored. If `rejectlong` is `false` (the default), the dictionary returns the first `maxlen` digits of the integer. If `rejectlong` is `true`, the dictionary treats an overlength integer as a stop word, so that it will not be indexed. Note that this also means that such an integer cannot be searched for.

F.11.2. Usage

Installing the `dict_int` extension creates a text search template `intdict_template` and a dictionary `intdict` based on it, with the default parameters. You can alter the parameters, for example

```
mydb# ALTER TEXT SEARCH DICTIONARY intdict (MAXLEN = 4, REJECTLONG
= true);
ALTER TEXT SEARCH DICTIONARY
```

or create new dictionaries based on the template.

To test the dictionary, you can try

```
mydb# select ts_lexize('intdict', '12345678');
   ts_lexize
-----
 {123456}
```

but real-world usage will involve including it in a text search configuration as described in Chapter 12. That might look like this:

```
ALTER TEXT SEARCH CONFIGURATION english
    ALTER MAPPING FOR int, uint WITH intdict;
```

F.12. dict_xsyn

`dict_xsyn` (Extended Synonym Dictionary) is an example of an add-on dictionary template for full-text search. This dictionary type replaces words with groups of their synonyms, and so makes it possible to search for a word using any of its synonyms.

F.12.1. Configuration

A `dict_xsyn` dictionary accepts the following options:

- `matchorig` controls whether the original word is accepted by the dictionary. Default is `true`.
- `matchsynonyms` controls whether the synonyms are accepted by the dictionary. Default is `false`.
- `keeporig` controls whether the original word is included in the dictionary's output. Default is `true`.
- `keepsynonyms` controls whether the synonyms are included in the dictionary's output. Default is `true`.
- `rules` is the base name of the file containing the list of synonyms. This file must be stored in `$$SHAREDIR/tsearch_data/` (where `$$SHAREDIR` means the PostgreSQL installation's shared-data directory). Its name must end in `.rules` (which is not to be included in the `rules` parameter).

The rules file has the following format:

- Each line represents a group of synonyms for a single word, which is given first on the line. Synonyms are separated by whitespace, thus:

```
word syn1 syn2 syn3
```

- The sharp (`#`) sign is a comment delimiter. It may appear at any position in a line. The rest of the line will be skipped.

Look at `xsyn_sample.rules`, which is installed in `$$SHAREDIR/tsearch_data/`, for an example.

F.12.2. Usage

Installing the `dict_xsyn` extension creates a text search template `xsyn_template` and a dictionary `xsyn` based on it, with default parameters. You can alter the parameters, for example

```
mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
      KEEPORIG=false);
ALTER TEXT SEARCH DICTIONARY
```

or create new dictionaries based on the template.

To test the dictionary, you can try

```
mydb=# SELECT ts_lexize('xsyn', 'word');
       ts_lexize
-----
```

```
{syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
KEEPORIG=true);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'word');
         ts_lexize
-----
 {word,syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
KEEPORIG=false, MATCHSYNONYMS=true);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'syn1');
         ts_lexize
-----
 {syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules',
KEEPORIG=true, MATCHORIG=false, KEEPSYNONYMS=false);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'syn1');
         ts_lexize
-----
 {word}
```

Real-world usage will involve including it in a text search configuration as described in Chapter 12. That might look like this:

```
ALTER TEXT SEARCH CONFIGURATION english
ALTER MAPPING FOR word, asciiword WITH xsyn, english_stem;
```

F.13. earthdistance

The `earthdistance` module provides two different approaches to calculating great circle distances on the surface of the Earth. The one described first depends on the `cube` module (which *must* be installed before `earthdistance` can be installed). The second one is based on the built-in `point` data type, using longitude and latitude for the coordinates.

In this module, the Earth is assumed to be perfectly spherical. (If that's too inaccurate for you, you might want to look at the PostGIS¹ project.)

F.13.1. Cube-Based Earth Distances

Data is stored in cubes that are points (both corners are the same) using 3 coordinates representing the x, y, and z distance from the center of the Earth. A domain `earth` over `cube` is provided, which includes constraint checks that the value meets these restrictions and is reasonably close to the actual surface of the Earth.

The radius of the Earth is obtained from the `earth()` function. It is given in meters. But by changing this one function you can change the module to use some other units, or to use a different value of the radius that you feel is more appropriate.

¹ <http://postgis.net/>

This package has applications to astronomical databases as well. Astronomers will probably want to change `earth()` to return a radius of $180/\pi()$ so that distances are in degrees.

Functions are provided to support input in latitude and longitude (in degrees), to support output of latitude and longitude, to calculate the great circle distance between two points and to easily specify a bounding box usable for index searches.

The provided functions are shown in Table F.5.

Table F.5. Cube-Based Earthdistance Functions

Function	Returns	Description
<code>earth()</code>	float8	Returns the assumed radius of the Earth.
<code>sec_to_gc(float8)</code>	float8	Converts the normal straight line (secant) distance between two points on the surface of the Earth to the great circle distance between them.
<code>gc_to_sec(float8)</code>	float8	Converts the great circle distance between two points on the surface of the Earth to the normal straight line (secant) distance between them.
<code>ll_to_earth(float8, float8)</code>	earth	Returns the location of a point on the surface of the Earth given its latitude (argument 1) and longitude (argument 2) in degrees.
<code>latitude(earth)</code>	float8	Returns the latitude in degrees of a point on the surface of the Earth.
<code>longitude(earth)</code>	float8	Returns the longitude in degrees of a point on the surface of the Earth.
<code>earth_distance(earth, earth)</code>	float8	Returns the great circle distance between two points on the surface of the Earth.
<code>earth_box(earth, float8)</code>	cube	Returns a box suitable for an indexed search using the cube <code>@></code> operator for points within a given great circle distance of a location. Some points in this box are further than the specified great circle distance from the location, so a second check using <code>earth_distance</code> should be included in the query.

F.13.2. Point-Based Earth Distances

The second part of the module relies on representing Earth locations as values of type `point`, in which the first component is taken to represent longitude in degrees, and the second component is taken to represent latitude in degrees. Points are taken as (longitude, latitude) and not vice versa because longitude is closer to the intuitive idea of x-axis and latitude to y-axis.

A single operator is provided, shown in Table F.6.

Table F.6. Point-Based Earthdistance Operators

Operator	Returns	Description
<code>point <@> point</code>	<code>float8</code>	Gives the distance in statute miles between two points on the Earth's surface.

Note that unlike the `cube`-based part of the module, units are hardwired here: changing the `earth()` function will not affect the results of this operator.

One disadvantage of the longitude/latitude representation is that you need to be careful about the edge conditions near the poles and near ± 180 degrees of longitude. The `cube`-based representation avoids these discontinuities.

F.14. `file_fdw`

The `file_fdw` module provides the foreign-data wrapper `file_fdw`, which can be used to access data files in the server's file system, or to execute programs on the server and read their output. The data file or program output must be in a format that can be read by `COPY FROM`; see `COPY` for details. Access to data files is currently read-only.

A foreign table created using this wrapper can have the following options:

`filename`

Specifies the file to be read. Must be an absolute path name. Either `filename` or `program` must be specified, but not both.

`program`

Specifies the command to be executed. The standard output of this command will be read as though `COPY FROM PROGRAM` were used. Either `program` or `filename` must be specified, but not both.

`format`

Specifies the data format, the same as `COPY`'s `FORMAT` option.

`header`

Specifies whether the data has a header line, the same as `COPY`'s `HEADER` option.

`delimiter`

Specifies the data delimiter character, the same as `COPY`'s `DELIMITER` option.

`quote`

Specifies the data quote character, the same as `COPY`'s `QUOTE` option.

`escape`

Specifies the data escape character, the same as `COPY`'s `ESCAPE` option.

`null`

Specifies the data null string, the same as `COPY`'s `NULL` option.

`encoding`

Specifies the data encoding, the same as `COPY`'s `ENCODING` option.

Note that while `COPY` allows options such as `HEADER` to be specified without a corresponding value, the foreign table option syntax requires a value to be present in all cases. To activate `COPY` options typically written without a value, you can pass the value `TRUE`, since all such options are Booleans.

A column of a foreign table created using this wrapper can have the following options:

`force_not_null`

This is a Boolean option. If true, it specifies that values of the column should not be matched against the null string (that is, the table-level `null` option). This has the same effect as listing the column in `COPY`'s `FORCE_NOT_NULL` option.

`force_null`

This is a Boolean option. If true, it specifies that values of the column which match the null string are returned as `NULL` even if the value is quoted. Without this option, only unquoted values matching the null string are returned as `NULL`. This has the same effect as listing the column in `COPY`'s `FORCE_NULL` option.

`COPY`'s `FORCE_QUOTE` option is currently not supported by `file_fdw`.

These options can only be specified for a foreign table or its columns, not in the options of the `file_fdw` foreign-data wrapper, nor in the options of a server or user mapping using the wrapper.

Changing table-level options requires being a superuser or having the privileges of the default role `pg_read_server_files` (to use a filename) or the default role `pg_execute_server_program` (to use a program), for security reasons: only certain users should be able to control which file is read or which program is run. In principle regular users could be allowed to change the other options, but that's not supported at present.

When specifying the `program` option, keep in mind that the option string is executed by the shell. If you need to pass any arguments to the command that come from an untrusted source, you must be careful to strip or escape any characters that might have special meaning to the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in it.

For a foreign table using `file_fdw`, `EXPLAIN` shows the name of the file to be read or program to be run. For a file, unless `COSTS OFF` is specified, the file size (in bytes) is shown as well.

Example F.1. Create a Foreign Table for PostgreSQL CSV Logs

One of the obvious uses for `file_fdw` is to make the PostgreSQL activity log available as a table for querying. To do this, first you must be logging to a CSV file, which here we will call `pglog.csv`. First, install `file_fdw` as an extension:

```
CREATE EXTENSION file_fdw;
```

Then create a foreign server:

```
CREATE SERVER pglog FOREIGN DATA WRAPPER file_fdw;
```

Now you are ready to create the foreign data table. Using the `CREATE FOREIGN TABLE` command, you will need to define the columns for the table, the CSV file name, and its format:

```
CREATE FOREIGN TABLE pglog (  
    log_time timestamp(3) with time zone,  
    user_name text,
```

```
database_name text,  
process_id integer,  
connection_from text,  
session_id text,  
session_line_num bigint,  
command_tag text,  
session_start_time timestamp with time zone,  
virtual_transaction_id text,  
transaction_id bigint,  
error_severity text,  
sql_state_code text,  
message text,  
detail text,  
hint text,  
internal_query text,  
internal_query_pos integer,  
context text,  
query text,  
query_pos integer,  
location text,  
application_name text  
) SERVER pglog  
OPTIONS ( filename '/home/josh/data/log/pglog.csv', format 'csv' );
```

That's it — now you can query your log directly. In production, of course, you would need to define some way to deal with log rotation.

F.15. fuzzystmatch

The `fuzzystmatch` module provides several functions to determine similarities and distance between strings.

Caution

At present, the `soundex`, `metaphone`, `dmetaphone`, and `dmetaphone_alt` functions do not work well with multibyte encodings (such as UTF-8).

F.15.1. Soundex

The Soundex system is a method of matching similar-sounding names by converting them to the same code. It was initially used by the United States Census in 1880, 1900, and 1910. Note that Soundex is not very useful for non-English names.

The `fuzzystmatch` module provides two functions for working with Soundex codes:

```
soundex(text) returns text  
difference(text, text) returns int
```

The `soundex` function converts a string to its Soundex code. The `difference` function converts two strings to their Soundex codes and then reports the number of matching code positions. Since Soundex codes have four characters, the result ranges from zero to four, with zero being no match and four being an exact match. (Thus, the function is misnamed — `similarity` would have been a better name.)

Here are some usage examples:

```
SELECT soundex('hello world!');

SELECT soundex('Anne'), soundex('Ann'), difference('Anne', 'Ann');
SELECT soundex('Anne'), soundex('Andrew'), difference('Anne',
  'Andrew');
SELECT soundex('Anne'), soundex('Margaret'), difference('Anne',
  'Margaret');

CREATE TABLE s (nm text);

INSERT INTO s VALUES ('john');
INSERT INTO s VALUES ('joan');
INSERT INTO s VALUES ('wobbly');
INSERT INTO s VALUES ('jack');

SELECT * FROM s WHERE soundex(nm) = soundex('john');

SELECT * FROM s WHERE difference(s.nm, 'john') > 2;
```

F.15.2. Levenshtein

This function calculates the Levenshtein distance between two strings:

```
levenshtein(text source, text target, int ins_cost, int del_cost,
  int sub_cost) returns int
levenshtein(text source, text target) returns int
levenshtein_less_equal(text source, text target, int ins_cost, int
  del_cost, int sub_cost, int max_d) returns int
levenshtein_less_equal(text source, text target, int max_d) returns
  int
```

Both source and target can be any non-null string, with a maximum of 255 characters. The cost parameters specify how much to charge for a character insertion, deletion, or substitution, respectively. You can omit the cost parameters, as in the second version of the function; in that case they all default to 1.

`levenshtein_less_equal` is an accelerated version of the Levenshtein function for use when only small distances are of interest. If the actual distance is less than or equal to `max_d`, then `levenshtein_less_equal` returns the correct distance; otherwise it returns some value greater than `max_d`. If `max_d` is negative then the behavior is the same as `levenshtein`.

Examples:

```
test=# SELECT levenshtein('GUMBO', 'GAMBOL');
 levenshtein
-----
                2
(1 row)

test=# SELECT levenshtein('GUMBO', 'GAMBOL', 2, 1, 1);
 levenshtein
-----
```

```
          3
(1 row)

test=# SELECT levenshtein_less_equal('extensive', 'exhaustive', 2);
 levenshtein_less_equal
-----
          3
(1 row)

test=# SELECT levenshtein_less_equal('extensive', 'exhaustive', 4);
 levenshtein_less_equal
-----
          4
(1 row)
```

F.15.3. Metaphone

Metaphone, like Soundex, is based on the idea of constructing a representative code for an input string. Two strings are then deemed similar if they have the same codes.

This function calculates the metaphone code of an input string:

```
metaphone(text source, int max_output_length) returns text
```

source has to be a non-null string with a maximum of 255 characters. max_output_length sets the maximum length of the output metaphone code; if longer, the output is truncated to this length.

Example:

```
test=# SELECT metaphone('GUMBO', 4);
 metaphone
-----
      KM
(1 row)
```

F.15.4. Double Metaphone

The Double Metaphone system computes two “sounds like” strings for a given input string — a “primary” and an “alternate”. In most cases they are the same, but for non-English names especially they can be a bit different, depending on pronunciation. These functions compute the primary and alternate codes:

```
dmetaphone(text source) returns text
dmetaphone_alt(text source) returns text
```

There is no length limit on the input strings.

Example:

```
test=# SELECT dmetaphone('gumbo');
 dmetaphone
-----
```

```
KMP
(1 row)
```

F.16. hstore

This module implements the `hstore` data type for storing sets of key/value pairs within a single PostgreSQL value. This can be useful in various scenarios, such as rows with many attributes that are rarely examined, or semi-structured data. Keys and values are simply text strings.

F.16.1. hstore External Representation

The text representation of an `hstore`, used for input and output, includes zero or more *key => value* pairs separated by commas. Some examples:

```
k => v
foo => bar, baz => whatever
"1-a" => "anything at all"
```

The order of the pairs is not significant (and may not be reproduced on output). Whitespace between pairs or around the `=>` sign is ignored. Double-quote keys and values that include whitespace, commas, `=`s or `>`s. To include a double quote or a backslash in a key or value, escape it with a backslash.

Each key in an `hstore` is unique. If you declare an `hstore` with duplicate keys, only one will be stored in the `hstore` and there is no guarantee as to which will be kept:

```
SELECT 'a=>1,a=>2'::hstore;
 hstore
-----
"a"=>"1"
```

A value (but not a key) can be an SQL `NULL`. For example:

```
key => NULL
```

The `NULL` keyword is case-insensitive. Double-quote the `NULL` to treat it as the ordinary string `"NULL"`.

Note

Keep in mind that the `hstore` text format, when used for input, applies *before* any required quoting or escaping. If you are passing an `hstore` literal via a parameter, then no additional processing is needed. But if you're passing it as a quoted literal constant, then any single-quote characters and (depending on the setting of the `standard_conforming_strings` configuration parameter) backslash characters need to be escaped correctly. See Section 4.1.2.1 for more on the handling of string constants.

On output, double quotes always surround keys and values, even when it's not strictly necessary.

F.16.2. hstore Operators and Functions

The operators provided by the `hstore` module are shown in Table F.7, the functions in Table F.8.

Table F.7. hstore Operators

Operator	Description	Example	Result
<code>hstore -> text</code>	get value for key (NULL if not present)	<code>'a=>x, b=>y'::hstore -> 'a'</code>	x
<code>hstore -> text[]</code>	get values for keys (NULL if not present)	<code>'a=>x, b=>y, c=>z'::hstore -> ARRAY['c','a']</code>	<code>{"z","x"}</code>
<code>hstore hstore</code>	concatenate hstores	<code>'a=>b, c=>d'::hstore 'c=>x, d=>q'::hstore</code>	<code>"a"=>"b", "c"=>"x", "d"=>"q"</code>
<code>hstore ? text</code>	does hstore contain key?	<code>'a=>1'::hstore ? 'a'</code>	t
<code>hstore ?& text[]</code>	does hstore contain all specified keys?	<code>'a=>1,b=>2'::hstore ?& ARRAY['a','b']</code>	t
<code>hstore ? text[]</code>	does hstore contain any of the specified keys?	<code>'a=>1,b=>2'::hstore ? ARRAY['b','c']</code>	t
<code>hstore @> hstore</code>	does left operand contain right?	<code>'a=>b, b=>1, c=>NULL'::hstore @> 'b=>1'</code>	t
<code>hstore <@ hstore</code>	is left operand contained in right?	<code>'a=>c'::hstore <@ 'a=>b, b=>1, c=>NULL'</code>	f
<code>hstore - text</code>	delete key from left operand	<code>'a=>1, b=>2, c=>3'::hstore - 'b'::text</code>	<code>"a"=>"1", "c"=>"3"</code>
<code>hstore - text[]</code>	delete keys from left operand	<code>'a=>1, b=>2, c=>3'::hstore - ARRAY['a','b']</code>	<code>"c"=>"3"</code>
<code>hstore - hstore</code>	delete matching pairs from left operand	<code>'a=>1, b=>2, c=>3'::hstore - 'a=>4, b=>2'::hstore</code>	<code>"a"=>"1", "c"=>"3"</code>
<code>record # = hstore</code>	replace fields in record with matching values from hstore	see Examples section	
<code>%% hstore</code>	convert hstore to array of alternating keys and values	<code>%% 'a=>foo, b=>bar'::hstore</code>	<code>{a,foo,b,bar}</code>
<code>%# hstore</code>	convert hstore to two-dimensional key/value array	<code>%# 'a=>foo, b=>bar'::hstore</code>	<code>{{a,foo},{b,bar}}</code>

Note

Prior to PostgreSQL 8.2, the containment operators @> and <@ were called @ and ~, respectively. These names are still available, but are deprecated and will eventually be removed. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!

Table F.8. hstore Functions

Function	Return Type	Description	Example	Result
hstore(record)	hstore	construct an hstore from a record or row	hstore(ROW(1,2))	f1=>1, f2=>2
hstore(text[])	hstore	construct an hstore from an array, which may be either a key/value array, or a two-dimensional array	hstore(ARRAY['a','1','b','2'] hstore(ARRAY[['c','3'], ['d','4']]))	a=>1, b=>2, c=>3, d=>4
hstore(text[], text[])	hstore	construct an hstore from separate key and value arrays	hstore(ARRAY['a','b'], ARRAY['1','2'])	"a"=>"1", "b"=>"2"
hstore(text, text)	hstore	make single-item hstore	hstore('a', 'b')	"a"=>"b"
akeys(hstore)	text[]	get hstore's keys as an array	akeys('a=>1, b=>2')	{a, b}
skeys(hstore)	setof text	get hstore's keys as a set	skeys('a=>1, b=>2')	a b
avals(hstore)	text[]	get hstore's values as an array	avals('a=>1, b=>2')	{1, 2}
svals(hstore)	setof text	get hstore's values as a set	svals('a=>1, b=>2')	1 2
hstore_to_array(hstore)	text[]	get hstore's keys and values as an array of alternating keys and values	hstore_to_array('a=>1, b=>2')	{a, 1, b, 2}
hstore_to_matrix(hstore)	text[]	get hstore's keys and values as a two-dimensional array	hstore_to_matrix('a=>1, b=>2')	{{a, 1}, {b, 2}}
hstore_to_json(hstore)	json	get hstore as a json value, converting all non-null values to JSON strings	hstore_to_json('"a key"=>1, b=>t, c=>null, d=>12345, e=>012345, f=>1.234, g=>2.345e+4')	{"a key": "1", "b": "t", "c": null, "d": "12345", "e": "012345", "f": "1.234", "g": "2.345e+4"}
hstore_to_jsonb(hstore)	jsonb	get hstore as a jsonb value, converting all non-null values to JSON strings	hstore_to_jsonb('"a key"=>1, b=>t, c=>null, d=>12345, e=>012345, f=>1.234, g=>2.345e+4')	{"a key": "1", "b": "t", "c": null, "d": "12345", "e": "012345", "f": "1.234", "g": "2.345e+4"}

Function	Return Type	Description	Example	Result
			f=>1.234, g=>2.345e +4')	"g": "2.345e +4" }
hstore_to_j- son_loose(h- store)	json	get hstore as a json value, but attempt to distinguish numerical and Boolean values so they are unquoted in the JSON	hstore_to_j- son_loose('"a key"=>1, b=>t, c=>null, d=>12345, e=>012345, f=>1.234, g=>2.345e +4')	{"a key": 1, "b": true, "c": null, "d": 12345, "e": "012345", "f": 1.234, "g": 2.345e +4}
hstore_to_j- son- b_loose(h- store)	jsonb	get hstore as a jsonb value, but attempt to distinguish numerical and Boolean values so they are unquoted in the JSON	hstore_to_j- son- b_loose('"a key"=>1, b=>t, c=>null, d=>12345, e=>012345, f=>1.234, g=>2.345e +4')	{"a key": 1, "b": true, "c": null, "d": 12345, "e": "012345", "f": 1.234, "g": 2.345e +4}
slice(h- store, text[])	hstore	extract a subset of an hstore	slice('a=>1,b=>2,c=>3'::h- store, AR- RAY['b','c','x'])	
each(hstore)	setof(key text, value text)	get hstore's keys and values as a set	select * from each('a=>1,b=>2')--	key value +----- a 1 b 2
exist(h- store,text)	boolean	does hstore contain key?	ex- ist('a=>1','a')	t
defined(h- store,text)	boolean	does hstore contain non-NULL value for key?	de- fined('a=>NULL','a')	f
delete(h- store,text)	hstore	delete pair with matching key	delete('a=>1,b=>2','b')	
delete(h- store, tex- t[])	hstore	delete pairs with matching keys	delete('a=>1,b=>2,c=>3',AR- RAY['a','b'])	
delete(h- store,h- store)	hstore	delete pairs matching those in the second argument	delete('a=>1,b=>2','a=>4,b=>2'::h- store)	
popu- late_record(record,h- store)	record	replace fields in record with matching values from hstore	see Examples section	

Note

The function `hstore_to_json` is used when an `hstore` value is cast to `json`. Likewise, `hstore_to_jsonb` is used when an `hstore` value is cast to `jsonb`.

Note

The function `populate_record` is actually declared with `anyelement`, not `record`, as its first argument, but it will reject non-record types with a run-time error.

F.16.3. Indexes

`hstore` has GiST and GIN index support for the `@>`, `?`, `?&` and `?|` operators. For example:

```
CREATE INDEX hidx ON testhstore USING GIST (h);
```

```
CREATE INDEX hidx ON testhstore USING GIN (h);
```

`hstore` also supports `btree` or `hash` indexes for the `=` operator. This allows `hstore` columns to be declared `UNIQUE`, or to be used in `GROUP BY`, `ORDER BY` or `DISTINCT` expressions. The sort ordering for `hstore` values is not particularly useful, but these indexes may be useful for equivalence lookups. Create indexes for `=` comparisons as follows:

```
CREATE INDEX hidx ON testhstore USING BTREE (h);
```

```
CREATE INDEX hidx ON testhstore USING HASH (h);
```

F.16.4. Examples

Add a key, or update an existing key with a new value:

```
UPDATE tab SET h = h || hstore('c', '3');
```

Delete a key:

```
UPDATE tab SET h = delete(h, 'k1');
```

Convert a record to an `hstore`:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);
INSERT INTO test VALUES (123, 'foo', 'bar');
```

```
SELECT hstore(t) FROM test AS t;
           hstore
```

```
-----
"col1"=>"123", "col2"=>"foo", "col3"=>"bar"
(1 row)
```

Convert an hstore to a predefined record type:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);

SELECT * FROM populate_record(null::test,
                              '"col1"=>"456", "col2"=>"zzz"');

 col1 | col2 | col3
-----+-----+-----
  456 | zzz  |
(1 row)
```

Modify an existing record using the values from an hstore:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);
INSERT INTO test VALUES (123, 'foo', 'bar');

SELECT (r).* FROM (SELECT t #= '"col3"=>"baz"' AS r FROM test t) s;

 col1 | col2 | col3
-----+-----+-----
  123 | foo  | baz
(1 row)
```

F.16.5. Statistics

The hstore type, because of its intrinsic liberality, could contain a lot of different keys. Checking for valid keys is the task of the application. The following examples demonstrate several techniques for checking keys and obtaining statistics.

Simple example:

```
SELECT * FROM each('aaa=>bq, b=>NULL, ""=>1');
```

Using a table:

```
SELECT (each(h)).key, (each(h)).value INTO stat FROM testhstore;
```

Online statistics:

```
SELECT key, count(*) FROM
  (SELECT (each(h)).key FROM testhstore) AS stat
GROUP BY key
ORDER BY count DESC, key;

 key      | count
-----+-----
 line     |    883
 query    |    207
 pos      |    203
 node     |    202
 space    |    197
 status   |    195
 public   |    194
 title    |    190
 org      |    189
.....
```

F.16.6. Compatibility

As of PostgreSQL 9.0, `hstore` uses a different internal representation than previous versions. This presents no obstacle for dump/restore upgrades since the text representation (used in the dump) is unchanged.

In the event of a binary upgrade, upward compatibility is maintained by having the new code recognize old-format data. This will entail a slight performance penalty when processing data that has not yet been modified by the new code. It is possible to force an upgrade of all values in a table column by doing an `UPDATE` statement as follows:

```
UPDATE tablename SET hstorecol = hstorecol || '';
```

Another way to do it is:

```
ALTER TABLE tablename ALTER hstorecol TYPE hstore USING hstorecol || '';
```

The `ALTER TABLE` method requires an exclusive lock on the table, but does not result in bloating the table with old row versions.

F.16.7. Transforms

Additional extensions are available that implement transforms for the `hstore` type for the languages PL/Perl and PL/Python. The extensions for PL/Perl are called `hstore_plperl` and `hstore_plperlu`, for trusted and untrusted PL/Perl. If you install these transforms and specify them when creating a function, `hstore` values are mapped to Perl hashes. The extensions for PL/Python are called `hstore_plpythonu`, `hstore_plpython2u`, and `hstore_plpython3u` (see Section 45.1 for the PL/Python naming convention). If you use them, `hstore` values are mapped to Python dictionaries.

F.16.8. Authors

Oleg Bartunov <oleg@sai.msu.su>, Moscow, Moscow University, Russia

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F.17. intagg

The `intagg` module provides an integer aggregator and an enumerator. `intagg` is now obsolete, because there are built-in functions that provide a superset of its capabilities. However, the module is still provided as a compatibility wrapper around the built-in functions.

F.17.1. Functions

The aggregator is an aggregate function `int_array_aggregate(integer)` that produces an integer array containing exactly the integers it is fed. This is a wrapper around `array_agg`, which does the same thing for any array type.

The enumerator is a function `int_array_enum(integer[])` that returns `setof integer`. It is essentially the reverse operation of the aggregator: given an array of integers, expand it into a set of rows. This is a wrapper around `unnest`, which does the same thing for any array type.

F.17.2. Sample Uses

Many database systems have the notion of a one to many table. Such a table usually sits between two indexed tables, for example:

```
CREATE TABLE left (id INT PRIMARY KEY, ...);
CREATE TABLE right (id INT PRIMARY KEY, ...);
CREATE TABLE one_to_many(left INT REFERENCES left, right INT
  REFERENCES right);
```

It is typically used like this:

```
SELECT right.* from right JOIN one_to_many ON (right.id =
  one_to_many.right)
  WHERE one_to_many.left = item;
```

This will return all the items in the right hand table for an entry in the left hand table. This is a very common construct in SQL.

Now, this methodology can be cumbersome with a very large number of entries in the `one_to_many` table. Often, a join like this would result in an index scan and a fetch for each right hand entry in the table for a particular left hand entry. If you have a very dynamic system, there is not much you can do. However, if you have some data which is fairly static, you can create a summary table with the aggregator.

```
CREATE TABLE summary AS
  SELECT left, int_array_aggregate(right) AS right
  FROM one_to_many
  GROUP BY left;
```

This will create a table with one row per left item, and an array of right items. Now this is pretty useless without some way of using the array; that's why there is an array enumerator. You can do

```
SELECT left, int_array_enum(right) FROM summary WHERE left = item;
```

The above query using `int_array_enum` produces the same results as

```
SELECT left, right FROM one_to_many WHERE left = item;
```

The difference is that the query against the summary table has to get only one row from the table, whereas the direct query against `one_to_many` must index scan and fetch a row for each entry.

On one system, an EXPLAIN showed a query with a cost of 8488 was reduced to a cost of 329. The original query was a join involving the `one_to_many` table, which was replaced by:

```
SELECT right, count(right) FROM
  ( SELECT left, int_array_enum(right) AS right
    FROM summary JOIN (SELECT left FROM left_table WHERE left
  = item) AS lefts
    ON (summary.left = lefts.left)
  ) AS list
  GROUP BY right
  ORDER BY count DESC;
```

F.18. intarray

The `intarray` module provides a number of useful functions and operators for manipulating null-free arrays of integers. There is also support for indexed searches using some of the operators.

All of these operations will throw an error if a supplied array contains any NULL elements.

Many of these operations are only sensible for one-dimensional arrays. Although they will accept input arrays of more dimensions, the data is treated as though it were a linear array in storage order.

F.18.1. intarray Functions and Operators

The functions provided by the `intarray` module are shown in Table F.9, the operators in Table F.10.

Table F.9. intarray Functions

Function	Return Type	Description	Example	Result
<code>icount(int[])</code>	<code>int</code>	number of elements in array	<code>icount('{1,2,3}'::int[])</code>	3
<code>sort(int[], text dir)</code>	<code>int[]</code>	sort array — <i>dir</i> must be <code>asc</code> or <code>desc</code>	<code>sort('{1,2,3}'::int[], 'desc')</code>	{3,2,1}
<code>sort(int[])</code>	<code>int[]</code>	sort in ascending order	<code>sort(array[11,77,44])</code>	{11,44,77}
<code>sort_asc(int[])</code>	<code>int[]</code>	sort in ascending order		
<code>sort_desc(int[])</code>	<code>int[]</code>	sort in descending order		
<code>uniq(int[])</code>	<code>int[]</code>	remove adjacent duplicates	<code>uniq(sort('{1,2,2,2,1}'::int[]))</code>	{1,2,1}
<code>idx(int[], int item)</code>	<code>int</code>	index of first element matching <i>item</i> (0 if none)	<code>idx(array[11,22,33,22,11], 22)</code>	2
<code>subarray(int[], int start, int len)</code>	<code>int[]</code>	portion of array starting at position <i>start</i> , <i>len</i> elements	<code>subarray('{1,2,3,2,1}'::int[], 2, 3)</code>	{2,3,2}
<code>subarray(int[], int start)</code>	<code>int[]</code>	portion of array starting at position <i>start</i>	<code>subarray('{1,2,3,2,1}'::int[], 2)</code>	{2,3,2,1}
<code>intset(int)</code>	<code>int[]</code>	make single-element array	<code>intset(42)</code>	{42}

Table F.10. intarray Operators

Operator	Returns	Description
<code>int[] && int[]</code>	boolean	overlap — true if arrays have at least one common element
<code>int[] @> int[]</code>	boolean	contains — true if left array contains right array
<code>int[] <@ int[]</code>	boolean	contained — true if left array is contained in right array

Operator	Returns	Description
# int[]	int	number of elements in array
int[] # int	int	index (same as idx function)
int[] + int	int[]	push element onto array (add it to end of array)
int[] + int[]	int[]	array concatenation (right array added to the end of left one)
int[] - int	int[]	remove entries matching right argument from array
int[] - int[]	int[]	remove elements of right array from left
int[] int	int[]	union of arguments
int[] int[]	int[]	union of arrays
int[] & int[]	int[]	intersection of arrays
int[] @@ query_int	boolean	true if array satisfies query (see below)
query_int ~~ int[]	boolean	true if array satisfies query (commutator of @@)

(Before PostgreSQL 8.2, the containment operators @> and <@ were respectively called @ and ~. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The operators &&, @> and <@ are equivalent to PostgreSQL's built-in operators of the same names, except that they work only on integer arrays that do not contain nulls, while the built-in operators work for any array type. This restriction makes them faster than the built-in operators in many cases.

The @@ and ~~ operators test whether an array satisfies a *query*, which is expressed as a value of a specialized data type `query_int`. A *query* consists of integer values that are checked against the elements of the array, possibly combined using the operators & (AND), | (OR), and ! (NOT). Parentheses can be used as needed. For example, the query `1 & (2 | 3)` matches arrays that contain 1 and also contain either 2 or 3.

F.18.2. Index Support

`intarray` provides index support for the &&, @>, <@, and @@ operators, as well as regular array equality.

Two GiST index operator classes are provided: `gist__int_ops` (used by default) is suitable for small- to medium-size data sets, while `gist__intbig_ops` uses a larger signature and is more suitable for indexing large data sets (i.e., columns containing a large number of distinct array values). The implementation uses an RD-tree data structure with built-in lossy compression.

There is also a non-default GIN operator class `gin__int_ops` supporting the same operators.

The choice between GiST and GIN indexing depends on the relative performance characteristics of GiST and GIN, which are discussed elsewhere.

F.18.3. Example

```
-- a message can be in one or more "sections"
CREATE TABLE message (mid INT PRIMARY KEY, sections INT[], ...);
```

```

-- create specialized index
CREATE INDEX message_rdtree_idx ON message USING GIST (sections
gist__int_ops);

-- select messages in section 1 OR 2 - OVERLAP operator
SELECT message.mid FROM message WHERE message.sections && '{1,2}';

-- select messages in sections 1 AND 2 - CONTAINS operator
SELECT message.mid FROM message WHERE message.sections @> '{1,2}';

-- the same, using QUERY operator
SELECT message.mid FROM message WHERE message.sections @@
'1&2'::query_int;

```

F.18.4. Benchmark

The source directory `contrib/intarray/bench` contains a benchmark test suite, which can be run against an installed PostgreSQL server. (It also requires `DBD:Pg` to be installed.) To run:

```

cd ../contrib/intarray/bench
createdb TEST
psql -c "CREATE EXTENSION intarray" TEST
./create_test.pl | psql TEST
./bench.pl

```

The `bench.pl` script has numerous options, which are displayed when it is run without any arguments.

F.18.5. Authors

All work was done by Teodor Sigaev (<teodor@sigaev.ru>) and Oleg Bartunov (<oleg@sai.msu.su>). See <http://www.sai.msu.su/~megeera/postgres/gist/> for additional information. Andrey Oktyabrski did a great work on adding new functions and operations.

F.19. isn

The `isn` module provides data types for the following international product numbering standards: EAN13, UPC, ISBN (books), ISMN (music), and ISSN (serials). Numbers are validated on input according to a hard-coded list of prefixes; this list of prefixes is also used to hyphenate numbers on output. Since new prefixes are assigned from time to time, the list of prefixes may be out of date. It is hoped that a future version of this module will obtain the prefix list from one or more tables that can be easily updated by users as needed; however, at present, the list can only be updated by modifying the source code and recompiling. Alternatively, prefix validation and hyphenation support may be dropped from a future version of this module.

F.19.1. Data Types

Table F.11 shows the data types provided by the `isn` module.

Table F.11. isn Data Types

Data Type	Description
EAN13	European Article Numbers, always displayed in the EAN13 display format

Data Type	Description
ISBN13	International Standard Book Numbers to be displayed in the new EAN13 display format
ISMN13	International Standard Music Numbers to be displayed in the new EAN13 display format
ISSN13	International Standard Serial Numbers to be displayed in the new EAN13 display format
ISBN	International Standard Book Numbers to be displayed in the old short display format
ISMN	International Standard Music Numbers to be displayed in the old short display format
ISSN	International Standard Serial Numbers to be displayed in the old short display format
UPC	Universal Product Codes

Some notes:

1. ISBN13, ISMN13, ISSN13 numbers are all EAN13 numbers.
2. EAN13 numbers aren't always ISBN13, ISMN13 or ISSN13 (some are).
3. Some ISBN13 numbers can be displayed as ISBN.
4. Some ISMN13 numbers can be displayed as ISMN.
5. Some ISSN13 numbers can be displayed as ISSN.
6. UPC numbers are a subset of the EAN13 numbers (they are basically EAN13 without the first 0 digit).
7. All UPC, ISBN, ISMN and ISSN numbers can be represented as EAN13 numbers.

Internally, all these types use the same representation (a 64-bit integer), and all are interchangeable. Multiple types are provided to control display formatting and to permit tighter validity checking of input that is supposed to denote one particular type of number.

The ISBN, ISMN, and ISSN types will display the short version of the number (ISxN 10) whenever it's possible, and will show ISxN 13 format for numbers that do not fit in the short version. The EAN13, ISBN13, ISMN13 and ISSN13 types will always display the long version of the ISxN (EAN13).

F.19.2. Casts

The `isbn` module provides the following pairs of type casts:

- ISBN13 <=> EAN13
- ISMN13 <=> EAN13
- ISSN13 <=> EAN13
- ISBN <=> EAN13
- ISMN <=> EAN13
- ISSN <=> EAN13
- UPC <=> EAN13
- ISBN <=> ISBN13

- ISMN <=> ISMN13
- ISSN <=> ISSN13

When casting from EAN13 to another type, there is a run-time check that the value is within the domain of the other type, and an error is thrown if not. The other casts are simply relabelings that will always succeed.

F.19.3. Functions and Operators

The `isbn` module provides the standard comparison operators, plus B-tree and hash indexing support for all these data types. In addition there are several specialized functions; shown in Table F.12. In this table, `isbn` means any one of the module's data types.

Table F.12. `isbn` Functions

Function	Returns	Description
<code>isbn_weak(boolean)</code>	boolean	Sets the weak input mode (returns new setting)
<code>isbn_weak()</code>	boolean	Gets the current status of the weak mode
<code>make_valid(isbn)</code>	isbn	Validates an invalid number (clears the invalid flag)
<code>is_valid(isbn)</code>	boolean	Checks for the presence of the invalid flag

Weak mode is used to be able to insert invalid data into a table. Invalid means the check digit is wrong, not that there are missing numbers.

Why would you want to use the weak mode? Well, it could be that you have a huge collection of ISBN numbers, and that there are so many of them that for weird reasons some have the wrong check digit (perhaps the numbers were scanned from a printed list and the OCR got the numbers wrong, perhaps the numbers were manually captured... who knows). Anyway, the point is you might want to clean the mess up, but you still want to be able to have all the numbers in your database and maybe use an external tool to locate the invalid numbers in the database so you can verify the information and validate it more easily; so for example you'd want to select all the invalid numbers in the table.

When you insert invalid numbers in a table using the weak mode, the number will be inserted with the corrected check digit, but it will be displayed with an exclamation mark (!) at the end, for example 0-11-000322-5!. This invalid marker can be checked with the `is_valid` function and cleared with the `make_valid` function.

You can also force the insertion of invalid numbers even when not in the weak mode, by appending the ! character at the end of the number.

Another special feature is that during input, you can write ? in place of the check digit, and the correct check digit will be inserted automatically.

F.19.4. Examples

```
--Using the types directly:
SELECT isbn('978-0-393-04002-9');
SELECT isbn13('0901690546');
SELECT issn('1436-4522');

--Casting types:
```

```

-- note that you can only cast from ean13 to another type when the
-- number would be valid in the realm of the target type;
-- thus, the following will NOT work: select
  isbn(ean13('0220356483481'));
-- but these will:
SELECT upc(ean13('0220356483481'));
SELECT ean13(upc('220356483481'));

--Create a table with a single column to hold ISBN numbers:
CREATE TABLE test (id isbn);
INSERT INTO test VALUES('9780393040029');

--Automatically calculate check digits (observe the '?'):
INSERT INTO test VALUES('220500896?');
INSERT INTO test VALUES('978055215372?');

SELECT issn('3251231?');
SELECT ismn('979047213542?');

--Using the weak mode:
SELECT isn_weak(true);
INSERT INTO test VALUES('978-0-11-000533-4');
INSERT INTO test VALUES('9780141219307');
INSERT INTO test VALUES('2-205-00876-X');
SELECT isn_weak(false);

SELECT id FROM test WHERE NOT is_valid(id);
UPDATE test SET id = make_valid(id) WHERE id = '2-205-00876-X!';

SELECT * FROM test;

SELECT isbn13(id) FROM test;

```

F.19.5. Bibliography

The information to implement this module was collected from several sites, including:

- <https://www.isbn-international.org/>
- <http://www.issn.org/>
- <https://www.ismn-international.org/>
- <https://www.wikipedia.org/>

The prefixes used for hyphenation were also compiled from:

- <https://www.gs1.org/standards/id-keys>
- https://en.wikipedia.org/wiki/List_of_ISBN_identifier_groups
- <https://www.isbn-international.org/content/isbn-users-manual>
- https://en.wikipedia.org/wiki/International_Standard_Music_Number
- <https://www.ismn-international.org/ranges.html>

Care was taken during the creation of the algorithms and they were meticulously verified against the suggested algorithms in the official ISBN, ISMN, ISSN User Manuals.

F.19.6. Author

Germán Méndez Bravo (Kronuz), 2004 - 2006

This module was inspired by Garrett A. Wollman's `isbn_issn` code.

F.20. lo

The `lo` module provides support for managing Large Objects (also called LOs or BLOBs). This includes a data type `lo` and a trigger `lo_manage`.

F.20.1. Rationale

One of the problems with the JDBC driver (and this affects the ODBC driver also), is that the specification assumes that references to BLOBs (Binary Large Objects) are stored within a table, and if that entry is changed, the associated BLOB is deleted from the database.

As PostgreSQL stands, this doesn't occur. Large objects are treated as objects in their own right; a table entry can reference a large object by OID, but there can be multiple table entries referencing the same large object OID, so the system doesn't delete the large object just because you change or remove one such entry.

Now this is fine for PostgreSQL-specific applications, but standard code using JDBC or ODBC won't delete the objects, resulting in orphan objects — objects that are not referenced by anything, and simply occupy disk space.

The `lo` module allows fixing this by attaching a trigger to tables that contain LO reference columns. The trigger essentially just does a `lo_unlink` whenever you delete or modify a value referencing a large object. When you use this trigger, you are assuming that there is only one database reference to any large object that is referenced in a trigger-controlled column!

The module also provides a data type `lo`, which is really just a domain of the `oid` type. This is useful for differentiating database columns that hold large object references from those that are OIDs of other things. You don't have to use the `lo` type to use the trigger, but it may be convenient to use it to keep track of which columns in your database represent large objects that you are managing with the trigger. It is also rumored that the ODBC driver gets confused if you don't use `lo` for BLOB columns.

F.20.2. How to Use It

Here's a simple example of usage:

```
CREATE TABLE image (title text, raster lo);

CREATE TRIGGER t_raster BEFORE UPDATE OR DELETE ON image
    FOR EACH ROW EXECUTE FUNCTION lo_manage(raster);
```

For each column that will contain unique references to large objects, create a `BEFORE UPDATE OR DELETE` trigger, and give the column name as the sole trigger argument. You can also restrict the trigger to only execute on updates to the column by using `BEFORE UPDATE OF column_name`. If you need multiple `lo` columns in the same table, create a separate trigger for each one, remembering to give a different name to each trigger on the same table.

F.20.3. Limitations

- Dropping a table will still orphan any objects it contains, as the trigger is not executed. You can avoid this by preceding the `DROP TABLE` with `DELETE FROM table`.

TRUNCATE has the same hazard.

If you already have, or suspect you have, orphaned large objects, see the `vacuumlo` module to help you clean them up. It's a good idea to run `vacuumlo` occasionally as a back-stop to the `lo_manage` trigger.

- Some frontends may create their own tables, and will not create the associated trigger(s). Also, users may not remember (or know) to create the triggers.

F.20.4. Author

Peter Mount < peter@retep.org.uk >

F.21. Itree

This module implements a data type `ltree` for representing labels of data stored in a hierarchical tree-like structure. Extensive facilities for searching through label trees are provided.

F.21.1. Definitions

A *label* is a sequence of alphanumeric characters and underscores (for example, in C locale the characters `A-Za-z0-9_` are allowed). Labels must be less than 256 bytes long.

Examples: `42`, `Personal_Services`

A *label path* is a sequence of zero or more labels separated by dots, for example `L1.L2.L3`, representing a path from the root of a hierarchical tree to a particular node. The length of a label path must be less than 65kB, but keeping it under 2kB is preferable.

Example: `Top.Countries.Europe.Russia`

The `ltree` module provides several data types:

- `ltree` stores a label path.
- `lquery` represents a regular-expression-like pattern for matching `ltree` values. A simple word matches that label within a path. A star symbol (`*`) matches zero or more labels. For example:

```
foo           Match the exact label path foo
*.foo.*       Match any label path containing the label foo
*.foo         Match any label path whose last label is foo
```

Star symbols can also be quantified to restrict how many labels they can match:

```
*{n}          Match exactly n labels
*{n,}         Match at least n labels
*{n,m}        Match at least n but not more than m labels
*{,m}         Match at most m labels – same as *{0,m}
```

There are several modifiers that can be put at the end of a non-star label in `lquery` to make it match more than just the exact match:

```
@             Match case-insensitively, for example a@ matches A
```

```
*           Match any label with this prefix, for example foo*
matches foobar
%           Match initial underscore-separated words
```

The behavior of % is a bit complicated. It tries to match words rather than the entire label. For example `foo_bar%` matches `foo_bar_baz` but not `foo_barbaz`. If combined with `*`, prefix matching applies to each word separately, for example `foo_bar%*` matches `foo1_bar2_baz` but not `foo1_br2_baz`.

Also, you can write several possibly-modified labels separated with `|` (OR) to match any of those labels, and you can put `!` (NOT) at the start to match any label that doesn't match any of the alternatives.

Here's an annotated example of `lquery`:

```
Top.*{0,2}.sport*@.!football|tennis.Russ*|Spain
a.  b.      c.      d.                e.
```

This query will match any label path that:

- a. begins with the label `Top`
- b. and next has zero to two labels before
- c. a label beginning with the case-insensitive prefix `sport`
- d. then a label not matching `football` nor `tennis`
- e. and then ends with a label beginning with `Russ` or exactly matching `Spain`.

- `ltxquery` represents a full-text-search-like pattern for matching `ltree` values. An `ltxquery` value contains words, possibly with the modifiers `@`, `*`, `%` at the end; the modifiers have the same meanings as in `lquery`. Words can be combined with `&` (AND), `|` (OR), `!` (NOT), and parentheses. The key difference from `lquery` is that `ltxquery` matches words without regard to their position in the label path.

Here's an example `ltxquery`:

```
Europe & Russia*@ & !Transportation
```

This will match paths that contain the label `Europe` and any label beginning with `Russia` (case-insensitive), but not paths containing the label `Transportation`. The location of these words within the path is not important. Also, when `%` is used, the word can be matched to any underscore-separated word within a label, regardless of position.

Note: `ltxquery` allows whitespace between symbols, but `ltree` and `lquery` do not.

F.21.2. Operators and Functions

Type `ltree` has the usual comparison operators `=`, `<>`, `<`, `>`, `<=`, `>=`. Comparison sorts in the order of a tree traversal, with the children of a node sorted by label text. In addition, the specialized operators shown in Table F.13 are available.

Table F.13. `ltree` Operators

Operator	Returns	Description
<code>ltree @> ltree</code>	boolean	is left argument an ancestor of right (or equal)?

Operator	Returns	Description
<code>ltree <@ ltree</code>	boolean	is left argument a descendant of right (or equal)?
<code>ltree ~ lquery</code>	boolean	does ltree match lquery?
<code>lquery ~ ltree</code>	boolean	does ltree match lquery?
<code>ltree ? lquery[]</code>	boolean	does ltree match any lquery in array?
<code>lquery[] ? ltree</code>	boolean	does ltree match any lquery in array?
<code>ltree @ ltxtquery</code>	boolean	does ltree match ltxtquery?
<code>ltxtquery @ ltree</code>	boolean	does ltree match ltxtquery?
<code>ltree ltree</code>	ltree	concatenate ltree paths
<code>ltree text</code>	ltree	convert text to ltree and concatenate
<code>text ltree</code>	ltree	convert text to ltree and concatenate
<code>ltree[] @> ltree</code>	boolean	does array contain an ancestor of ltree?
<code>ltree <@ ltree[]</code>	boolean	does array contain an ancestor of ltree?
<code>ltree[] <@ ltree</code>	boolean	does array contain a descendant of ltree?
<code>ltree @> ltree[]</code>	boolean	does array contain a descendant of ltree?
<code>ltree[] ~ lquery</code>	boolean	does array contain any path matching lquery?
<code>lquery ~ ltree[]</code>	boolean	does array contain any path matching lquery?
<code>ltree[] ? lquery[]</code>	boolean	does ltree array contain any path matching any lquery?
<code>lquery[] ? ltree[]</code>	boolean	does ltree array contain any path matching any lquery?
<code>ltree[] @ ltxtquery</code>	boolean	does array contain any path matching ltxtquery?
<code>ltxtquery @ ltree[]</code>	boolean	does array contain any path matching ltxtquery?
<code>ltree[] ?@> ltree</code>	ltree	first array entry that is an ancestor of ltree; NULL if none
<code>ltree[] ?<@ ltree</code>	ltree	first array entry that is a descendant of ltree; NULL if none
<code>ltree[] ?~ lquery</code>	ltree	first array entry that matches lquery; NULL if none
<code>ltree[] ?@ ltxtquery</code>	ltree	first array entry that matches ltxtquery; NULL if none

The operators `<@`, `@>`, `@` and `~` have analogues `^<@`, `^@>`, `^@`, `^~`, which are the same except they do not use indexes. These are useful only for testing purposes.

The available functions are shown in Table F.14.

Table F.14. ltree Functions

Function	Return Type	Description	Example	Result
subltree(ltree, int start, int end)	ltree	subpath of ltree from position <i>start</i> to position <i>end</i> -1 (counting from 0)	subltree('Top.Child1.Child2', 1, 2)	
subpath(ltree, int offset, int len)	ltree	subpath of ltree starting at position <i>offset</i> , length <i>len</i> . If <i>offset</i> is negative, subpath starts that far from the end of the path. If <i>len</i> is negative, leaves that many labels off the end of the path.	subpath('Top.Child1.Child2', 0, 2)	Top.Child1
subpath(ltree, int offset)	ltree	subpath of ltree starting at position <i>offset</i> , extending to end of path. If <i>offset</i> is negative, subpath starts that far from the end of the path.	subpath('Top.Child1.Child2', 1)	Child1.Child2
nlevel(ltree)	integer	number of labels in path	nlevel('Top.Child1.Child2')	3
index(ltree a, ltree b)	integer	position of first occurrence of <i>b</i> in <i>a</i> ; -1 if not found	index('0.1.2.3.5.4.5.6.8.5.6.8', '5.6')	6
index(ltree a, ltree b, int offset)	integer	position of first occurrence of <i>b</i> in <i>a</i> , searching starting at <i>offset</i> ; negative <i>offset</i> means start <i>-offset</i> labels from the end of the path	index('0.1.2.3.5.4.5.6.8.5.6.8', '5.6', -4)	9
text2ltree(text)	ltree	cast text to ltree		
ltree2text(ltree)	text	cast ltree to text		
lca(ltree, ltree, ...)	ltree	longest common ancestor of paths (up to 8 arguments supported)	lca('1.2.3', '1.2.3.4.5.6')	1.2
lca(ltree[])	ltree	longest common ancestor of paths in array	lca(array['1.2.3'::ltree, '1.2.3.4'])	1.2

F.21.3. Indexes

ltree supports several types of indexes that can speed up the indicated operators:

- B-tree index over ltree: <, <=, =, >=, >
- GiST index over ltree: <, <=, =, >=, >, @>, <@, @, ~, ?

Example of creating such an index:

```
CREATE INDEX path_gist_idx ON test USING GIST (path);
```

- GiST index over ltree[]: ltree[] <@ ltree, ltree @> ltree[], @, ~, ?

Example of creating such an index:

```
CREATE INDEX path_gist_idx ON test USING GIST (array_path);
```

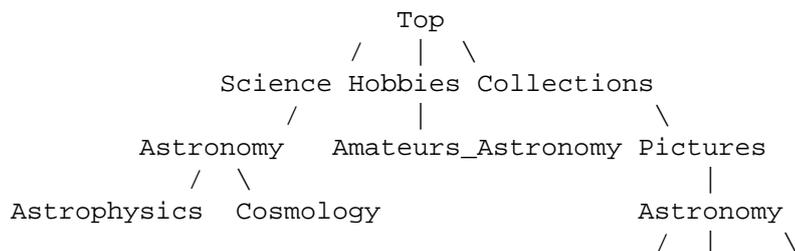
Note: This index type is lossy.

F.21.4. Example

This example uses the following data (also available in file contrib/ltree/ltreetest.sql in the source distribution):

```
CREATE TABLE test (path ltree);
INSERT INTO test VALUES ('Top');
INSERT INTO test VALUES ('Top.Science');
INSERT INTO test VALUES ('Top.Science.Astronomy');
INSERT INTO test VALUES ('Top.Science.Astronomy.Astrophysics');
INSERT INTO test VALUES ('Top.Science.Astronomy.Cosmology');
INSERT INTO test VALUES ('Top.Hobbies');
INSERT INTO test VALUES ('Top.Hobbies.Amateurs_Astronomy');
INSERT INTO test VALUES ('Top.Collections');
INSERT INTO test VALUES ('Top.Collections.Pictures');
INSERT INTO test VALUES ('Top.Collections.Pictures.Astronomy');
INSERT INTO test VALUES
  ('Top.Collections.Pictures.Astronomy.Stars');
INSERT INTO test VALUES
  ('Top.Collections.Pictures.Astronomy.Galaxies');
INSERT INTO test VALUES
  ('Top.Collections.Pictures.Astronomy.Astronauts');
CREATE INDEX path_gist_idx ON test USING GIST (path);
CREATE INDEX path_idx ON test USING BTREE (path);
```

Now, we have a table test populated with data describing the hierarchy shown below:



Galaxies Stars Astronauts

We can do inheritance:

```
ltreetest=> SELECT path FROM test WHERE path <@ 'Top.Science';
           path
```

```
-----
Top.Science
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
(4 rows)
```

Here are some examples of path matching:

```
ltreetest=> SELECT path FROM test WHERE path ~ '*.Astronomy.*';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
Top.Collections.Pictures.Astronomy
Top.Collections.Pictures.Astronomy.Stars
Top.Collections.Pictures.Astronomy.Galaxies
Top.Collections.Pictures.Astronomy.Astronauts
(7 rows)
```

```
ltreetest=> SELECT path FROM test WHERE path ~ '*.!
pictures@.*.Astronomy.*';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
(3 rows)
```

Here are some examples of full text search:

```
ltreetest=> SELECT path FROM test WHERE path @ 'Astro*% & !
pictures@';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
Top.Hobbies.Amateurs_Astronomy
(4 rows)
```

```
ltreetest=> SELECT path FROM test WHERE path @ 'Astro* & !
pictures@';
           path
```

```
-----
Top.Science.Astronomy
Top.Science.Astronomy.Astrophysics
Top.Science.Astronomy.Cosmology
(3 rows)
```

Path construction using functions:

```
ltreetest=> SELECT subpath(path,0,2) || 'Space' || subpath(path,2) FROM
test WHERE path <@ 'Top.Science.Astronomy';
           ?column?
```

```
-----
Top.Science.Space.Astronomy
Top.Science.Space.Astronomy.Astrophysics
Top.Science.Space.Astronomy.Cosmology
(3 rows)
```

We could simplify this by creating a SQL function that inserts a label at a specified position in a path:

```
CREATE FUNCTION ins_label(ltree, int, text) RETURNS ltree
AS 'select subpath($1,0,$2) || $3 || subpath($1,$2);'
LANGUAGE SQL IMMUTABLE;
```

```
ltreetest=> SELECT ins_label(path,2,'Space') FROM test WHERE path
<@ 'Top.Science.Astronomy';
           ins_label
```

```
-----
Top.Science.Space.Astronomy
Top.Science.Space.Astronomy.Astrophysics
Top.Science.Space.Astronomy.Cosmology
(3 rows)
```

F.21.5. Transforms

Additional extensions are available that implement transforms for the `ltree` type for PL/Python. The extensions are called `ltree_plpythonu`, `ltree_plpython2u`, and `ltree_plpython3u` (see Section 45.1 for the PL/Python naming convention). If you install these transforms and specify them when creating a function, `ltree` values are mapped to Python lists. (The reverse is currently not supported, however.)

F.21.6. Authors

All work was done by Teodor Sigaev (<teodor@stack.net>) and Oleg Bartunov (<oleg@sai.msu.su>). See <http://www.sai.msu.su/~megeera/postgres/gist/> for additional information. Authors would like to thank Eugeny Rodichev for helpful discussions. Comments and bug reports are welcome.

F.22. pageinspect

The `pageinspect` module provides functions that allow you to inspect the contents of database pages at a low level, which is useful for debugging purposes. All of these functions may be used only by superusers.

F.22.1. General Functions

`get_raw_page(relname text, fork text, blkno int)` returns `bytea`

`get_raw_page` reads the specified block of the named relation and returns a copy as a `bytea` value. This allows a single time-consistent copy of the block to be obtained. `fork` should be 'main' for the main data fork, 'fsm' for the free space map, 'vm' for the visibility map, or 'init' for the initialization fork.

`get_raw_page(relname text, blkno int)` returns `bytea`

A shorthand version of `get_raw_page`, for reading from the main fork. Equivalent to `get_raw_page(relname, 'main', blkno)`

`page_header(page bytea)` returns `record`

`page_header` shows fields that are common to all PostgreSQL heap and index pages.

A page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM page_header(get_raw_page('pg_class', 0));
   lsn   | checksum | flags | lower | upper | special |
   pagesize | version | prune_xid
-----+-----+-----+-----+-----+-----
0/24A1B50 |          0 |      1 |  232 |  368 |    8192 |
8192 |          4 |          0
```

The returned columns correspond to the fields in the `PageHeaderData` struct. See `src/include/storage/bufpage.h` for details.

The `checksum` field is the checksum stored in the page, which might be incorrect if the page is somehow corrupted. If data checksums are not enabled for this instance, then the value stored is meaningless.

`page_checksum(page bytea, blkno int4)` returns `smallint`

`page_checksum` computes the checksum for the page, as if it was located at the given block.

A page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT page_checksum(get_raw_page('pg_class', 0), 0);
 page_checksum
-----
          13443
```

Note that the checksum depends on the block number, so matching block numbers should be passed (except when doing esoteric debugging).

The checksum computed with this function can be compared with the `checksum` result field of the function `page_header`. If data checksums are enabled for this instance, then the two values should be equal.

`fsm_page_contents(page bytea)` returns `text`

`fsm_page_contents` shows the internal node structure of a FSM page. For example:

```
test=# SELECT fsm_page_contents(get_raw_page('pg_class', 'fsm',
0));
```

The output is a multiline string, with one line per node in the binary tree within the page. Only those nodes that are not zero are printed. The so-called "next" pointer, which points to the next slot to be returned from the page, is also printed.

See `src/backend/storage/freespace/README` for more information on the structure of an FSM page.

F.22.2. Heap Functions

`heap_page_items(page bytea)` returns setof record

`heap_page_items` shows all line pointers on a heap page. For those line pointers that are in use, tuple headers as well as tuple raw data are also shown. All tuples are shown, whether or not the tuples were visible to an MVCC snapshot at the time the raw page was copied.

A heap page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM heap_page_items(get_raw_page('pg_class',
0));
```

See `src/include/storage/itemid.h` and `src/include/access/htup_details.h` for explanations of the fields returned.

`tuple_data_split(rel_oid oid, t_data bytea, t_infomask integer, t_infomask2 integer, t_bits text [, do_detoast bool])` returns bytea[]

`tuple_data_split` splits tuple data into attributes in the same way as backend internals.

```
test=# SELECT tuple_data_split('pg_class'::regclass,
t_data, t_infomask, t_infomask2, t_bits) FROM
heap_page_items(get_raw_page('pg_class', 0));
```

This function should be called with the same arguments as the return attributes of `heap_page_items`.

If `do_detoast` is true, attribute that will be detoasted as needed. Default value is false.

`heap_page_item_attrs(page bytea, rel_oid regclass [, do_detoast bool])` returns setof record

`heap_page_item_attrs` is equivalent to `heap_page_items` except that it returns tuple raw data as an array of attributes that can optionally be detoasted by `do_detoast` which is false by default.

A heap page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM
heap_page_item_attrs(get_raw_page('pg_class', 0),
'pg_class'::regclass);
```

F.22.3. B-Tree Functions

`bt_metap(relname text)` returns record

`bt_metap` returns information about a B-tree index's metapage. For example:

```
test=# SELECT * FROM bt_metap('pg_cast_oid_index');
-[ RECORD 1 ]-----+-----
magic           | 340322
version         | 3
root            | 1
level           | 0
fastroot        | 1
fastlevel       | 0
```

```
oldest_xact          | 582
last_cleanup_num_tuples | 1000
```

`bt_page_stats(relname text, blkno int)` returns record

`bt_page_stats` returns summary information about single pages of B-tree indexes. For example:

```
test=# SELECT * FROM bt_page_stats('pg_cast_oid_index', 1);
-[ RECORD 1 ]-+-----
blkno          | 1
type           | 1
live_items     | 256
dead_items     | 0
avg_item_size  | 12
page_size      | 8192
free_size      | 4056
btpo_prev      | 0
btpo_next      | 0
btpo           | 0
btpo_flags     | 3
```

`bt_page_items(relname text, blkno int)` returns setof record

`bt_page_items` returns detailed information about all of the items on a B-tree index page. For example:

```
test=# SELECT * FROM bt_page_items('pg_cast_oid_index', 1);
 itemoffset | ctid  | itemlen | nulls | vars | data
-----+-----+-----+-----+-----+-----
          1 | (0,1) |      12 | f     | f    | 23 27 00 00
          2 | (0,2) |      12 | f     | f    | 24 27 00 00
          3 | (0,3) |      12 | f     | f    | 25 27 00 00
          4 | (0,4) |      12 | f     | f    | 26 27 00 00
          5 | (0,5) |      12 | f     | f    | 27 27 00 00
          6 | (0,6) |      12 | f     | f    | 28 27 00 00
          7 | (0,7) |      12 | f     | f    | 29 27 00 00
          8 | (0,8) |      12 | f     | f    | 2a 27 00 00
```

In a B-tree leaf page, `ctid` points to a heap tuple. In an internal page, the block number part of `ctid` points to another page in the index itself, while the offset part (the second number) is ignored and is usually 1.

Note that the first item on any non-rightmost page (any page with a non-zero value in the `btpo_next` field) is the page's "high key", meaning its data serves as an upper bound on all items appearing on the page, while its `ctid` field is meaningless. Also, on non-leaf pages, the first real data item (the first item that is not a high key) is a "minus infinity" item, with no actual value in its data field. Such an item does have a valid downlink in its `ctid` field, however.

`bt_page_items(page bytea)` returns setof record

It is also possible to pass a page to `bt_page_items` as a `bytea` value. A page image obtained with `get_raw_page` should be passed as argument. So the last example could also be rewritten like this:

```
test=# SELECT * FROM
      bt_page_items(get_raw_page('pg_cast_oid_index', 1));
```

itemoffset	ctid	itemlen	nulls	vars	data
1	(0,1)	12	f	f	23 27 00 00
2	(0,2)	12	f	f	24 27 00 00
3	(0,3)	12	f	f	25 27 00 00
4	(0,4)	12	f	f	26 27 00 00
5	(0,5)	12	f	f	27 27 00 00
6	(0,6)	12	f	f	28 27 00 00
7	(0,7)	12	f	f	29 27 00 00
8	(0,8)	12	f	f	2a 27 00 00

All the other details are the same as explained in the previous item.

F.22.4. BRIN Functions

`brin_page_type(page bytea)` returns text

`brin_page_type` returns the page type of the given BRIN index page, or throws an error if the page is not a valid BRIN page. For example:

```
test=# SELECT brin_page_type(get_raw_page('brinidx', 0));
brin_page_type
-----
meta
```

`brin_metapage_info(page bytea)` returns record

`brin_metapage_info` returns assorted information about a BRIN index metapage. For example:

```
test=# SELECT * FROM brin_metapage_info(get_raw_page('brinidx',
0));
 magic | version | pagesperpage | lastrevmappage
-----+-----+-----+-----
0xA8109CFA | 1 | 4 | 2
```

`brin_revmap_data(page bytea)` returns setof tid

`brin_revmap_data` returns the list of tuple identifiers in a BRIN index range map page. For example:

```
test=# SELECT * FROM brin_revmap_data(get_raw_page('brinidx',
2)) LIMIT 5;
 pages
-----
(6,137)
(6,138)
(6,139)
(6,140)
(6,141)
```

`brin_page_items(page bytea, index oid)` returns setof record

`brin_page_items` returns the data stored in the BRIN data page. For example:

```
test=# SELECT * FROM brin_page_items(get_raw_page('brinidx', 5),
'brinidx')
```

```

ORDER BY blknum, attnum LIMIT 6;
itemoffset | blknum | attnum | allnulls | hasnulls |
placeholder | value
-----+-----+-----+-----+-----
+-----+-----+-----+-----+-----
      137 |      0 |      1 | t         | f         | f
|
      137 |      0 |      2 | f         | f         | f
| {1 .. 88}
      138 |      4 |      1 | t         | f         | f
|
      138 |      4 |      2 | f         | f         | f
| {89 .. 176}
      139 |      8 |      1 | t         | f         | f
|
      139 |      8 |      2 | f         | f         | f
| {177 .. 264}

```

The returned columns correspond to the fields in the `BrinMemTuple` and `BrinValues` structs. See `src/include/access/brin_tuple.h` for details.

F.22.5. GIN Functions

`gin_metapage_info(page bytea)` returns record

`gin_metapage_info` returns information about a GIN index metapage. For example:

```

test=# SELECT * FROM gin_metapage_info(get_raw_page('gin_index',
0));
-[ RECORD 1 ]-----+-----
pending_head         | 4294967295
pending_tail         | 4294967295
tail_free_size       | 0
n_pending_pages      | 0
n_pending_tuples     | 0
n_total_pages        | 7
n_entry_pages        | 6
n_data_pages         | 0
n_entries            | 693
version              | 2

```

`gin_page_opaque_info(page bytea)` returns record

`gin_page_opaque_info` returns information about a GIN index opaque area, like the page type. For example:

```

test=# SELECT * FROM
gin_page_opaque_info(get_raw_page('gin_index', 2));
rightlink | maxoff | flags
-----+-----+-----
          5 |      0 | {data,leaf,compressed}
(1 row)

```

`gin_leafpage_items(page bytea)` returns setof record

`gin_leafpage_items` returns information about the data stored in a GIN leaf page. For example:

```

test=# SELECT first_tid, nbytes, tids[0:5] AS some_tids
       FROM gin_leafpage_items(get_raw_page('gin_test_idx',
2));
 first_tid | nbytes |          some_tids
-----+-----
+-----+-----
(8,41)    |    244 | {"(8,41)","(8,43)","(8,44)","(8,45)","(8,46)"}
(10,45)   |    248 | {"(10,45)","(10,46)","(10,47)","(10,48)","(10,49)"}
(12,52)   |    248 | {"(12,52)","(12,53)","(12,54)","(12,55)","(12,56)"}
(14,59)   |    320 | {"(14,59)","(14,60)","(14,61)","(14,62)","(14,63)"}
(167,16)  |    376 | {"(167,16)","(167,17)","(167,18)","(167,19)","(167,20)"}
(170,30)  |    376 | {"(170,30)","(170,31)","(170,32)","(170,33)","(170,34)"}
(173,44)  |    197 | {"(173,44)","(173,45)","(173,46)","(173,47)","(173,48)"}
(7 rows)

```

F.22.6. Hash Functions

`hash_page_type(page bytea)` returns text

`hash_page_type` returns page type of the given HASH index page. For example:

```

test=# SELECT hash_page_type(get_raw_page('con_hash_index', 0));
 hash_page_type
-----
metapage

```

`hash_page_stats(page bytea)` returns setof record

`hash_page_stats` returns information about a bucket or overflow page of a HASH index. For example:

```

test=# SELECT * FROM
       hash_page_stats(get_raw_page('con_hash_index', 1));
-[ RECORD 1 ]-----+-----
live_items          | 407
dead_items          | 0
page_size           | 8192
free_size           | 8
hasho_prevblkno    | 4096
hasho_nextblkno    | 8474
hasho_bucket        | 0
hasho_flag          | 66
hasho_page_id       | 65408

```

`hash_page_items(page bytea)` returns setof record

`hash_page_items` returns information about the data stored in a bucket or overflow page of a HASH index page. For example:

```
test=# SELECT * FROM
  hash_page_items(get_raw_page('con_hash_index', 1)) LIMIT 5;
 itemoffset |   ctid   |   data
-----+-----+-----
          1 | (899,77) | 1053474816
          2 | (897,29) | 1053474816
          3 | (894,207)| 1053474816
          4 | (892,159)| 1053474816
          5 | (890,111)| 1053474816
```

hash_bitmap_info(index oid, blkno int) returns record

hash_bitmap_info shows the status of a bit in the bitmap page for a particular overflow page of HASH index. For example:

```
test=# SELECT * FROM hash_bitmap_info('con_hash_index', 2052);
 bitmapblkno | bitmapbit | bitstatus
-----+-----+-----
           65 |          3 | t
```

hash_metapage_info(page bytea) returns record

hash_metapage_info returns information stored in meta page of a HASH index. For example:

```
test=# SELECT magic, version, ntuples, ffactor, bsize, bmsize,
  bmshift,
test-#      maxbucket, highmask, lowmask, ovflpoint, firstfree,
  nmaps, procid,
test-#      regexp_replace(spares::text, '(,0)*}', '}') as
  spares,
test-#      regexp_replace(mapp::text, '(,0)*}', '}') as mapp
test=# FROM hash_metapage_info(get_raw_page('con_hash_index',
  0));
-[ RECORD
  1 ]-----+-----
magic      | 105121344
version    | 4
ntuples    | 500500
ffactor    | 40
bsize      | 8152
bmsize     | 4096
bmshift    | 15
maxbucket  | 12512
highmask   | 16383
lowmask    | 8191
ovflpoint  | 28
firstfree  | 1204
nmaps      | 1
procid     | 450
spares     |
{0,0,0,0,0,0,1,1,1,1,1,1,1,1,1,1,3,4,4,4,45,55,58,59,508,567,628,704,1193,1202,
mapp      | {65}
```

F.23. passwordcheck

The `passwordcheck` module checks users' passwords whenever they are set with `CREATE ROLE` or `ALTER ROLE`. If a password is considered too weak, it will be rejected and the command will terminate with an error.

To enable this module, add `'$libdir/passwordcheck'` to `shared_preload_libraries` in `postgresql.conf`, then restart the server.

You can adapt this module to your needs by changing the source code. For example, you can use `CrackLib`² to check passwords — this only requires uncommenting two lines in the `Makefile` and rebuilding the module. (We cannot include `CrackLib` by default for license reasons.) Without `CrackLib`, the module enforces a few simple rules for password strength, which you can modify or extend as you see fit.

Caution

To prevent unencrypted passwords from being sent across the network, written to the server log or otherwise stolen by a database administrator, PostgreSQL allows the user to supply pre-encrypted passwords. Many client programs make use of this functionality and encrypt the password before sending it to the server.

This limits the usefulness of the `passwordcheck` module, because in that case it can only try to guess the password. For this reason, `passwordcheck` is not recommended if your security requirements are high. It is more secure to use an external authentication method such as GSSAPI (see Chapter 20) than to rely on passwords within the database.

Alternatively, you could modify `passwordcheck` to reject pre-encrypted passwords, but forcing users to set their passwords in clear text carries its own security risks.

F.24. `pg_buffercache`

The `pg_buffercache` module provides a means for examining what's happening in the shared buffer cache in real time.

The module provides a C function `pg_buffercache_pages` that returns a set of records, plus a view `pg_buffercache` that wraps the function for convenient use.

By default use is restricted to superusers and members of the `pg_read_all_stats` role. Access may be granted to others using `GRANT`.

F.24.1. The `pg_buffercache` View

The definitions of the columns exposed by the view are shown in Table F.15.

Table F.15. `pg_buffercache` Columns

Name	Type	References	Description
<code>bufferid</code>	<code>integer</code>		ID, in the range <code>1..shared_buffers</code>
<code>relfilenode</code>	<code>oid</code>	<code>pg_class.relfilenode</code>	Filenode number of the relation

² <https://sourceforge.net/projects/cracklib/>

Name	Type	References	Description
reltablespace	oid	pg_tablespace.oid	Tablespace OID of the relation
reldatabase	oid	pg_database.oid	Database OID of the relation
relforknumber	smallint		Fork number within the relation; see include/common/relpath.h
relblocknumber	bigint		Page number within the relation
isdirty	boolean		Is the page dirty?
usagecount	smallint		Clock-sweep access count
pinning_backends	integer		Number of backends pinning this buffer

There is one row for each buffer in the shared cache. Unused buffers are shown with all fields null except `bufferid`. Shared system catalogs are shown as belonging to database zero.

Because the cache is shared by all the databases, there will normally be pages from relations not belonging to the current database. This means that there may not be matching join rows in `pg_class` for some rows, or that there could even be incorrect joins. If you are trying to join against `pg_class`, it's a good idea to restrict the join to rows having `reldatabase` equal to the current database's OID or zero.

When the `pg_buffercache` view is accessed, internal buffer manager locks are taken for long enough to copy all the buffer state data that the view will display. This ensures that the view produces a consistent set of results, while not blocking normal buffer activity longer than necessary. Nonetheless there could be some impact on database performance if this view is read often.

F.24.2. Sample Output

```
regression=# SELECT c.relname, count(*) AS buffers
              FROM pg_buffercache b INNER JOIN pg_class c
              ON b.relfilenode = pg_relation_filenode(c.oid) AND
                 b.reldatabase IN (0, (SELECT oid FROM pg_database
                                       WHERE datname =
current_database()))
              GROUP BY c.relname
              ORDER BY 2 DESC
              LIMIT 10;
```

relname	buffers
tenk2	345
tenk1	141
pg_proc	46
pg_class	45
pg_attribute	43
pg_class_relname_nsp_index	30
pg_proc_proname_args_nsp_index	28
pg_attribute_relid_attnam_index	26
pg_depend	22

```
pg_depend_reference_index | 20
(10 rows)
```

F.24.3. Authors

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Design suggestions: Neil Conway <neilc@samurai.com>

Debugging advice: Tom Lane <tgl@sss.pgh.pa.us>

F.25. pgcrypto

The `pgcrypto` module provides cryptographic functions for PostgreSQL.

F.25.1. General Hashing Functions

F.25.1.1. `digest()`

```
digest(data text, type text) returns bytea
digest(data bytea, type text) returns bytea
```

Computes a binary hash of the given *data*. *type* is the algorithm to use. Standard algorithms are `md5`, `sha1`, `sha224`, `sha256`, `sha384` and `sha512`. If `pgcrypto` was built with OpenSSL, more algorithms are available, as detailed in Table F.19.

If you want the digest as a hexadecimal string, use `encode()` on the result. For example:

```
CREATE OR REPLACE FUNCTION sha1(bytea) returns text AS $$
    SELECT encode(digest($1, 'sha1'), 'hex')
$$ LANGUAGE SQL STRICT IMMUTABLE;
```

F.25.1.2. `hmac()`

```
hmac(data text, key text, type text) returns bytea
hmac(data bytea, key bytea, type text) returns bytea
```

Calculates hashed MAC for *data* with key *key*. *type* is the same as in `digest()`.

This is similar to `digest()` but the hash can only be recalculated knowing the key. This prevents the scenario of someone altering data and also changing the hash to match.

If the key is larger than the hash block size it will first be hashed and the result will be used as key.

F.25.2. Password Hashing Functions

The functions `crypt()` and `gen_salt()` are specifically designed for hashing passwords. `crypt()` does the hashing and `gen_salt()` prepares algorithm parameters for it.

The algorithms in `crypt()` differ from the usual MD5 or SHA1 hashing algorithms in the following respects:

1. They are slow. As the amount of data is so small, this is the only way to make brute-forcing passwords hard.

2. They use a random value, called the *salt*, so that users having the same password will have different encrypted passwords. This is also an additional defense against reversing the algorithm.
3. They include the algorithm type in the result, so passwords hashed with different algorithms can co-exist.
4. Some of them are adaptive — that means when computers get faster, you can tune the algorithm to be slower, without introducing incompatibility with existing passwords.

Table F.16 lists the algorithms supported by the `crypt()` function.

Table F.16. Supported Algorithms for `crypt()`

Algorithm	Max Password Length	Adaptive?	Salt Bits	Output Length	Description
bf	72	yes	128	60	Blow-fish-based, variant 2a
md5	unlimited	no	48	34	MD5-based crypt
xdes	8	yes	24	20	Extended DES
des	8	no	12	13	Original UNIX crypt

F.25.2.1. `crypt()`

`crypt(password text, salt text)` returns `text`

Calculates a crypt(3)-style hash of *password*. When storing a new password, you need to use `gen_salt()` to generate a new *salt* value. To check a password, pass the stored hash value as *salt*, and test whether the result matches the stored value.

Example of setting a new password:

```
UPDATE ... SET pswhash = crypt('new password', gen_salt('md5'));
```

Example of authentication:

```
SELECT (pswhash = crypt('entered password', pswhash)) AS pswmatch
FROM ... ;
```

This returns `true` if the entered password is correct.

F.25.2.2. `gen_salt()`

`gen_salt(type text [, iter_count integer])` returns `text`

Generates a new random salt string for use in `crypt()`. The salt string also tells `crypt()` which algorithm to use.

The *type* parameter specifies the hashing algorithm. The accepted types are: `des`, `xdes`, `md5` and `bf`.

The *iter_count* parameter lets the user specify the iteration count, for algorithms that have one. The higher the count, the more time it takes to hash the password and therefore the more time to

break it. Although with too high a count the time to calculate a hash may be several years — which is somewhat impractical. If the *iter_count* parameter is omitted, the default iteration count is used. Allowed values for *iter_count* depend on the algorithm and are shown in Table F.17.

Table F.17. Iteration Counts for `crypt ()`

Algorithm	Default	Min	Max
xdes	725	1	16777215
bf	6	4	31

For xdes there is an additional limitation that the iteration count must be an odd number.

To pick an appropriate iteration count, consider that the original DES crypt was designed to have the speed of 4 hashes per second on the hardware of that time. Slower than 4 hashes per second would probably dampen usability. Faster than 100 hashes per second is probably too fast.

Table F.18 gives an overview of the relative slowness of different hashing algorithms. The table shows how much time it would take to try all combinations of characters in an 8-character password, assuming that the password contains either only lower case letters, or upper- and lower-case letters and numbers. In the `crypt-bf` entries, the number after a slash is the *iter_count* parameter of `gen_salt`.

Table F.18. Hash Algorithm Speeds

Algorithm	Hashes/sec	For [a-z]	For [A-Za-z0-9]	Duration relative to md5 hash
<code>crypt-bf/8</code>	1792	4 years	3927 years	100k
<code>crypt-bf/7</code>	3648	2 years	1929 years	50k
<code>crypt-bf/6</code>	7168	1 year	982 years	25k
<code>crypt-bf/5</code>	13504	188 days	521 years	12.5k
<code>crypt-md5</code>	171584	15 days	41 years	1k
<code>crypt-des</code>	23221568	157.5 minutes	108 days	7
<code>sha1</code>	37774272	90 minutes	68 days	4
<code>md5 (hash)</code>	150085504	22.5 minutes	17 days	1

Notes:

- The machine used is an Intel Mobile Core i3.
- `crypt-des` and `crypt-md5` algorithm numbers are taken from John the Ripper v1.6.38 `-test` output.
- `md5 hash` numbers are from `mdcrack 1.2`.
- `sha1` numbers are from `lcrack-20031130-beta`.
- `crypt-bf` numbers are taken using a simple program that loops over 1000 8-character passwords. That way I can show the speed with different numbers of iterations. For reference: `john -test` shows 13506 loops/sec for `crypt-bf/5`. (The very small difference in results is in accordance with the fact that the `crypt-bf` implementation in `pgcrypto` is the same one used in John the Ripper.)

Note that “try all combinations” is not a realistic exercise. Usually password cracking is done with the help of dictionaries, which contain both regular words and various mutations of them. So, even somewhat word-like passwords could be cracked much faster than the above numbers suggest, while a 6-character non-word-like password may escape cracking. Or not.

F.25.3. PGP Encryption Functions

The functions here implement the encryption part of the OpenPGP (RFC 4880) standard. Supported are both symmetric-key and public-key encryption.

An encrypted PGP message consists of 2 parts, or *packets*:

- Packet containing a session key — either symmetric-key or public-key encrypted.
- Packet containing data encrypted with the session key.

When encrypting with a symmetric key (i.e., a password):

1. The given password is hashed using a String2Key (S2K) algorithm. This is rather similar to `crypt()` algorithms — purposefully slow and with random salt — but it produces a full-length binary key.
2. If a separate session key is requested, a new random key will be generated. Otherwise the S2K key will be used directly as the session key.
3. If the S2K key is to be used directly, then only S2K settings will be put into the session key packet. Otherwise the session key will be encrypted with the S2K key and put into the session key packet.

When encrypting with a public key:

1. A new random session key is generated.
2. It is encrypted using the public key and put into the session key packet.

In either case the data to be encrypted is processed as follows:

1. Optional data-manipulation: compression, conversion to UTF-8, and/or conversion of line-endings.
2. The data is prefixed with a block of random bytes. This is equivalent to using a random IV.
3. An SHA1 hash of the random prefix and data is appended.
4. All this is encrypted with the session key and placed in the data packet.

F.25.3.1. `pgp_sym_encrypt()`

```
pgp_sym_encrypt(data text, psw text [, options text ]) returns  
bytea  
pgp_sym_encrypt_bytea(data bytea, psw text [, options text ])  
returns bytea
```

Encrypt *data* with a symmetric PGP key *psw*. The *options* parameter can contain option settings, as described below.

F.25.3.2. `pgp_sym_decrypt()`

```
pgp_sym_decrypt(msg bytea, psw text [, options text ]) returns text  
pgp_sym_decrypt_bytea(msg bytea, psw text [, options text ])  
returns bytea
```

Decrypt a symmetric-key-encrypted PGP message.

Decrypting *bytea* data with `pgp_sym_decrypt` is disallowed. This is to avoid outputting invalid character data. Decrypting originally textual data with `pgp_sym_decrypt_bytea` is fine.

The *options* parameter can contain option settings, as described below.

F.25.3.3. `pgp_pub_encrypt ()`

```
pgp_pub_encrypt(data text, key bytea [, options text ]) returns
bytea
pgp_pub_encrypt_bytea(data bytea, key bytea [, options text ])
returns bytea
```

Encrypt *data* with a public PGP key *key*. Giving this function a secret key will produce an error.

The *options* parameter can contain option settings, as described below.

F.25.3.4. `pgp_pub_decrypt ()`

```
pgp_pub_decrypt(msg bytea, key bytea [, psw text [, options
text]]) returns text
pgp_pub_decrypt_bytea(msg bytea, key bytea [, psw text [, options
text]]) returns bytea
```

Decrypt a public-key-encrypted message. *key* must be the secret key corresponding to the public key that was used to encrypt. If the secret key is password-protected, you must give the password in *psw*. If there is no password, but you want to specify options, you need to give an empty password.

Decrypting *bytea* data with `pgp_pub_decrypt` is disallowed. This is to avoid outputting invalid character data. Decrypting originally textual data with `pgp_pub_decrypt_bytea` is fine.

The *options* parameter can contain option settings, as described below.

F.25.3.5. `pgp_key_id ()`

```
pgp_key_id(bytea) returns text
```

`pgp_key_id` extracts the key ID of a PGP public or secret key. Or it gives the key ID that was used for encrypting the data, if given an encrypted message.

It can return 2 special key IDs:

- SYMKEY

The message is encrypted with a symmetric key.

- ANYKEY

The message is public-key encrypted, but the key ID has been removed. That means you will need to try all your secret keys on it to see which one decrypts it. `pgcrypto` itself does not produce such messages.

Note that different keys may have the same ID. This is rare but a normal event. The client application should then try to decrypt with each one, to see which fits — like handling ANYKEY.

F.25.3.6. `armor () , dearmor ()`

```
armor(data bytea [, keys text[], values text[]]) returns text
dearmor(data text) returns bytea
```

These functions wrap/unwrap binary data into PGP ASCII-armor format, which is basically Base64 with CRC and additional formatting.

If the *keys* and *values* arrays are specified, an *armor header* is added to the armored format for each key/value pair. Both arrays must be single-dimensional, and they must be of the same length. The keys and values cannot contain any non-ASCII characters.

F.25.3.7. `pgp_armor_headers`

`pgp_armor_headers(data text, key out text, value out text)` returns
setof record

`pgp_armor_headers()` extracts the armor headers from *data*. The return value is a set of rows with two columns, key and value. If the keys or values contain any non-ASCII characters, they are treated as UTF-8.

F.25.3.8. Options for PGP Functions

Options are named to be similar to GnuPG. An option's value should be given after an equal sign; separate options from each other with commas. For example:

```
pgp_sym_encrypt(data, psw, 'compress-algo=1, cipher-algo=aes256')
```

All of the options except `convert-crlf` apply only to encrypt functions. Decrypt functions get the parameters from the PGP data.

The most interesting options are probably `compress-algo` and `unicode-mode`. The rest should have reasonable defaults.

F.25.3.8.1. `cipher-algo`

Which cipher algorithm to use.

Values: bf, aes128, aes192, aes256 (OpenSSL-only: 3des, cast5)

Default: aes128

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

F.25.3.8.2. `compress-algo`

Which compression algorithm to use. Only available if PostgreSQL was built with zlib.

Values:

0 - no compression

1 - ZIP compression

2 - ZLIB compression (= ZIP plus meta-data and block CRCs)

Default: 0

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

F.25.3.8.3. `compress-level`

How much to compress. Higher levels compress smaller but are slower. 0 disables compression.

Values: 0, 1-9

Default: 6

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

F.25.3.8.4. convert-crlf

Whether to convert `\n` into `\r\n` when encrypting and `\r\n` to `\n` when decrypting. RFC 4880 specifies that text data should be stored using `\r\n` line-feeds. Use this to get fully RFC-compliant behavior.

Values: 0, 1

Default: 0

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`, `pgp_sym_decrypt`, `pgp_pub_decrypt`

F.25.3.8.5. disable-mdc

Do not protect data with SHA-1. The only good reason to use this option is to achieve compatibility with ancient PGP products, predating the addition of SHA-1 protected packets to RFC 4880. Recent `gnupg.org` and `pgp.com` software supports it fine.

Values: 0, 1

Default: 0

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

F.25.3.8.6. sess-key

Use separate session key. Public-key encryption always uses a separate session key; this option is for symmetric-key encryption, which by default uses the S2K key directly.

Values: 0, 1

Default: 0

Applies to: `pgp_sym_encrypt`

F.25.3.8.7. s2k-mode

Which S2K algorithm to use.

Values:

0 - Without salt. Dangerous!

1 - With salt but with fixed iteration count.

3 - Variable iteration count.

Default: 3

Applies to: `pgp_sym_encrypt`

F.25.3.8.8. s2k-count

The number of iterations of the S2K algorithm to use. It must be a value between 1024 and 65011712, inclusive.

Default: A random value between 65536 and 253952

Applies to: `pgp_sym_encrypt`, only with `s2k-mode=3`

F.25.3.8.9. s2k-digest-algo

Which digest algorithm to use in S2K calculation.

Values: `md5`, `sha1`

Default: `sha1`

Applies to: `pgp_sym_encrypt`

F.25.3.8.10. `s2k-cipher-algo`

Which cipher to use for encrypting separate session key.

Values: `bf`, `aes`, `aes128`, `aes192`, `aes256`

Default: `use cipher-algo`

Applies to: `pgp_sym_encrypt`

F.25.3.8.11. `unicode-mode`

Whether to convert textual data from database internal encoding to UTF-8 and back. If your database already is UTF-8, no conversion will be done, but the message will be tagged as UTF-8. Without this option it will not be.

Values: `0`, `1`

Default: `0`

Applies to: `pgp_sym_encrypt`, `pgp_pub_encrypt`

F.25.3.9. Generating PGP Keys with GnuPG

To generate a new key:

```
gpg --gen-key
```

The preferred key type is “DSA and Elgamal”.

For RSA encryption you must create either DSA or RSA sign-only key as master and then add an RSA encryption subkey with `gpg --edit-key`.

To list keys:

```
gpg --list-secret-keys
```

To export a public key in ASCII-armor format:

```
gpg -a --export KEYID > public.key
```

To export a secret key in ASCII-armor format:

```
gpg -a --export-secret-keys KEYID > secret.key
```

You need to use `dearmor()` on these keys before giving them to the PGP functions. Or if you can handle binary data, you can drop `-a` from the command.

For more details see `man gpg`, The GNU Privacy Handbook³ and other documentation on <https://www.gnupg.org/>.

F.25.3.10. Limitations of PGP Code

- No support for signing. That also means that it is not checked whether the encryption subkey belongs to the master key.

³ <https://www.gnupg.org/gph/en/manual.html>

- No support for encryption key as master key. As such practice is generally discouraged, this should not be a problem.
- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with `pgcrypto`, but create new ones, as the usage scenario is rather different.

F.25.4. Raw Encryption Functions

These functions only run a cipher over data; they don't have any advanced features of PGP encryption. Therefore they have some major problems:

1. They use user key directly as cipher key.
2. They don't provide any integrity checking, to see if the encrypted data was modified.
3. They expect that users manage all encryption parameters themselves, even IV.
4. They don't handle text.

So, with the introduction of PGP encryption, usage of raw encryption functions is discouraged.

```
encrypt(data bytea, key bytea, type text) returns bytea
decrypt(data bytea, key bytea, type text) returns bytea
```

```
encrypt_iv(data bytea, key bytea, iv bytea, type text) returns
bytea
decrypt_iv(data bytea, key bytea, iv bytea, type text) returns
bytea
```

Encrypt/decrypt data using the cipher method specified by *type*. The syntax of the *type* string is:

```
algorithm [ - mode ] [ /pad: padding ]
```

where *algorithm* is one of:

- `bf` — Blowfish
- `aes` — AES (Rijndael-128, -192 or -256)

and *mode* is one of:

- `cbc` — next block depends on previous (default)
- `ecb` — each block is encrypted separately (for testing only)

and *padding* is one of:

- `pkcs` — data may be any length (default)
- `none` — data must be multiple of cipher block size

So, for example, these are equivalent:

```
encrypt(data, 'fooz', 'bf')
encrypt(data, 'fooz', 'bf-cbc/pad:pkcs')
```

In `encrypt_iv` and `decrypt_iv`, the `iv` parameter is the initial value for the CBC mode; it is ignored for ECB. It is clipped or padded with zeroes if not exactly block size. It defaults to all zeroes in the functions without this parameter.

F.25.5. Random-Data Functions

`gen_random_bytes(count integer)` returns `bytea`

Returns `count` cryptographically strong random bytes. At most 1024 bytes can be extracted at a time. This is to avoid draining the randomness generator pool.

`gen_random_uuid()` returns `uuid`

Returns a version 4 (random) UUID.

F.25.6. Notes

F.25.6.1. Configuration

`pgcrypto` configures itself according to the findings of the main PostgreSQL `configure` script. The options that affect it are `--with-zlib` and `--with-openssl`.

When compiled with `zlib`, PGP encryption functions are able to compress data before encrypting.

When compiled with `OpenSSL`, there will be more algorithms available. Also public-key encryption functions will be faster as `OpenSSL` has more optimized `BIGNUM` functions.

Table F.19. Summary of Functionality with and without OpenSSL

Functionality	Built-in	With OpenSSL
MD5	yes	yes
SHA1	yes	yes
SHA224/256/384/512	yes	yes
Other digest algorithms	no	yes (Note 1)
Blowfish	yes	yes
AES	yes	yes
DES/3DES/CAST5	no	yes
Raw encryption	yes	yes
PGP Symmetric encryption	yes	yes
PGP Public-Key encryption	yes	yes

Notes:

1. Any digest algorithm `OpenSSL` supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly.

F.25.6.2. NULL Handling

As is standard in SQL, all functions return `NULL`, if any of the arguments are `NULL`. This may create security risks on careless usage.

F.25.6.3. Security Limitations

All `pgcrypto` functions run inside the database server. That means that all the data and passwords move between `pgcrypto` and client applications in clear text. Thus you must:

1. Connect locally or use SSL connections.
2. Trust both system and database administrator.

If you cannot, then better do crypto inside client application.

The implementation does not resist side-channel attacks⁴. For example, the time required for a `pgcrypto` decryption function to complete varies among ciphertexts of a given size.

F.25.6.4. Useful Reading

- <https://www.gnupg.org/gph/en/manual.html>
The GNU Privacy Handbook.
- <http://www.openwall.com/crypt/>
Describes the crypt-blowfish algorithm.
- <http://www.iusmentis.com/security/passphrasefaq/>
How to choose a good password.
- <http://world.std.com/~reinhold/diceware.html>
Interesting idea for picking passwords.
- <http://www.interhack.net/people/cmcurtin/snake-oil-faq.html>
Describes good and bad cryptography.

F.25.6.5. Technical References

- <https://tools.ietf.org/html/rfc4880>
OpenPGP message format.
- <https://tools.ietf.org/html/rfc1321>
The MD5 Message-Digest Algorithm.
- <https://tools.ietf.org/html/rfc2104>
HMAC: Keyed-Hashing for Message Authentication.
- <https://www.usenix.org/legacy/events/usenix99/provos.html>
Comparison of crypt-des, crypt-md5 and bcrypt algorithms.
- [https://en.wikipedia.org/wiki/Fortuna_\(PRNG\)](https://en.wikipedia.org/wiki/Fortuna_(PRNG))
Description of Fortuna CSPRNG.
- <http://jlcooke.ca/random/>
Jean-Luc Cooke Fortuna-based `/dev/random` driver for Linux.

⁴ https://en.wikipedia.org/wiki/Side-channel_attack

F.25.7. Author

Marko Kreen <markokr@gmail.com>

pgcrypto uses code from the following sources:

Algorithm	Author	Source origin
DES crypt	David Burren and others	FreeBSD libcrypt
MD5 crypt	Poul-Henning Kamp	FreeBSD libcrypt
Blowfish crypt	Solar Designer	www.openwall.com
Blowfish cipher	Simon Tatham	PuTTY
Rijndael cipher	Brian Gladman	OpenBSD sys/crypto
MD5 hash and SHA1	WIDE Project	KAME kame/sys/crypto
SHA256/384/512	Aaron D. Gifford	OpenBSD sys/crypto
BIGNUM math	Michael J. Fromberger	dartmouth.edu/~sting/sw/imath

F.26. pg_freespacemap

The `pg_freespacemap` module provides a means for examining the free space map (FSM). It provides a function called `pg_freespace`, or two overloaded functions, to be precise. The functions show the value recorded in the free space map for a given page, or for all pages in the relation.

By default use is restricted to superusers and members of the `pg_stat_scan_tables` role. Access may be granted to others using `GRANT`.

F.26.1. Functions

`pg_freespace(rel regclass IN, blkno bigint IN) returns int2`

Returns the amount of free space on the page of the relation, specified by `blkno`, according to the FSM.

`pg_freespace(rel regclass IN, blkno OUT bigint, avail OUT int2)`

Displays the amount of free space on each page of the relation, according to the FSM. A set of `(blkno bigint, avail int2)` tuples is returned, one tuple for each page in the relation.

The values stored in the free space map are not exact. They're rounded to precision of 1/256th of `BLCKSZ` (32 bytes with default `BLCKSZ`), and they're not kept fully up-to-date as tuples are inserted and updated.

For indexes, what is tracked is entirely-unused pages, rather than free space within pages. Therefore, the values are not meaningful, just whether a page is full or empty.

Note

The interface was changed in version 8.4, to reflect the new FSM implementation introduced in the same version.

F.26.2. Sample Output

```
postgres=# SELECT * FROM pg_freespace('foo');
 blkno | avail
-----+-----
      0 |      0
      1 |      0
      2 |      0
      3 |     32
      4 |    704
      5 |    704
      6 |    704
      7 |   1216
      8 |    704
      9 |    704
     10 |    704
     11 |    704
     12 |    704
     13 |    704
     14 |    704
     15 |    704
     16 |    704
     17 |    704
     18 |    704
     19 |   3648
(20 rows)
```

```
postgres=# SELECT * FROM pg_freespace('foo', 7);
 pg_freespace
-----
          1216
(1 row)
```

F.26.3. Author

Original version by Mark Kirkwood <markir@paradise.net.nz>. Rewritten in version 8.4 to suit new FSM implementation by Heikki Linnakangas <heikki@enterprisedb.com>

F.27. pg_prewarm

The `pg_prewarm` module provides a convenient way to load relation data into either the operating system buffer cache or the PostgreSQL buffer cache. Prewarming can be performed manually using the `pg_prewarm` function, or can be performed automatically by including `pg_prewarm` in `shared_preload_libraries`. In the latter case, the system will run a background worker which periodically records the contents of shared buffers in a file called `autoprewarm.blocks` and will, using 2 background workers, reload those same blocks after a restart.

F.27.1. Functions

```
pg_prewarm(regclass, mode text default 'buffer', fork text default
'main',
           first_block int8 default null,
           last_block int8 default null) RETURNS int8
```

The first argument is the relation to be prewarmed. The second argument is the prewarming method to be used, as further discussed below; the third is the relation fork to be prewarmed, usually `main`. The fourth argument is the first block number to prewarm (NULL is accepted as a synonym for zero).

The fifth argument is the last block number to prewarm (NULL means prewarm through the last block in the relation). The return value is the number of blocks prewarmed.

There are three available prewarming methods. `prefetch` issues asynchronous prefetch requests to the operating system, if this is supported, or throws an error otherwise. `read` reads the requested range of blocks; unlike `prefetch`, this is synchronous and supported on all platforms and builds, but may be slower. `buffer` reads the requested range of blocks into the database buffer cache.

Note that with any of these methods, attempting to prewarm more blocks than can be cached — by the OS when using `prefetch` or `read`, or by PostgreSQL when using `buffer` — will likely result in lower-numbered blocks being evicted as higher numbered blocks are read in. Prewarmed data also enjoys no special protection from cache evictions, so it is possible that other system activity may evict the newly prewarmed blocks shortly after they are read; conversely, prewarming may also evict other data from cache. For these reasons, prewarming is typically most useful at startup, when caches are largely empty.

```
autoprewarm_start_worker() RETURNS void
```

Launch the main autoprewarm worker. This will normally happen automatically, but is useful if automatic prewarm was not configured at server startup time and you wish to start up the worker at a later time.

```
autoprewarm_dump_now() RETURNS int8
```

Update `autoprewarm.blocks` immediately. This may be useful if the autoprewarm worker is not running but you anticipate running it after the next restart. The return value is the number of records written to `autoprewarm.blocks`.

F.27.2. Configuration Parameters

```
pg_prewarm.autoprewarm (boolean)
```

Controls whether the server should run the autoprewarm worker. This is on by default. This parameter can only be set at server start.

```
pg_prewarm.autoprewarm_interval (int)
```

This is the interval between updates to `autoprewarm.blocks`. The default is 300 seconds. If set to 0, the file will not be dumped at regular intervals, but only when the server is shut down.

F.27.3. Author

Robert Haas <rhaas@postgresql.org>

F.28. pgrowlocks

The `pgrowlocks` module provides a function to show row locking information for a specified table.

By default use is restricted to superusers, members of the `pg_stat_scan_tables` role, and users with `SELECT` permissions on the table.

F.28.1. Overview

```
pgrowlocks(text) returns setof record
```

The parameter is the name of a table. The result is a set of records, with one row for each locked row within the table. The output columns are shown in Table F.20.

Table F.20. `pgrowlocks` Output Columns

Name	Type	Description
<code>locked_row</code>	<code>tid</code>	Tuple ID (TID) of locked row
<code>locker</code>	<code>xid</code>	Transaction ID of locker, or multixact ID if multitransaction
<code>multi</code>	<code>boolean</code>	True if locker is a multitransaction
<code>xids</code>	<code>xid[]</code>	Transaction IDs of lockers (more than one if multitransaction)
<code>modes</code>	<code>text[]</code>	Lock mode of lockers (more than one if multitransaction), an array of Key Share, Share, For No Key Update, No Key Update, For Update, Update.
<code>pids</code>	<code>integer[]</code>	Process IDs of locking backends (more than one if multitransaction)

`pgrowlocks` takes `AccessShareLock` for the target table and reads each row one by one to collect the row locking information. This is not very speedy for a large table. Note that:

1. If the table as a whole is exclusive-locked by someone else, `pgrowlocks` will be blocked.
2. `pgrowlocks` is not guaranteed to produce a self-consistent snapshot. It is possible that a new row lock is taken, or an old lock is freed, during its execution.

`pgrowlocks` does not show the contents of locked rows. If you want to take a look at the row contents at the same time, you could do something like this:

```
SELECT * FROM accounts AS a, pgrowlocks('accounts') AS p
WHERE p.locked_row = a.ctid;
```

Be aware however that such a query will be very inefficient.

F.28.2. Sample Output

```
=# SELECT * FROM pgrowlocks('t1');
locked_row | locker | multi | xids | modes | pids
-----+-----+-----+-----+-----+-----
(0,1)      |    609 | f      | {609} | {"For Share"} | {3161}
(0,2)      |    609 | f      | {609} | {"For Share"} | {3161}
(0,3)      |    607 | f      | {607} | {"For Update"} | {3107}
(0,4)      |    607 | f      | {607} | {"For Update"} | {3107}
(4 rows)
```

F.28.3. Author

Tatsuo Ishii

F.29. pg_stat_statements

The `pg_stat_statements` module provides a means for tracking execution statistics of all SQL statements executed by a server.

The module must be loaded by adding `pg_stat_statements` to `shared_preload_libraries` in `postgresql.conf`, because it requires additional shared memory. This means that a server restart is needed to add or remove the module.

When `pg_stat_statements` is loaded, it tracks statistics across all databases of the server. To access and manipulate these statistics, the module provides a view, `pg_stat_statements`, and the utility functions `pg_stat_statements_reset` and `pg_stat_statements`. These are not available globally but can be enabled for a specific database with `CREATE EXTENSION pg_stat_statements`.

F.29.1. The pg_stat_statements View

The statistics gathered by the module are made available via a view named `pg_stat_statements`. This view contains one row for each distinct database ID, user ID and query ID (up to the maximum number of distinct statements that the module can track). The columns of the view are shown in Table F.21.

Table F.21. pg_stat_statements Columns

Name	Type	References	Description
<code>userid</code>	<code>oid</code>	<code>pg_authid.oid</code>	OID of user who executed the statement
<code>dbid</code>	<code>oid</code>	<code>pg_database.oid</code>	OID of database in which the statement was executed
<code>queryid</code>	<code>bigint</code>		Internal hash code, computed from the statement's parse tree
<code>query</code>	<code>text</code>		Text of a representative statement
<code>calls</code>	<code>bigint</code>		Number of times executed
<code>total_time</code>	<code>double precision</code>		Total time spent in the statement, in milliseconds
<code>min_time</code>	<code>double precision</code>		Minimum time spent in the statement, in milliseconds
<code>max_time</code>	<code>double precision</code>		Maximum time spent in the statement, in milliseconds
<code>mean_time</code>	<code>double precision</code>		Mean time spent in the statement, in milliseconds
<code>stddev_time</code>	<code>double precision</code>		Population standard deviation of time spent in the statement, in milliseconds

Name	Type	References	Description
rows	bigint		Total number of rows retrieved or affected by the statement
shared_blks_hit	bigint		Total number of shared block cache hits by the statement
shared_blks_read	bigint		Total number of shared blocks read by the statement
shared_blks_dirtied	bigint		Total number of shared blocks dirtied by the statement
shared_blks_written	bigint		Total number of shared blocks written by the statement
local_blks_hit	bigint		Total number of local block cache hits by the statement
local_blks_read	bigint		Total number of local blocks read by the statement
local_blks_dirtied	bigint		Total number of local blocks dirtied by the statement
local_blks_written	bigint		Total number of local blocks written by the statement
temp_blks_read	bigint		Total number of temp blocks read by the statement
temp_blks_written	bigint		Total number of temp blocks written by the statement
blk_read_time	double precision		Total time the statement spent reading blocks, in milliseconds (if <code>track_io_timing</code> is enabled, otherwise zero)
blk_write_time	double precision		Total time the statement spent writing blocks, in milliseconds (if <code>track_io_timing</code> is enabled, otherwise zero)

For security reasons, only superusers and members of the `pg_read_all_stats` role are allowed to see the SQL text and `queryid` of queries executed by other users. Other users can see the statistics, however, if the view has been installed in their database.

Plannable queries (that is, `SELECT`, `INSERT`, `UPDATE`, and `DELETE`) are combined into a single `pg_stat_statements` entry whenever they have identical query structures according to an inter-

nal hash calculation. Typically, two queries will be considered the same for this purpose if they are semantically equivalent except for the values of literal constants appearing in the query. Utility commands (that is, all other commands) are compared strictly on the basis of their textual query strings, however.

When a constant's value has been ignored for purposes of matching the query to other queries, the constant is replaced by a parameter symbol, such as `$1`, in the `pg_stat_statements` display. The rest of the query text is that of the first query that had the particular `queryid` hash value associated with the `pg_stat_statements` entry.

In some cases, queries with visibly different texts might get merged into a single `pg_stat_statements` entry. Normally this will happen only for semantically equivalent queries, but there is a small chance of hash collisions causing unrelated queries to be merged into one entry. (This cannot happen for queries belonging to different users or databases, however.)

Since the `queryid` hash value is computed on the post-parse-analysis representation of the queries, the opposite is also possible: queries with identical texts might appear as separate entries, if they have different meanings as a result of factors such as different `search_path` settings.

Consumers of `pg_stat_statements` may wish to use `queryid` (perhaps in combination with `dbid` and `userid`) as a more stable and reliable identifier for each entry than its query text. However, it is important to understand that there are only limited guarantees around the stability of the `queryid` hash value. Since the identifier is derived from the post-parse-analysis tree, its value is a function of, among other things, the internal object identifiers appearing in this representation. This has some counterintuitive implications. For example, `pg_stat_statements` will consider two apparently-identical queries to be distinct, if they reference a table that was dropped and recreated between the executions of the two queries. The hashing process is also sensitive to differences in machine architecture and other facets of the platform. Furthermore, it is not safe to assume that `queryid` will be stable across major versions of PostgreSQL.

As a rule of thumb, `queryid` values can be assumed to be stable and comparable only so long as the underlying server version and catalog metadata details stay exactly the same. Two servers participating in replication based on physical WAL replay can be expected to have identical `queryid` values for the same query. However, logical replication schemes do not promise to keep replicas identical in all relevant details, so `queryid` will not be a useful identifier for accumulating costs across a set of logical replicas. If in doubt, direct testing is recommended.

The parameter symbols used to replace constants in representative query texts start from the next number after the highest `$n` parameter in the original query text, or `$1` if there was none. It's worth noting that in some cases there may be hidden parameter symbols that affect this numbering. For example, PL/pgSQL uses hidden parameter symbols to insert values of function local variables into queries, so that a PL/pgSQL statement like `SELECT i + 1 INTO j` would have representative text like `SELECT i + $2`.

The representative query texts are kept in an external disk file, and do not consume shared memory. Therefore, even very lengthy query texts can be stored successfully. However, if many long query texts are accumulated, the external file might grow unmanageably large. As a recovery method if that happens, `pg_stat_statements` may choose to discard the query texts, whereupon all existing entries in the `pg_stat_statements` view will show null `query` fields, though the statistics associated with each `queryid` are preserved. If this happens, consider reducing `pg_stat_statements.max` to prevent recurrences.

F.29.2. Functions

```
pg_stat_statements_reset(userid Oid, dbid Oid, queryid bigint) returns void
```

`pg_stat_statements_reset` discards statistics gathered so far by `pg_stat_statements` corresponding to the specified `userid`, `dbid` and `queryid`. If any of the parameters

are not specified, the default value 0 (invalid) is used for each of them and the statistics that match with other parameters will be reset. If no parameter is specified or all the specified parameters are 0 (invalid), it will discard all statistics. By default, this function can only be executed by superusers. Access may be granted to others using GRANT.

`pg_stat_statements(showtext boolean)` returns setof record

The `pg_stat_statements` view is defined in terms of a function also named `pg_stat_statements`. It is possible for clients to call the `pg_stat_statements` function directly, and by specifying `showtext := false` have query text be omitted (that is, the OUT argument that corresponds to the view's `query` column will return nulls). This feature is intended to support external tools that might wish to avoid the overhead of repeatedly retrieving query texts of indeterminate length. Such tools can instead cache the first query text observed for each entry themselves, since that is all `pg_stat_statements` itself does, and then retrieve query texts only as needed. Since the server stores query texts in a file, this approach may reduce physical I/O for repeated examination of the `pg_stat_statements` data.

F.29.3. Configuration Parameters

`pg_stat_statements.max` (integer)

`pg_stat_statements.max` is the maximum number of statements tracked by the module (i.e., the maximum number of rows in the `pg_stat_statements` view). If more distinct statements than that are observed, information about the least-executed statements is discarded. The default value is 5000. This parameter can only be set at server start.

`pg_stat_statements.track` (enum)

`pg_stat_statements.track` controls which statements are counted by the module. Specify `top` to track top-level statements (those issued directly by clients), `all` to also track nested statements (such as statements invoked within functions), or `none` to disable statement statistics collection. The default value is `top`. Only superusers can change this setting.

`pg_stat_statements.track_utility` (boolean)

`pg_stat_statements.track_utility` controls whether utility commands are tracked by the module. Utility commands are all those other than `SELECT`, `INSERT`, `UPDATE` and `DELETE`. The default value is `on`. Only superusers can change this setting.

`pg_stat_statements.save` (boolean)

`pg_stat_statements.save` specifies whether to save statement statistics across server shutdowns. If it is `off` then statistics are not saved at shutdown nor reloaded at server start. The default value is `on`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

The module requires additional shared memory proportional to `pg_stat_statements.max`. Note that this memory is consumed whenever the module is loaded, even if `pg_stat_statements.track` is set to `none`.

These parameters must be set in `postgresql.conf`. Typical usage might be:

```
# postgresql.conf
shared_preload_libraries = 'pg_stat_statements'

pg_stat_statements.max = 10000
pg_stat_statements.track = all
```

F.29.4. Sample Output

```

bench=# SELECT pg_stat_statements_reset();

$ pgbench -i bench
$ pgbench -c10 -t300 bench

bench=# \x
bench=# SELECT query, calls, total_time, rows, 100.0 *
        shared_blks_hit /
        nullif(shared_blks_hit + shared_blks_read, 0) AS
        hit_percent
        FROM pg_stat_statements ORDER BY total_time DESC LIMIT 5;
-[ RECORD
1 ]-----
query      | UPDATE pgbench_branches SET bbalance = bbalance + $1
WHERE bid = $2
calls      | 3000
total_time | 25565.855387
rows       | 3000
hit_percent | 100.0000000000000000
-[ RECORD
2 ]-----
query      | UPDATE pgbench_tellers SET tbalance = tbalance + $1
WHERE tid = $2
calls      | 3000
total_time | 20756.669379
rows       | 3000
hit_percent | 100.0000000000000000
-[ RECORD
3 ]-----
query      | copy pgbench_accounts from stdin
calls      | 1
total_time | 291.865911
rows       | 100000
hit_percent | 100.0000000000000000
-[ RECORD
4 ]-----
query      | UPDATE pgbench_accounts SET abalance = abalance + $1
WHERE aid = $2
calls      | 3000
total_time | 271.232977
rows       | 3000
hit_percent | 98.5723926698852723
-[ RECORD
5 ]-----
query      | alter table pgbench_accounts add primary key (aid)
calls      | 1
total_time | 160.588563
rows       | 0
hit_percent | 100.0000000000000000

bench=# SELECT pg_stat_statements_reset(0,0,s.queryid) FROM
        pg_stat_statements AS s

```

```
WHERE s.query = 'UPDATE pgbench_branches SET bbalance =
bbalance + $1 WHERE bid = $2';
```

```
bench=# SELECT query, calls, total_time, rows, 100.0 *
shared_blks_hit /
nullif(shared_blks_hit + shared_blks_read, 0) AS
hit_percent
FROM pg_stat_statements ORDER BY total_time DESC LIMIT 5;
```

```
-[ RECORD
1 ]-----
```

```
query          | UPDATE pgbench_tellers SET tbalance = tbalance + $1
WHERE tid = $2
calls          | 3000
total_time     | 20756.669379
rows          | 3000
hit_percent    | 100.0000000000000000
```

```
-[ RECORD
2 ]-----
```

```
query          | copy pgbench_accounts from stdin
calls          | 1
total_time     | 291.865911
rows          | 100000
hit_percent    | 100.0000000000000000
```

```
-[ RECORD
3 ]-----
```

```
query          | UPDATE pgbench_accounts SET abalance = abalance + $1
WHERE aid = $2
calls          | 3000
total_time     | 271.232977
rows          | 3000
hit_percent    | 98.5723926698852723
```

```
-[ RECORD
4 ]-----
```

```
query          | alter table pgbench_accounts add primary key (aid)
calls          | 1
total_time     | 160.588563
rows          | 0
hit_percent    | 100.0000000000000000
```

```
-[ RECORD
5 ]-----
```

```
query          | vacuum analyze pgbench_accounts
calls          | 1
total_time     | 136.448116
rows          | 0
hit_percent    | 99.9201915403032721
```

```
bench=# SELECT pg_stat_statements_reset(0,0,0);
```

```
bench=# SELECT query, calls, total_time, rows, 100.0 *
shared_blks_hit /
nullif(shared_blks_hit + shared_blks_read, 0) AS
hit_percent
FROM pg_stat_statements ORDER BY total_time DESC LIMIT 5;
```

```
-[ RECORD 1 ]-----
```

```
query          | SELECT pg_stat_statements_reset(0,0,0)
calls          | 1
total_time     | 0.189497
rows          | 1
```

hit_percent |

F.29.5. Authors

Takahiro Itagaki <itagaki.takahiro@oss.ntt.co.jp>. Query normalization added by Peter Geoghegan <peter@2ndquadrant.com>.

F.30. pgstattuple

The `pgstattuple` module provides various functions to obtain tuple-level statistics.

Because these functions return detailed page-level information, access is restricted by default. By default, only the role `pg_stat_scan_tables` has `EXECUTE` privilege. Superusers of course bypass this restriction. After the extension has been installed, users may issue `GRANT` commands to change the privileges on the functions to allow others to execute them. However, it might be preferable to add those users to the `pg_stat_scan_tables` role instead.

F.30.1. Functions

`pgstattuple(regclass)` returns record

`pgstattuple` returns a relation's physical length, percentage of “dead” tuples, and other info. This may help users to determine whether vacuum is necessary or not. The argument is the target relation's name (optionally schema-qualified) or OID. For example:

```
test=> SELECT * FROM pgstattuple('pg_catalog.pg_proc');
-[ RECORD 1 ]-----+-----
table_len      | 458752
tuple_count    | 1470
tuple_len      | 438896
tuple_percent  | 95.67
dead_tuple_count | 11
dead_tuple_len | 3157
dead_tuple_percent | 0.69
free_space     | 8932
free_percent   | 1.95
```

The output columns are described in Table F.22.

Table F.22. `pgstattuple` Output Columns

Column	Type	Description
<code>table_len</code>	<code>bigint</code>	Physical relation length in bytes
<code>tuple_count</code>	<code>bigint</code>	Number of live tuples
<code>tuple_len</code>	<code>bigint</code>	Total length of live tuples in bytes
<code>tuple_percent</code>	<code>float8</code>	Percentage of live tuples
<code>dead_tuple_count</code>	<code>bigint</code>	Number of dead tuples
<code>dead_tuple_len</code>	<code>bigint</code>	Total length of dead tuples in bytes
<code>dead_tuple_percent</code>	<code>float8</code>	Percentage of dead tuples
<code>free_space</code>	<code>bigint</code>	Total free space in bytes

Column	Type	Description
free_percent	float8	Percentage of free space

Note

The table_len will always be greater than the sum of the tuple_len, dead_tuple_len and free_space. The difference is accounted for by fixed page overhead, the per-page table of pointers to tuples, and padding to ensure that tuples are correctly aligned.

pgstattuple acquires only a read lock on the relation. So the results do not reflect an instantaneous snapshot; concurrent updates will affect them.

pgstattuple judges a tuple is “dead” if HeapTupleSatisfiesDirty returns false.

pgstattuple(text) returns record

This is the same as pgstattuple(regclass), except that the target relation is specified as TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in some future release.

pgstatindex(regclass) returns record

pgstatindex returns a record showing information about a B-tree index. For example:

```
test=> SELECT * FROM pgstatindex('pg_cast_oid_index');
-[ RECORD 1 ]-----+-----
version          | 2
tree_level       | 0
index_size       | 16384
root_block_no    | 1
internal_pages   | 0
leaf_pages       | 1
empty_pages      | 0
deleted_pages    | 0
avg_leaf_density | 54.27
leaf_fragmentation | 0
```

The output columns are:

Column	Type	Description
version	integer	B-tree version number
tree_level	integer	Tree level of the root page
index_size	bigint	Total index size in bytes
root_block_no	bigint	Location of root page (zero if none)
internal_pages	bigint	Number of “internal” (upper-level) pages
leaf_pages	bigint	Number of leaf pages
empty_pages	bigint	Number of empty pages
deleted_pages	bigint	Number of deleted pages
avg_leaf_density	float8	Average density of leaf pages
leaf_fragmentation	float8	Leaf page fragmentation

The reported `index_size` will normally correspond to one more page than is accounted for by `internal_pages` + `leaf_pages` + `empty_pages` + `deleted_pages`, because it also includes the index's metapage.

As with `pgstattuple`, the results are accumulated page-by-page, and should not be expected to represent an instantaneous snapshot of the whole index.

`pgstatindex(text)` returns record

This is the same as `pgstatindex(regclass)`, except that the target index is specified as TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in some future release.

`pgstatginindex(regclass)` returns record

`pgstatginindex` returns a record showing information about a GIN index. For example:

```
test=> SELECT * FROM pgstatginindex('test_gin_index');
-[ RECORD 1 ]--+-
version          | 1
pending_pages    | 0
pending_tuples   | 0
```

The output columns are:

Column	Type	Description
version	integer	GIN version number
pending_pages	integer	Number of pages in the pending list
pending_tuples	bigint	Number of tuples in the pending list

`pgstathashindex(regclass)` returns record

`pgstathashindex` returns a record showing information about a HASH index. For example:

```
test=> select * from pgstathashindex('con_hash_index');
-[ RECORD 1 ]--+-
version          | 4
bucket_pages     | 33081
overflow_pages   | 0
bitmap_pages     | 1
unused_pages     | 32455
live_items       | 10204006
dead_items       | 0
free_percent     | 61.8005949100872
```

The output columns are:

Column	Type	Description
version	integer	HASH version number
bucket_pages	bigint	Number of bucket pages
overflow_pages	bigint	Number of overflow pages
bitmap_pages	bigint	Number of bitmap pages
unused_pages	bigint	Number of unused pages

Column	Type	Description
live_items	bigint	Number of live tuples
dead_tuples	bigint	Number of dead tuples
free_percent	float	Percentage of free space

`pg_relpages(regclass)` returns `bigint`

`pg_relpages` returns the number of pages in the relation.

`pg_relpages(text)` returns `bigint`

This is the same as `pg_relpages(regclass)`, except that the target relation is specified as `TEXT`. This function is kept because of backward-compatibility so far, and will be deprecated in some future release.

`pgstattuple_approx(regclass)` returns `record`

`pgstattuple_approx` is a faster alternative to `pgstattuple` that returns approximate results. The argument is the target relation's name or OID. For example:

```
test=> SELECT * FROM
  pgstattuple_approx('pg_catalog.pg_proc'::regclass);
-[ RECORD 1 ]-----+-----
table_len          | 573440
scanned_percent    | 2
approx_tuple_count | 2740
approx_tuple_len   | 561210
approx_tuple_percent | 97.87
dead_tuple_count   | 0
dead_tuple_len     | 0
dead_tuple_percent | 0
approx_free_space  | 11996
approx_free_percent | 2.09
```

The output columns are described in Table F.23.

Whereas `pgstattuple` always performs a full-table scan and returns an exact count of live and dead tuples (and their sizes) and free space, `pgstattuple_approx` tries to avoid the full-table scan and returns exact dead tuple statistics along with an approximation of the number and size of live tuples and free space.

It does this by skipping pages that have only visible tuples according to the visibility map (if a page has the corresponding VM bit set, then it is assumed to contain no dead tuples). For such pages, it derives the free space value from the free space map, and assumes that the rest of the space on the page is taken up by live tuples.

For pages that cannot be skipped, it scans each tuple, recording its presence and size in the appropriate counters, and adding up the free space on the page. At the end, it estimates the total number of live tuples based on the number of pages and tuples scanned (in the same way that `VACUUM` estimates `pg_class.reltuples`).

Table F.23. `pgstattuple_approx` Output Columns

Column	Type	Description
table_len	bigint	Physical relation length in bytes (exact)
scanned_percent	float8	Percentage of table scanned

Column	Type	Description
approx_tuple_count	bigint	Number of live tuples (estimated)
approx_tuple_len	bigint	Total length of live tuples in bytes (estimated)
approx_tuple_percent	float8	Percentage of live tuples
dead_tuple_count	bigint	Number of dead tuples (exact)
dead_tuple_len	bigint	Total length of dead tuples in bytes (exact)
dead_tuple_percent	float8	Percentage of dead tuples
approx_free_space	bigint	Total free space in bytes (estimated)
approx_free_percent	float8	Percentage of free space

In the above output, the free space figures may not match the `pgstattuple` output exactly, because the free space map gives us an exact figure, but is not guaranteed to be accurate to the byte.

F.30.2. Authors

Tatsuo Ishii, Satoshi Nagayasu and Abhijit Menon-Sen

F.31. `pg_trgm`

The `pg_trgm` module provides functions and operators for determining the similarity of alphanumeric text based on trigram matching, as well as index operator classes that support fast searching for similar strings.

F.31.1. Trigram (or Trigraph) Concepts

A trigram is a group of three consecutive characters taken from a string. We can measure the similarity of two strings by counting the number of trigrams they share. This simple idea turns out to be very effective for measuring the similarity of words in many natural languages.

Note

`pg_trgm` ignores non-word characters (non-alphanumerics) when extracting trigrams from a string. Each word is considered to have two spaces prefixed and one space suffixed when determining the set of trigrams contained in the string. For example, the set of trigrams in the string "cat" is " c", " ca", "cat", and "at ". The set of trigrams in the string "foo|bar" is " f", " fo", "foo", "oo ", " b", " ba", "bar", and "ar ".

F.31.2. Functions and Operators

The functions provided by the `pg_trgm` module are shown in Table F.24, the operators in Table F.25.

Table F.24. `pg_trgm` Functions

Function	Returns	Description
<code>similarity(text, text)</code>	real	Returns a number that indicates how similar the two arguments

Function	Returns	Description
		are. The range of the result is zero (indicating that the two strings are completely dissimilar) to one (indicating that the two strings are identical).
<code>show_trgm(text)</code>	<code>text[]</code>	Returns an array of all the trigrams in the given string. (In practice this is seldom useful except for debugging.)
<code>word_similarity(text, text)</code>	real	Returns a number that indicates the greatest similarity between the set of trigrams in the first string and any continuous extent of an ordered set of trigrams in the second string. For details, see the explanation below.
<code>strict_word_similarity(text, text)</code>	real	Same as <code>word_similarity(text, text)</code> , but forces extent boundaries to match word boundaries. Since we don't have cross-word trigrams, this function actually returns greatest similarity between first string and any continuous extent of words of the second string.
<code>show_limit()</code>	real	Returns the current similarity threshold used by the <code>%</code> operator. This sets the minimum similarity between two words for them to be considered similar enough to be misspellings of each other, for example (<i>deprecated</i>).
<code>set_limit(real)</code>	real	Sets the current similarity threshold that is used by the <code>%</code> operator. The threshold must be between 0 and 1 (default is 0.3). Returns the same value passed in (<i>deprecated</i>).

Consider the following example:

```
# SELECT word_similarity('word', 'two words');
 word_similarity
-----
                0.8
(1 row)
```

In the first string, the set of trigrams is {" w", " wo", "wor", "ord", "rd "}. In the second string, the ordered set of trigrams is {" t", " tw", "two", "wo ", " w", " wo", "wor", "ord", "rds", "ds "}. The most similar extent of an ordered set of trigrams in the second string is {" w", " wo", "wor", "ord"}, and the similarity is 0.8.

This function returns a value that can be approximately understood as the greatest similarity between the first string and any substring of the second string. However, this function does not add padding to

the boundaries of the extent. Thus, the number of additional characters present in the second string is not considered, except for the mismatched word boundaries.

At the same time, `strict_word_similarity(text, text)` selects an extent of words in the second string. In the example above, `strict_word_similarity(text, text)` would select the extent of a single word 'words', whose set of trigrams is {" w", " wo", "wor", "or-d", "rds", "ds " }.

```
# SELECT strict_word_similarity('word', 'two words'),
       similarity('word', 'words');
strict_word_similarity | similarity
-----+-----
                0.571429 |    0.571429
(1 row)
```

Thus, the `strict_word_similarity(text, text)` function is useful for finding the similarity to whole words, while `word_similarity(text, text)` is more suitable for finding the similarity for parts of words.

Table F.25. pg_trgm Operators

Operator	Returns	Description
<code>text % text</code>	boolean	Returns true if its arguments have a similarity that is greater than the current similarity threshold set by <code>pg_trgm.similarity_threshold</code> .
<code>text <% text</code>	boolean	Returns true if the similarity between the trigram set in the first argument and a continuous extent of an ordered trigram set in the second argument is greater than the current word similarity threshold set by <code>pg_trgm.word_similarity_threshold</code> parameter.
<code>text %> text</code>	boolean	Commutator of the <code><%</code> operator.
<code>text <<% text</code>	boolean	Returns true if its second argument has a continuous extent of an ordered trigram set that matches word boundaries, and its similarity to the trigram set of the first argument is greater than the current strict word similarity threshold set by the <code>pg_trgm.strict_word_similarity_threshold</code> parameter.
<code>text %>> text</code>	boolean	Commutator of the <code><<%</code> operator.
<code>text <-> text</code>	real	Returns the “distance” between the arguments, that is one minus the <code>similarity()</code> value.

Operator	Returns	Description
<code>text <<-> text</code>	real	Returns the “distance” between the arguments, that is one minus the <code>word_similarity()</code> value.
<code>text <->> text</code>	real	Commutator of the <code><<-></code> operator.
<code>text <<<-> text</code>	real	Returns the “distance” between the arguments, that is one minus the <code>strict_word_similarity()</code> value.
<code>text <->>> text</code>	real	Commutator of the <code><<<-></code> operator.

F.31.3. GUC Parameters

`pg_trgm.similarity_threshold` (real)

Sets the current similarity threshold that is used by the `%` operator. The threshold must be between 0 and 1 (default is 0.3).

`pg_trgm.word_similarity_threshold` (real)

Sets the current word similarity threshold that is used by the `<%` and `%>` operators. The threshold must be between 0 and 1 (default is 0.6).

`pg_trgm.strict_word_similarity_threshold` (real)

Sets the current strict word similarity threshold that is used by the `<<%` and `%>>` operators. The threshold must be between 0 and 1 (default is 0.5).

F.31.4. Index Support

The `pg_trgm` module provides GiST and GIN index operator classes that allow you to create an index over a text column for the purpose of very fast similarity searches. These index types support the above-described similarity operators, and additionally support trigram-based index searches for `LIKE`, `ILIKE`, `~` and `~*` queries. (These indexes do not support equality nor simple comparison operators, so you may need a regular B-tree index too.)

Example:

```
CREATE TABLE test_trgm (t text);
CREATE INDEX trgm_idx ON test_trgm USING GIST (t gist_trgm_ops);
```

or

```
CREATE INDEX trgm_idx ON test_trgm USING GIN (t gin_trgm_ops);
```

At this point, you will have an index on the `t` column that you can use for similarity searching. A typical query is

```
SELECT t, similarity(t, 'word') AS sml
FROM test_trgm
WHERE t % 'word'
```

```
ORDER BY sml DESC, t;
```

This will return all values in the text column that are sufficiently similar to *word*, sorted from best match to worst. The index will be used to make this a fast operation even over very large data sets.

A variant of the above query is

```
SELECT t, t <-> 'word' AS dist
FROM test_trgm
ORDER BY dist LIMIT 10;
```

This can be implemented quite efficiently by GiST indexes, but not by GIN indexes. It will usually beat the first formulation when only a small number of the closest matches is wanted.

Also you can use an index on the *t* column for word similarity or strict word similarity. Typical queries are:

```
SELECT t, word_similarity('word', t) AS sml
FROM test_trgm
WHERE 'word' <% t
ORDER BY sml DESC, t;
```

and

```
SELECT t, strict_word_similarity('word', t) AS sml
FROM test_trgm
WHERE 'word' <<% t
ORDER BY sml DESC, t;
```

This will return all values in the text column for which there is a continuous extent in the corresponding ordered trigram set that is sufficiently similar to the trigram set of *word*, sorted from best match to worst. The index will be used to make this a fast operation even over very large data sets.

Possible variants of the above queries are:

```
SELECT t, 'word' <<-> t AS dist
FROM test_trgm
ORDER BY dist LIMIT 10;
```

and

```
SELECT t, 'word' <<<-> t AS dist
FROM test_trgm
ORDER BY dist LIMIT 10;
```

This can be implemented quite efficiently by GiST indexes, but not by GIN indexes.

Beginning in PostgreSQL 9.1, these index types also support index searches for `LIKE` and `ILIKE`, for example

```
SELECT * FROM test_trgm WHERE t LIKE '%foo%bar';
```

The index search works by extracting trigrams from the search string and then looking these up in the index. The more trigrams in the search string, the more effective the index search is. Unlike B-tree based searches, the search string need not be left-anchored.

Beginning in PostgreSQL 9.3, these index types also support index searches for regular-expression matches (~ and ~* operators), for example

```
SELECT * FROM test_trgm WHERE t ~ '(foo|bar)';
```

The index search works by extracting trigrams from the regular expression and then looking these up in the index. The more trigrams that can be extracted from the regular expression, the more effective the index search is. Unlike B-tree based searches, the search string need not be left-anchored.

For both LIKE and regular-expression searches, keep in mind that a pattern with no extractable trigrams will degenerate to a full-index scan.

The choice between GiST and GIN indexing depends on the relative performance characteristics of GiST and GIN, which are discussed elsewhere.

F.31.5. Text Search Integration

Trigram matching is a very useful tool when used in conjunction with a full text index. In particular it can help to recognize misspelled input words that will not be matched directly by the full text search mechanism.

The first step is to generate an auxiliary table containing all the unique words in the documents:

```
CREATE TABLE words AS SELECT word FROM
    ts_stat('SELECT to_tsvector(''simple'', bodytext) FROM
    documents');
```

where `documents` is a table that has a text field `bodytext` that we wish to search. The reason for using the `simple` configuration with the `to_tsvector` function, instead of using a language-specific configuration, is that we want a list of the original (unstemmed) words.

Next, create a trigram index on the word column:

```
CREATE INDEX words_idx ON words USING GIN (word gin_trgm_ops);
```

Now, a `SELECT` query similar to the previous example can be used to suggest spellings for misspelled words in user search terms. A useful extra test is to require that the selected words are also of similar length to the misspelled word.

Note

Since the `words` table has been generated as a separate, static table, it will need to be periodically regenerated so that it remains reasonably up-to-date with the document collection. Keeping it exactly current is usually unnecessary.

F.31.6. References

GiST Development Site <http://www.sai.msu.su/~megera/postgres/gist/>

Tsearch2 Development Site <http://www.sai.msu.su/~megera/postgres/gist/tsearch/V2/>

F.31.7. Authors

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This module is sponsored by Delta-Soft Ltd., Moscow, Russia.

F.32. pg_visibility

The `pg_visibility` module provides a means for examining the visibility map (VM) and page-level visibility information of a table. It also provides functions to check the integrity of a visibility map and to force it to be rebuilt.

Three different bits are used to store information about page-level visibility. The all-visible bit in the visibility map indicates that every tuple in the corresponding page of the relation is visible to every current and future transaction. The all-frozen bit in the visibility map indicates that every tuple in the page is frozen; that is, no future vacuum will need to modify the page until such time as a tuple is inserted, updated, deleted, or locked on that page. The page header's `PD_ALL_VISIBLE` bit has the same meaning as the all-visible bit in the visibility map, but is stored within the data page itself rather than in a separate data structure. These two bits will normally agree, but the page's all-visible bit can sometimes be set while the visibility map bit is clear after a crash recovery. The reported values can also disagree because of a change that occurs after `pg_visibility` examines the visibility map and before it examines the data page. Any event that causes data corruption can also cause these bits to disagree.

Functions that display information about `PD_ALL_VISIBLE` bits are much more costly than those that only consult the visibility map, because they must read the relation's data blocks rather than only the (much smaller) visibility map. Functions that check the relation's data blocks are similarly expensive.

F.32.1. Functions

```
pg_visibility_map(relation regclass, blkno bigint, all_visible OUT
boolean, all_frozen OUT boolean) returns record
```

Returns the all-visible and all-frozen bits in the visibility map for the given block of the given relation.

```
pg_visibility(relation regclass, blkno bigint, all_visible OUT
boolean, all_frozen OUT boolean, pd_all_visible OUT boolean) returns
record
```

Returns the all-visible and all-frozen bits in the visibility map for the given block of the given relation, plus the `PD_ALL_VISIBLE` bit of that block.

```
pg_visibility_map(relation regclass, blkno OUT bigint, all_visible
OUT boolean, all_frozen OUT boolean) returns setof record
```

Returns the all-visible and all-frozen bits in the visibility map for each block of the given relation.

```
pg_visibility(relation regclass, blkno OUT bigint, all_visible OUT
boolean, all_frozen OUT boolean, pd_all_visible OUT boolean) returns
setof record
```

Returns the all-visible and all-frozen bits in the visibility map for each block of the given relation, plus the `PD_ALL_VISIBLE` bit of each block.

`pg_visibility_map_summary(relation regclass, all_visible OUT bigint, all_frozen OUT bigint)` returns record

Returns the number of all-visible pages and the number of all-frozen pages in the relation according to the visibility map.

`pg_check_frozen(relation regclass, t_ctid OUT tid)` returns setof tid

Returns the TIDs of non-frozen tuples stored in pages marked all-frozen in the visibility map. If this function returns a non-empty set of TIDs, the visibility map is corrupt.

`pg_check_visible(relation regclass, t_ctid OUT tid)` returns setof tid

Returns the TIDs of non-all-visible tuples stored in pages marked all-visible in the visibility map. If this function returns a non-empty set of TIDs, the visibility map is corrupt.

`pg_truncate_visibility_map(relation regclass)` returns void

Truncates the visibility map for the given relation. This function is useful if you believe that the visibility map for the relation is corrupt and wish to force rebuilding it. The first `VACUUM` executed on the given relation after this function is executed will scan every page in the relation and rebuild the visibility map. (Until that is done, queries will treat the visibility map as containing all zeroes.)

By default, these functions are executable only by superusers and members of the `pg_stat_scan_tables` role, with the exception of `pg_truncate_visibility_map(relation regclass)` which can only be executed by superusers.

F.32.2. Author

Robert Haas <rhaas@postgresql.org>

F.33. postgres_fdw

The `postgres_fdw` module provides the foreign-data wrapper `postgres_fdw`, which can be used to access data stored in external PostgreSQL servers.

The functionality provided by this module overlaps substantially with the functionality of the older `dblink` module. But `postgres_fdw` provides more transparent and standards-compliant syntax for accessing remote tables, and can give better performance in many cases.

To prepare for remote access using `postgres_fdw`:

1. Install the `postgres_fdw` extension using `CREATE EXTENSION`.
2. Create a foreign server object, using `CREATE SERVER`, to represent each remote database you want to connect to. Specify connection information, except `user` and `password`, as options of the server object.
3. Create a user mapping, using `CREATE USER MAPPING`, for each database user you want to allow to access each foreign server. Specify the remote user name and password to use as `user` and `password` options of the user mapping.
4. Create a foreign table, using `CREATE FOREIGN TABLE` or `IMPORT FOREIGN SCHEMA`, for each remote table you want to access. The columns of the foreign table must match the referenced remote table. You can, however, use table and/or column names different from the remote table's, if you specify the correct remote names as options of the foreign table object.

Now you need only `SELECT` from a foreign table to access the data stored in its underlying remote table. You can also modify the remote table using `INSERT`, `UPDATE`, or `DELETE`. (Of course, the remote user you have specified in your user mapping must have privileges to do these things.)

Note that `postgres_fdw` currently lacks support for `INSERT` statements with an `ON CONFLICT DO UPDATE` clause. However, the `ON CONFLICT DO NOTHING` clause is supported, provided a

unique index inference specification is omitted. Note also that `postgres_fdw` supports row movement invoked by `UPDATE` statements executed on partitioned tables, but it currently does not handle the case where a remote partition chosen to insert a moved row into is also an `UPDATE` target partition that will be updated later.

It is generally recommended that the columns of a foreign table be declared with exactly the same data types, and collations if applicable, as the referenced columns of the remote table. Although `postgres_fdw` is currently rather forgiving about performing data type conversions at need, surprising semantic anomalies may arise when types or collations do not match, due to the remote server interpreting `WHERE` clauses slightly differently from the local server.

Note that a foreign table can be declared with fewer columns, or with a different column order, than its underlying remote table has. Matching of columns to the remote table is by name, not position.

F.33.1. FDW Options of `postgres_fdw`

F.33.1.1. Connection Options

A foreign server using the `postgres_fdw` foreign data wrapper can have the same options that `libpq` accepts in connection strings, as described in Section 33.1.2, except that these options are not allowed:

- `user` and `password` (specify these in a user mapping, instead)
- `client_encoding` (this is automatically set from the local server encoding)
- `fallback_application_name` (always set to `postgres_fdw`)

Only superusers may connect to foreign servers without password authentication, so always specify the `password` option for user mappings belonging to non-superusers.

F.33.1.2. Object Name Options

These options can be used to control the names used in SQL statements sent to the remote PostgreSQL server. These options are needed when a foreign table is created with names different from the underlying remote table's names.

`schema_name`

This option, which can be specified for a foreign table, gives the schema name to use for the foreign table on the remote server. If this option is omitted, the name of the foreign table's schema is used.

`table_name`

This option, which can be specified for a foreign table, gives the table name to use for the foreign table on the remote server. If this option is omitted, the foreign table's name is used.

`column_name`

This option, which can be specified for a column of a foreign table, gives the column name to use for the column on the remote server. If this option is omitted, the column's name is used.

F.33.1.3. Cost Estimation Options

`postgres_fdw` retrieves remote data by executing queries against remote servers, so ideally the estimated cost of scanning a foreign table should be whatever it costs to be done on the remote server, plus some overhead for communication. The most reliable way to get such an estimate is to ask the remote server and then add something for overhead — but for simple queries, it may not be worth the cost of an additional remote query to get a cost estimate. So `postgres_fdw` provides the following options to control how cost estimation is done:

`use_remote_estimate`

This option, which can be specified for a foreign table or a foreign server, controls whether `postgres_fdw` issues remote `EXPLAIN` commands to obtain cost estimates. A setting for a foreign table overrides any setting for its server, but only for that table. The default is `false`.

`fdw_startup_cost`

This option, which can be specified for a foreign server, is a numeric value that is added to the estimated startup cost of any foreign-table scan on that server. This represents the additional overhead of establishing a connection, parsing and planning the query on the remote side, etc. The default value is 100.

`fdw_tuple_cost`

This option, which can be specified for a foreign server, is a numeric value that is used as extra cost per-tuple for foreign-table scans on that server. This represents the additional overhead of data transfer between servers. You might increase or decrease this number to reflect higher or lower network delay to the remote server. The default value is 0.01.

When `use_remote_estimate` is true, `postgres_fdw` obtains row count and cost estimates from the remote server and then adds `fdw_startup_cost` and `fdw_tuple_cost` to the cost estimates. When `use_remote_estimate` is false, `postgres_fdw` performs local row count and cost estimation and then adds `fdw_startup_cost` and `fdw_tuple_cost` to the cost estimates. This local estimation is unlikely to be very accurate unless local copies of the remote table's statistics are available. Running `ANALYZE` on the foreign table is the way to update the local statistics; this will perform a scan of the remote table and then calculate and store statistics just as though the table were local. Keeping local statistics can be a useful way to reduce per-query planning overhead for a remote table — but if the remote table is frequently updated, the local statistics will soon be obsolete.

F.33.1.4. Remote Execution Options

By default, only `WHERE` clauses using built-in operators and functions will be considered for execution on the remote server. Clauses involving non-built-in functions are checked locally after rows are fetched. If such functions are available on the remote server and can be relied on to produce the same results as they do locally, performance can be improved by sending such `WHERE` clauses for remote execution. This behavior can be controlled using the following option:

`extensions`

This option is a comma-separated list of names of PostgreSQL extensions that are installed, in compatible versions, on both the local and remote servers. Functions and operators that are immutable and belong to a listed extension will be considered shippable to the remote server. This option can only be specified for foreign servers, not per-table.

When using the `extensions` option, *it is the user's responsibility* that the listed extensions exist and behave identically on both the local and remote servers. Otherwise, remote queries may fail or behave unexpectedly.

`fetch_size`

This option specifies the number of rows `postgres_fdw` should get in each fetch operation. It can be specified for a foreign table or a foreign server. The option specified on a table overrides an option specified for the server. The default is 100.

F.33.1.5. Updatability Options

By default all foreign tables using `postgres_fdw` are assumed to be updatable. This may be overridden using the following option:

`updatable`

This option controls whether `postgres_fdw` allows foreign tables to be modified using `INSERT`, `UPDATE` and `DELETE` commands. It can be specified for a foreign table or a foreign server. A table-level option overrides a server-level option. The default is `true`.

Of course, if the remote table is not in fact updatable, an error would occur anyway. Use of this option primarily allows the error to be thrown locally without querying the remote server. Note however that the `information_schema` views will report a `postgres_fdw` foreign table to be updatable (or not) according to the setting of this option, without any check of the remote server.

F.33.1.6. Importing Options

`postgres_fdw` is able to import foreign table definitions using `IMPORT FOREIGN SCHEMA`. This command creates foreign table definitions on the local server that match tables or views present on the remote server. If the remote tables to be imported have columns of user-defined data types, the local server must have compatible types of the same names.

Importing behavior can be customized with the following options (given in the `IMPORT FOREIGN SCHEMA` command):

`import_collate`

This option controls whether column `COLLATE` options are included in the definitions of foreign tables imported from a foreign server. The default is `true`. You might need to turn this off if the remote server has a different set of collation names than the local server does, which is likely to be the case if it's running on a different operating system.

`import_default`

This option controls whether column `DEFAULT` expressions are included in the definitions of foreign tables imported from a foreign server. The default is `false`. If you enable this option, be wary of defaults that might get computed differently on the local server than they would be on the remote server; `nextval()` is a common source of problems. The `IMPORT` will fail altogether if an imported default expression uses a function or operator that does not exist locally.

`import_not_null`

This option controls whether column `NOT NULL` constraints are included in the definitions of foreign tables imported from a foreign server. The default is `true`.

Note that constraints other than `NOT NULL` will never be imported from the remote tables. Although PostgreSQL does support `CHECK` constraints on foreign tables, there is no provision for importing them automatically, because of the risk that a constraint expression could evaluate differently on the local and remote servers. Any such inconsistency in the behavior of a `CHECK` constraint could lead to hard-to-detect errors in query optimization. So if you wish to import `CHECK` constraints, you must do so manually, and you should verify the semantics of each one carefully. For more detail about the treatment of `CHECK` constraints on foreign tables, see `CREATE FOREIGN TABLE`.

Tables or foreign tables which are partitions of some other table are automatically excluded. Partitioned tables are imported, unless they are a partition of some other table. Since all data can be accessed through the partitioned table which is the root of the partitioning hierarchy, this approach should allow access to all the data without creating extra objects.

F.33.2. Connection Management

`postgres_fdw` establishes a connection to a foreign server during the first query that uses a foreign table associated with the foreign server. This connection is kept and re-used for subsequent queries in

the same session. However, if multiple user identities (user mappings) are used to access the foreign server, a connection is established for each user mapping.

F.33.3. Transaction Management

During a query that references any remote tables on a foreign server, `postgres_fdw` opens a transaction on the remote server if one is not already open corresponding to the current local transaction. The remote transaction is committed or aborted when the local transaction commits or aborts. Savepoints are similarly managed by creating corresponding remote savepoints.

The remote transaction uses `SERIALIZABLE` isolation level when the local transaction has `SERIALIZABLE` isolation level; otherwise it uses `REPEATABLE READ` isolation level. This choice ensures that if a query performs multiple table scans on the remote server, it will get snapshot-consistent results for all the scans. A consequence is that successive queries within a single transaction will see the same data from the remote server, even if concurrent updates are occurring on the remote server due to other activities. That behavior would be expected anyway if the local transaction uses `SERIALIZABLE` or `REPEATABLE READ` isolation level, but it might be surprising for a `READ COMMITTED` local transaction. A future PostgreSQL release might modify these rules.

Note that it is currently not supported by `postgres_fdw` to prepare the remote transaction for two-phase commit.

F.33.4. Remote Query Optimization

`postgres_fdw` attempts to optimize remote queries to reduce the amount of data transferred from foreign servers. This is done by sending query `WHERE` clauses to the remote server for execution, and by not retrieving table columns that are not needed for the current query. To reduce the risk of misexecution of queries, `WHERE` clauses are not sent to the remote server unless they use only data types, operators, and functions that are built-in or belong to an extension that's listed in the foreign server's `extensions` option. Operators and functions in such clauses must be `IMMUTABLE` as well. For an `UPDATE` or `DELETE` query, `postgres_fdw` attempts to optimize the query execution by sending the whole query to the remote server if there are no query `WHERE` clauses that cannot be sent to the remote server, no local joins for the query, no row-level local `BEFORE` or `AFTER` triggers or stored generated columns on the target table, and no `CHECK OPTION` constraints from parent views. In `UPDATE`, expressions to assign to target columns must use only built-in data types, `IMMUTABLE` operators, or `IMMUTABLE` functions, to reduce the risk of misexecution of the query.

When `postgres_fdw` encounters a join between foreign tables on the same foreign server, it sends the entire join to the foreign server, unless for some reason it believes that it will be more efficient to fetch rows from each table individually, or unless the table references involved are subject to different user mappings. While sending the `JOIN` clauses, it takes the same precautions as mentioned above for the `WHERE` clauses.

The query that is actually sent to the remote server for execution can be examined using `EXPLAIN VERBOSE`.

F.33.5. Remote Query Execution Environment

In the remote sessions opened by `postgres_fdw`, the `search_path` parameter is set to just `pg_catalog`, so that only built-in objects are visible without schema qualification. This is not an issue for queries generated by `postgres_fdw` itself, because it always supplies such qualification. However, this can pose a hazard for functions that are executed on the remote server via triggers or rules on remote tables. For example, if a remote table is actually a view, any functions used in that view will be executed with the restricted search path. It is recommended to schema-qualify all names in such functions, or else attach `SET search_path` options (see `CREATE FUNCTION`) to such functions to establish their expected search path environment.

`postgres_fdw` likewise establishes remote session settings for various parameters:

- TimeZone is set to UTC
- DateStyle is set to ISO
- IntervalStyle is set to postgres
- extra_float_digits is set to 3 for remote servers 9.0 and newer and is set to 2 for older versions

These are less likely to be problematic than `search_path`, but can be handled with function SET options if the need arises.

It is *not* recommended that you override this behavior by changing the session-level settings of these parameters; that is likely to cause `postgres_fdw` to malfunction.

F.33.6. Cross-Version Compatibility

`postgres_fdw` can be used with remote servers dating back to PostgreSQL 8.3. Read-only capability is available back to 8.1. A limitation however is that `postgres_fdw` generally assumes that immutable built-in functions and operators are safe to send to the remote server for execution, if they appear in a WHERE clause for a foreign table. Thus, a built-in function that was added since the remote server's release might be sent to it for execution, resulting in “function does not exist” or a similar error. This type of failure can be worked around by rewriting the query, for example by embedding the foreign table reference in a sub-SELECT with `OFFSET 0` as an optimization fence, and placing the problematic function or operator outside the sub-SELECT.

F.33.7. Examples

Here is an example of creating a foreign table with `postgres_fdw`. First install the extension:

```
CREATE EXTENSION postgres_fdw;
```

Then create a foreign server using `CREATE SERVER`. In this example we wish to connect to a PostgreSQL server on host `192.83.123.89` listening on port `5432`. The database to which the connection is made is named `foreign_db` on the remote server:

```
CREATE SERVER foreign_server
    FOREIGN DATA WRAPPER postgres_fdw
    OPTIONS (host '192.83.123.89', port '5432', dbname
'foreign_db');
```

A user mapping, defined with `CREATE USER MAPPING`, is needed as well to identify the role that will be used on the remote server:

```
CREATE USER MAPPING FOR local_user
    SERVER foreign_server
    OPTIONS (user 'foreign_user', password 'password');
```

Now it is possible to create a foreign table with `CREATE FOREIGN TABLE`. In this example we wish to access the table named `some_schema.some_table` on the remote server. The local name for it will be `foreign_table`:

```
CREATE FOREIGN TABLE foreign_table (
    id integer NOT NULL,
    data text
)
    SERVER foreign_server
```

```
OPTIONS (schema_name 'some_schema', table_name
'some_table');
```

It's essential that the data types and other properties of the columns declared in `CREATE FOREIGN TABLE` match the actual remote table. Column names must match as well, unless you attach `column_name` options to the individual columns to show how they are named in the remote table. In many cases, use of `IMPORT FOREIGN SCHEMA` is preferable to constructing foreign table definitions manually.

F.33.8. Author

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F.34. seg

This module implements a data type `seg` for representing line segments, or floating point intervals. `seg` can represent uncertainty in the interval endpoints, making it especially useful for representing laboratory measurements.

F.34.1. Rationale

The geometry of measurements is usually more complex than that of a point in a numeric continuum. A measurement is usually a segment of that continuum with somewhat fuzzy limits. The measurements come out as intervals because of uncertainty and randomness, as well as because the value being measured may naturally be an interval indicating some condition, such as the temperature range of stability of a protein.

Using just common sense, it appears more convenient to store such data as intervals, rather than pairs of numbers. In practice, it even turns out more efficient in most applications.

Further along the line of common sense, the fuzziness of the limits suggests that the use of traditional numeric data types leads to a certain loss of information. Consider this: your instrument reads 6.50, and you input this reading into the database. What do you get when you fetch it? Watch:

```
test=> select 6.50 :: float8 as "pH";
pH
---
6.5
(1 row)
```

In the world of measurements, 6.50 is not the same as 6.5. It may sometimes be critically different. The experimenters usually write down (and publish) the digits they trust. 6.50 is actually a fuzzy interval contained within a bigger and even fuzzier interval, 6.5, with their center points being (probably) the only common feature they share. We definitely do not want such different data items to appear the same.

Conclusion? It is nice to have a special data type that can record the limits of an interval with arbitrarily variable precision. Variable in the sense that each data element records its own precision.

Check this out:

```
test=> select '6.25 .. 6.50'::seg as "pH";
pH
-----
6.25 .. 6.50
(1 row)
```

F.34.2. Syntax

The external representation of an interval is formed using one or two floating-point numbers joined by the range operator (`.` or `..`). Alternatively, it can be specified as a center point plus or minus a deviation. Optional certainty indicators (`<`, `>` or `~`) can be stored as well. (Certainty indicators are ignored by all the built-in operators, however.) Table F.26 gives an overview of allowed representations; Table F.27 shows some examples.

In Table F.26, x , y , and $delta$ denote floating-point numbers. x and y , but not $delta$, can be preceded by a certainty indicator.

Table F.26. `seg` External Representations

x	Single value (zero-length interval)
$x .. y$	Interval from x to y
$x (+-) delta$	Interval from $x - delta$ to $x + delta$
$x ..$	Open interval with lower bound x
$.. x$	Open interval with upper bound x

Table F.27. Examples of Valid `seg` Input

5.0	Creates a zero-length segment (a point, if you will)
~5.0	Creates a zero-length segment and records <code>~</code> in the data. <code>~</code> is ignored by <code>seg</code> operations, but is preserved as a comment.
<5.0	Creates a point at 5.0. <code><</code> is ignored but is preserved as a comment.
>5.0	Creates a point at 5.0. <code>></code> is ignored but is preserved as a comment.
5(+-.0.3	Creates an interval 4.7 .. 5.3. Note that the <code>(+-)</code> notation isn't preserved.
50 ..	Everything that is greater than or equal to 50
.. 0	Everything that is less than or equal to 0
1.5e-2 .. 2E-2	Creates an interval 0.015 .. 0.02
1 ... 2	The same as <code>1...2</code> , or <code>1 .. 2</code> , or <code>1 . 2</code> (spaces around the range operator are ignored)

Because `...` is widely used in data sources, it is allowed as an alternative spelling of `..`. Unfortunately, this creates a parsing ambiguity: it is not clear whether the upper bound in `0...23` is meant to be 23 or `0.23`. This is resolved by requiring at least one digit before the decimal point in all numbers in `seg` input.

As a sanity check, `seg` rejects intervals with the lower bound greater than the upper, for example `5 .. 2`.

F.34.3. Precision

`seg` values are stored internally as pairs of 32-bit floating point numbers. This means that numbers with more than 7 significant digits will be truncated.

Numbers with 7 or fewer significant digits retain their original precision. That is, if your query returns 0.00, you will be sure that the trailing zeroes are not the artifacts of formatting; they reflect the preci-

sion of the original data. The number of leading zeroes does not affect precision: the value 0.0067 is considered to have just 2 significant digits.

F.34.4. Usage

The `seg` module includes a GiST index operator class for `seg` values. The operators supported by the GiST operator class are shown in Table F.28.

Table F.28. Seg GiST Operators

Operator	Description
<code>[a, b] << [c, d]</code>	<code>[a, b]</code> is entirely to the left of <code>[c, d]</code> . That is, <code>[a, b] << [c, d]</code> is true if <code>b < c</code> and false otherwise.
<code>[a, b] >> [c, d]</code>	<code>[a, b]</code> is entirely to the right of <code>[c, d]</code> . That is, <code>[a, b] >> [c, d]</code> is true if <code>a > d</code> and false otherwise.
<code>[a, b] &< [c, d]</code>	Overlaps or is left of — This might be better read as “does not extend to right of”. It is true when <code>b <= d</code> .
<code>[a, b] &> [c, d]</code>	Overlaps or is right of — This might be better read as “does not extend to left of”. It is true when <code>a >= c</code> .
<code>[a, b] = [c, d]</code>	Same as — The segments <code>[a, b]</code> and <code>[c, d]</code> are identical, that is, <code>a = c</code> and <code>b = d</code> .
<code>[a, b] && [c, d]</code>	The segments <code>[a, b]</code> and <code>[c, d]</code> overlap.
<code>[a, b] @> [c, d]</code>	The segment <code>[a, b]</code> contains the segment <code>[c, d]</code> , that is, <code>a <= c</code> and <code>b >= d</code> .
<code>[a, b] <@ [c, d]</code>	The segment <code>[a, b]</code> is contained in <code>[c, d]</code> , that is, <code>a >= c</code> and <code>b <= d</code> .

(Before PostgreSQL 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The standard B-tree operators are also provided, for example

Operator	Description
<code>[a, b] < [c, d]</code>	Less than
<code>[a, b] > [c, d]</code>	Greater than

These operators do not make a lot of sense for any practical purpose but sorting. These operators first compare (a) to (c), and if these are equal, compare (b) to (d). That results in reasonably good sorting in most cases, which is useful if you want to use `ORDER BY` with this type.

F.34.5. Notes

For examples of usage, see the regression test `sql/seg.sql`.

The mechanism that converts (+-) to regular ranges isn't completely accurate in determining the number of significant digits for the boundaries. For example, it adds an extra digit to the lower boundary if the resulting interval includes a power of ten:

```
postgres=> select '10(+-)1'::seg as seg;
         seg
-----
```

9.0 .. 11 -- should be: 9 .. 11

The performance of an R-tree index can largely depend on the initial order of input values. It may be very helpful to sort the input table on the `seg` column; see the script `sort-segments.pl` for an example.

F.34.6. Credits

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My thanks are primarily to Prof. Joe Hellerstein (<http://db.cs.berkeley.edu/jmh/>) for elucidating the gist of the GiST (<http://gist.cs.berkeley.edu/>). I am also grateful to all Postgres developers, present and past, for enabling myself to create my own world and live undisturbed in it. And I would like to acknowledge my gratitude to Argonne Lab and to the U.S. Department of Energy for the years of faithful support of my database research.

F.35. sepgsql

`sepgsql` is a loadable module that supports label-based mandatory access control (MAC) based on SELinux security policy.

Warning

The current implementation has significant limitations, and does not enforce mandatory access control for all actions. See Section F.35.7.

F.35.1. Overview

This module integrates with SELinux to provide an additional layer of security checking above and beyond what is normally provided by PostgreSQL. From the perspective of SELinux, this module allows PostgreSQL to function as a user-space object manager. Each table or function access initiated by a DML query will be checked against the system security policy. This check is in addition to the usual SQL permissions checking performed by PostgreSQL.

SELinux access control decisions are made using security labels, which are represented by strings such as `system_u:object_r:sepgsql_table_t:s0`. Each access control decision involves two labels: the label of the subject attempting to perform the action, and the label of the object on which the operation is to be performed. Since these labels can be applied to any sort of object, access control decisions for objects stored within the database can be (and, with this module, are) subjected to the same general criteria used for objects of any other type, such as files. This design is intended to allow a centralized security policy to protect information assets independent of the particulars of how those assets are stored.

The `SECURITY LABEL` statement allows assignment of a security label to a database object.

F.35.2. Installation

`sepgsql` can only be used on Linux 2.6.28 or higher with SELinux enabled. It is not available on any other platform. You will also need `libselinux` 2.1.10 or higher and `selinux-policy` 3.9.13 or higher (although some distributions may backport the necessary rules into older policy versions).

The `sestatus` command allows you to check the status of SELinux. A typical display is:

```
$ sestatus
```

```
SELinux status:          enabled
SELinuxfs mount:        /selinux
Current mode:           enforcing
Mode from config file:  enforcing
Policy version:         24
Policy from config file: targeted
```

If SELinux is disabled or not installed, you must set that product up first before installing this module.

To build this module, include the option `--with-selinux` in your PostgreSQL configure command. Be sure that the `libselinux-devel` RPM is installed at build time.

To use this module, you must include `sepgsql` in the `shared_preload_libraries` parameter in `postgresql.conf`. The module will not function correctly if loaded in any other manner. Once the module is loaded, you should execute `sepgsql.sql` in each database. This will install functions needed for security label management, and assign initial security labels.

Here is an example showing how to initialize a fresh database cluster with `sepgsql` functions and security labels installed. Adjust the paths shown as appropriate for your installation:

```
$ export PGDATA=/path/to/data/directory
$ initdb
$ vi $PGDATA/postgresql.conf
  change
  #shared_preload_libraries = ''           # (change
requires restart)
  to
  shared_preload_libraries = 'sepgsql'    # (change
requires restart)
$ for DBNAME in template0 template1 postgres; do
  postgres --single -F -c exit_on_error=true $DBNAME \
    </usr/local/pgsql/share/contrib/sepgsql.sql >/dev/null
done
```

Please note that you may see some or all of the following notifications depending on the particular versions you have of `libselinux` and `selinux-policy`:

```
/etc/selinux/targeted/contexts/sepgsql_contexts: line 33 has
invalid object type db_blobs
/etc/selinux/targeted/contexts/sepgsql_contexts: line 36 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 37 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 38 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 39 has
invalid object type db_language
/etc/selinux/targeted/contexts/sepgsql_contexts: line 40 has
invalid object type db_language
```

These messages are harmless and should be ignored.

If the installation process completes without error, you can now start the server normally.

F.35.3. Regression Tests

Due to the nature of SELinux, running the regression tests for `sepgsql` requires several extra configuration steps, some of which must be done as root. The regression tests will not be run by an ordinary

`make check` or `make installcheck` command; you must set up the configuration and then invoke the test script manually. The tests must be run in the `contrib/sepgsql` directory of a configured PostgreSQL build tree. Although they require a build tree, the tests are designed to be executed against an installed server, that is they are comparable to `make installcheck` not `make check`.

First, set up `sepgsql` in a working database according to the instructions in Section F.35.2. Note that the current operating system user must be able to connect to the database as superuser without password authentication.

Second, build and install the policy package for the regression test. The `sepgsql-regtest` policy is a special purpose policy package which provides a set of rules to be allowed during the regression tests. It should be built from the policy source file `sepgsql-regtest.te`, which is done using `make` with a Makefile supplied by SELinux. You will need to locate the appropriate Makefile on your system; the path shown below is only an example. Once built, install this policy package using the `semodule` command, which loads supplied policy packages into the kernel. If the package is correctly installed, `semodule -l` should list `sepgsql-regtest` as an available policy package:

```
$ cd ../contrib/sepgsql
$ make -f /usr/share/selinux/devel/Makefile
$ sudo semodule -u sepgsql-regtest.pp
$ sudo semodule -l | grep sepgsql
sepgsql-regtest 1.07
```

Third, turn on `sepgsql_regression_test_mode`. For security reasons, the rules in `sepgsql-regtest` are not enabled by default; the `sepgsql_regression_test_mode` parameter enables the rules needed to launch the regression tests. It can be turned on using the `setsebool` command:

```
$ sudo setsebool sepgsql_regression_test_mode on
$ getsebool sepgsql_regression_test_mode
sepgsql_regression_test_mode --> on
```

Fourth, verify your shell is operating in the `unconfined_t` domain:

```
$ id -z
unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
```

See Section F.35.8 for details on adjusting your working domain, if necessary.

Finally, run the regression test script:

```
$ ./test_sepgsql
```

This script will attempt to verify that you have done all the configuration steps correctly, and then it will run the regression tests for the `sepgsql` module.

After completing the tests, it's recommended you disable the `sepgsql_regression_test_mode` parameter:

```
$ sudo setsebool sepgsql_regression_test_mode off
```

You might prefer to remove the `sepgsql-regtest` policy entirely:

```
$ sudo semodule -r sepgsql-regtest
```

F.35.4. GUC Parameters

`sepgsql.permissive` (boolean)

This parameter enables `sepgsql` to function in permissive mode, regardless of the system setting. The default is off. This parameter can only be set in the `postgresql.conf` file or on the server command line.

When this parameter is on, `sepgsql` functions in permissive mode, even if SELinux in general is working in enforcing mode. This parameter is primarily useful for testing purposes.

`sepgsql.debug_audit` (boolean)

This parameter enables the printing of audit messages regardless of the system policy settings. The default is off, which means that messages will be printed according to the system settings.

The security policy of SELinux also has rules to control whether or not particular accesses are logged. By default, access violations are logged, but allowed accesses are not.

This parameter forces all possible logging to be turned on, regardless of the system policy.

F.35.5. Features

F.35.5.1. Controlled Object Classes

The security model of SELinux describes all the access control rules as relationships between a subject entity (typically, a client of the database) and an object entity (such as a database object), each of which is identified by a security label. If access to an unlabeled object is attempted, the object is treated as if it were assigned the label `unlabeled_t`.

Currently, `sepgsql` allows security labels to be assigned to schemas, tables, columns, sequences, views, and functions. When `sepgsql` is in use, security labels are automatically assigned to supported database objects at creation time. This label is called a default security label, and is decided according to the system security policy, which takes as input the creator's label, the label assigned to the new object's parent object and optionally name of the constructed object.

A new database object basically inherits the security label of the parent object, except when the security policy has special rules known as type-transition rules, in which case a different label may be applied. For schemas, the parent object is the current database; for tables, sequences, views, and functions, it is the containing schema; for columns, it is the containing table.

F.35.5.2. DML Permissions

For tables, `db_table:select`, `db_table:insert`, `db_table:update` or `db_table:delete` are checked for all the referenced target tables depending on the kind of statement; in addition, `db_table:select` is also checked for all the tables that contain columns referenced in the `WHERE` or `RETURNING` clause, as a data source for `UPDATE`, and so on.

Column-level permissions will also be checked for each referenced column. `db_column:select` is checked on not only the columns being read using `SELECT`, but those being referenced in other DML statements; `db_column:update` or `db_column:insert` will also be checked for columns being modified by `UPDATE` or `INSERT`.

For example, consider:

```
UPDATE t1 SET x = 2, y = func1(y) WHERE z = 100;
```

Here, `db_column:update` will be checked for `t1.x`, since it is being updated, `db_column:{select update}` will be checked for `t1.y`, since it is both updated and referenced, and

`db_column:select` will be checked for `t1.z`, since it is only referenced. `db_table:{select update}` will also be checked at the table level.

For sequences, `db_sequence:get_value` is checked when we reference a sequence object using `SELECT`; however, note that we do not currently check permissions on execution of corresponding functions such as `lastval()`.

For views, `db_view:expand` will be checked, then any other required permissions will be checked on the objects being expanded from the view, individually.

For functions, `db_procedure:{execute}` will be checked when user tries to execute a function as a part of query, or using fast-path invocation. If this function is a trusted procedure, it also checks `db_procedure:{entrypoint}` permission to check whether it can perform as entry point of trusted procedure.

In order to access any schema object, `db_schema:search` permission is required on the containing schema. When an object is referenced without schema qualification, schemas on which this permission is not present will not be searched (just as if the user did not have `USAGE` privilege on the schema). If an explicit schema qualification is present, an error will occur if the user does not have the requisite permission on the named schema.

The client must be allowed to access all referenced tables and columns, even if they originated from views which were then expanded, so that we apply consistent access control rules independent of the manner in which the table contents are referenced.

The default database privilege system allows database superusers to modify system catalogs using DML commands, and reference or modify toast tables. These operations are prohibited when `sepgsql` is enabled.

F.35.5.3. DDL Permissions

SELinux defines several permissions to control common operations for each object type; such as creation, alter, drop and relabel of security label. In addition, several object types have special permissions to control their characteristic operations; such as addition or deletion of name entries within a particular schema.

Creating a new database object requires `create` permission. SELinux will grant or deny this permission based on the client's security label and the proposed security label for the new object. In some cases, additional privileges are required:

- `CREATE DATABASE` additionally requires `getattr` permission for the source or template database.
- Creating a schema object additionally requires `add_name` permission on the parent schema.
- Creating a table additionally requires permission to create each individual table column, just as if each table column were a separate top-level object.
- Creating a function marked as `LEAKPROOF` additionally requires `install` permission. (This permission is also checked when `LEAKPROOF` is set for an existing function.)

When `DROP` command is executed, `drop` will be checked on the object being removed. Permissions will be also checked for objects dropped indirectly via `CASCADE`. Deletion of objects contained within a particular schema (tables, views, sequences and procedures) additionally requires `remove_name` on the schema.

When `ALTER` command is executed, `setattr` will be checked on the object being modified for each object types, except for subsidiary objects such as the indexes or triggers of a table, where permissions are instead checked on the parent object. In some cases, additional permissions are required:

- Moving an object to a new schema additionally requires `remove_name` permission on the old schema and `add_name` permission on the new one.
- Setting the `LEAKPROOF` attribute on a function requires `install` permission.
- Using `SECURITY LABEL` on an object additionally requires `relabelfrom` permission for the object in conjunction with its old security label and `relabelto` permission for the object in conjunction with its new security label. (In cases where multiple label providers are installed and the user tries to set a security label, but it is not managed by SELinux, only `setattr` should be checked here. This is currently not done due to implementation restrictions.)

F.35.5.4. Trusted Procedures

Trusted procedures are similar to security definer functions or `setuid` commands. SELinux provides a feature to allow trusted code to run using a security label different from that of the client, generally for the purpose of providing highly controlled access to sensitive data (e.g. rows might be omitted, or the precision of stored values might be reduced). Whether or not a function acts as a trusted procedure is controlled by its security label and the operating system security policy. For example:

```
postgres=# CREATE TABLE customer (
           cid      int primary key,
           cname    text,
           credit   text
         );
CREATE TABLE
postgres=# SECURITY LABEL ON COLUMN customer.credit
           IS 'system_u:object_r:sepgsql_secret_table_t:s0';
SECURITY LABEL
postgres=# CREATE FUNCTION show_credit(int) RETURNS text
           AS 'SELECT regexp_replace(credit, ''-[0-9]+$'', ''-
xxxx'', 'g')
           FROM customer WHERE cid = $1'
           LANGUAGE sql;
CREATE FUNCTION
postgres=# SECURITY LABEL ON FUNCTION show_credit(int)
           IS
           'system_u:object_r:sepgsql_trusted_proc_exec_t:s0';
SECURITY LABEL
```

The above operations should be performed by an administrative user.

```
postgres=# SELECT * FROM customer;
ERROR: SELinux: security policy violation
postgres=# SELECT cid, cname, show_credit(cid) FROM customer;
 cid | cname | show_credit
-----+-----+-----
   1 | taro  | 1111-2222-3333-xxxx
   2 | hanako | 5555-6666-7777-xxxx
(2 rows)
```

In this case, a regular user cannot reference `customer.credit` directly, but a trusted procedure `show_credit` allows the user to print the credit card numbers of customers with some of the digits masked out.

F.35.5.5. Dynamic Domain Transitions

It is possible to use SELinux's dynamic domain transition feature to switch the security label of the client process, the client domain, to a new context, if that is allowed by the security policy. The client

domain needs the `setcurrent` permission and also `dyntransition` from the old to the new domain.

Dynamic domain transitions should be considered carefully, because they allow users to switch their label, and therefore their privileges, at their option, rather than (as in the case of a trusted procedure) as mandated by the system. Thus, the `dyntransition` permission is only considered safe when used to switch to a domain with a smaller set of privileges than the original one. For example:

```
regression=# select sepysql_getcon();
                sepysql_getcon
-----
unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
(1 row)

regression=# SELECT
  sepysql_setcon('unconfined_u:unconfined_r:unconfined_t:s0-
s0:c1.c4');
  sepysql_setcon
-----
t
(1 row)

regression=# SELECT
  sepysql_setcon('unconfined_u:unconfined_r:unconfined_t:s0-
s0:c1.c1023');
ERROR:  SELinux: security policy violation
```

In this example above we were allowed to switch from the larger MCS range `c1.c1023` to the smaller range `c1.c4`, but switching back was denied.

A combination of dynamic domain transition and trusted procedure enables an interesting use case that fits the typical process life-cycle of connection pooling software. Even if your connection pooling software is not allowed to run most of SQL commands, you can allow it to switch the security label of the client using the `sepysql_setcon()` function from within a trusted procedure; that should take some credential to authorize the request to switch the client label. After that, this session will have the privileges of the target user, rather than the connection pooler. The connection pooler can later revert the security label change by again using `sepysql_setcon()` with `NULL` argument, again invoked from within a trusted procedure with appropriate permissions checks. The point here is that only the trusted procedure actually has permission to change the effective security label, and only does so when given proper credentials. Of course, for secure operation, the credential store (table, procedure definition, or whatever) must be protected from unauthorized access.

F.35.5.6. Miscellaneous

We reject the `LOAD` command across the board, because any module loaded could easily circumvent security policy enforcement.

F.35.6. Sepysql Functions

Table F.29 shows the available functions.

Table F.29. Sepysql Functions

<code>sepysql_getcon()</code> returns text	Returns the client domain, the current security label of the client.
<code>sepysql_setcon(text)</code> returns bool	Switches the client domain of the current session to the new domain, if allowed by the security poli-

	cy. It also accepts NULL input as a request to transition to the client's original domain.
<code>sepgsql_mcstrans_in(text)</code> returns text	Translates the given qualified MLS/MCS range into raw format if the mcstrans daemon is running.
<code>sepgsql_mcstrans_out(text)</code> returns text	Translates the given raw MLS/MCS range into qualified format if the mcstrans daemon is running.
<code>sepgsql_restorecon(text)</code> returns bool	Sets up initial security labels for all objects within the current database. The argument may be NULL, or the name of a specfile to be used as alternative of the system default.

F.35.7. Limitations

Data Definition Language (DDL) Permissions

Due to implementation restrictions, some DDL operations do not check permissions.

Data Control Language (DCL) Permissions

Due to implementation restrictions, DCL operations do not check permissions.

Row-level access control

PostgreSQL supports row-level access, but `sepgsql` does not.

Covert channels

`sepgsql` does not try to hide the existence of a certain object, even if the user is not allowed to reference it. For example, we can infer the existence of an invisible object as a result of primary key conflicts, foreign key violations, and so on, even if we cannot obtain the contents of the object. The existence of a top secret table cannot be hidden; we only hope to conceal its contents.

F.35.8. External Resources

SE-PostgreSQL Introduction⁵

This wiki page provides a brief overview, security design, architecture, administration and upcoming features.

SELinux User's and Administrator's Guide⁶

This document provides a wide spectrum of knowledge to administer SELinux on your systems. It focuses primarily on Red Hat operating systems, but is not limited to them.

Fedora SELinux FAQ⁷

This document answers frequently asked questions about SELinux. It focuses primarily on Fedora, but is not limited to Fedora.

F.35.9. Author

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⁵ <https://wiki.postgresql.org/wiki/SEPostgreSQL>

⁶ https://access.redhat.com/documentation/en-US/Red_Hat_Enterprise_Linux/7/html/SELinux_Users_and_Administrators_Guide/

⁷ https://fedoraproject.org/wiki/SELinux_FAQ

F.36. spi

The `spi` module provides several workable examples of using the Server Programming Interface (SPI) and triggers. While these functions are of some value in their own right, they are even more useful as examples to modify for your own purposes. The functions are general enough to be used with any table, but you have to specify table and field names (as described below) while creating a trigger.

Each of the groups of functions described below is provided as a separately-installable extension.

F.36.1. `refint` — Functions for Implementing Referential Integrity

`check_primary_key()` and `check_foreign_key()` are used to check foreign key constraints. (This functionality is long since superseded by the built-in foreign key mechanism, of course, but the module is still useful as an example.)

`check_primary_key()` checks the referencing table. To use, create a `BEFORE INSERT OR UPDATE` trigger using this function on a table referencing another table. Specify as the trigger arguments: the referencing table's column name(s) which form the foreign key, the referenced table name, and the column names in the referenced table which form the primary/unique key. To handle multiple foreign keys, create a trigger for each reference.

`check_foreign_key()` checks the referenced table. To use, create a `BEFORE DELETE OR UPDATE` trigger using this function on a table referenced by other table(s). Specify as the trigger arguments: the number of referencing tables for which the function has to perform checking, the action if a referencing key is found (`cascade` — to delete the referencing row, `restrict` — to abort transaction if referencing keys exist, `setnull` — to set referencing key fields to null), the triggered table's column names which form the primary/unique key, then the referencing table name and column names (repeated for as many referencing tables as were specified by first argument). Note that the primary/unique key columns should be marked `NOT NULL` and should have a unique index.

There are examples in `refint.example`.

F.36.2. `autoinc` — Functions for Autoincrementing Fields

`autoinc()` is a trigger that stores the next value of a sequence into an integer field. This has some overlap with the built-in “serial column” feature, but it is not the same: `autoinc()` will override attempts to substitute a different field value during inserts, and optionally it can be used to increment the field during updates, too.

To use, create a `BEFORE INSERT` (or optionally `BEFORE INSERT OR UPDATE`) trigger using this function. Specify two trigger arguments: the name of the integer column to be modified, and the name of the sequence object that will supply values. (Actually, you can specify any number of pairs of such names, if you'd like to update more than one autoincrementing column.)

There is an example in `autoinc.example`.

F.36.3. `insert_username` — Functions for Tracking Who Changed a Table

`insert_username()` is a trigger that stores the current user's name into a text field. This can be useful for tracking who last modified a particular row within a table.

To use, create a `BEFORE INSERT` and/or `UPDATE` trigger using this function. Specify a single trigger argument: the name of the text column to be modified.

There is an example in `insert_username.example`.

F.36.4. `moddatetime` — Functions for Tracking Last Modification Time

`moddatetime()` is a trigger that stores the current time into a `timestamp` field. This can be useful for tracking the last modification time of a particular row within a table.

To use, create a `BEFORE UPDATE` trigger using this function. Specify a single trigger argument: the name of the column to be modified. The column must be of type `timestamp` or `timestamp with time zone`.

There is an example in `moddatetime.example`.

F.37. `sslinfo`

The `sslinfo` module provides information about the SSL certificate that the current client provided when connecting to PostgreSQL. The module is useless (most functions will return `NULL`) if the current connection does not use SSL.

Some of the information available through this module can also be obtained using the built-in system view `pg_stat_ssl`.

This extension won't build at all unless the installation was configured with `--with-openssl`.

F.37.1. Functions Provided

`ssl_is_used()` returns `boolean`

Returns true if current connection to server uses SSL, and false otherwise.

`ssl_version()` returns `text`

Returns the name of the protocol used for the SSL connection (e.g. `TLSv1.0` `TLSv1.1`, or `TLSv1.2`).

`ssl_cipher()` returns `text`

Returns the name of the cipher used for the SSL connection (e.g. `DHE-RSA-AES256-SHA`).

`ssl_client_cert_present()` returns `boolean`

Returns true if current client has presented a valid SSL client certificate to the server, and false otherwise. (The server might or might not be configured to require a client certificate.)

`ssl_client_serial()` returns `numeric`

Returns serial number of current client certificate. The combination of certificate serial number and certificate issuer is guaranteed to uniquely identify a certificate (but not its owner — the owner ought to regularly change their keys, and get new certificates from the issuer).

So, if you run your own CA and allow only certificates from this CA to be accepted by the server, the serial number is the most reliable (albeit not very mnemonic) means to identify a user.

`ssl_client_dn()` returns `text`

Returns the full subject of the current client certificate, converting character data into the current database encoding. It is assumed that if you use non-ASCII characters in the certificate names,

your database is able to represent these characters, too. If your database uses the SQL_ASCII encoding, non-ASCII characters in the name will be represented as UTF-8 sequences.

The result looks like /CN=Somebody /C=Some country/O=Some organization.

`ssl_issuer_dn()` returns text

Returns the full issuer name of the current client certificate, converting character data into the current database encoding. Encoding conversions are handled the same as for `ssl_client_dn`.

The combination of the return value of this function with the certificate serial number uniquely identifies the certificate.

This function is really useful only if you have more than one trusted CA certificate in your server's certificate authority file, or if this CA has issued some intermediate certificate authority certificates.

`ssl_client_dn_field(fieldname text)` returns text

This function returns the value of the specified field in the certificate subject, or NULL if the field is not present. Field names are string constants that are converted into ASN1 object identifiers using the OpenSSL object database. The following values are acceptable:

```
commonName (alias CN)
surname (alias SN)
name
givenName (alias GN)
countryName (alias C)
localityName (alias L)
stateOrProvinceName (alias ST)
organizationName (alias O)
organizationalUnitName (alias OU)
title
description
initials
postalCode
streetAddress
generationQualifier
description
dnQualifier
x500UniqueIdentifier
pseudonym
role
emailAddress
```

All of these fields are optional, except `commonName`. It depends entirely on your CA's policy which of them would be included and which wouldn't. The meaning of these fields, however, is strictly defined by the X.500 and X.509 standards, so you cannot just assign arbitrary meaning to them.

`ssl_issuer_field(fieldname text)` returns text

Same as `ssl_client_dn_field`, but for the certificate issuer rather than the certificate subject.

`ssl_extension_info()` returns setof record

Provide information about extensions of client certificate: extension name, extension value, and if it is a critical extension.

F.37.2. Author

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F.38. tablefunc

The `tablefunc` module includes various functions that return tables (that is, multiple rows). These functions are useful both in their own right and as examples of how to write C functions that return multiple rows.

F.38.1. Functions Provided

Table F.30 shows the functions provided by the `tablefunc` module.

Table F.30. tablefunc Functions

Function	Returns	Description
<code>normal_rand(int numvals, float8 mean, float8 stddev)</code>	setof float8	Produces a set of normally distributed random values
<code>crosstab(text sql)</code>	setof record	Produces a “pivot table” containing row names plus <i>N</i> value columns, where <i>N</i> is determined by the row type specified in the calling query
<code>crosstabN(text sql)</code>	setof table_crosstab_N	Produces a “pivot table” containing row names plus <i>N</i> value columns. <code>crosstab2</code> , <code>crosstab3</code> , and <code>crosstab4</code> are predefined, but you can create additional <code>crosstabN</code> functions as described below
<code>crosstab(text source_sql, text category_sql)</code>	setof record	Produces a “pivot table” with the value columns specified by a second query
<code>crosstab(text sql, int N)</code>	setof record	Obsolete version of <code>crosstab(text)</code> . The parameter <i>N</i> is now ignored, since the number of value columns is always determined by the calling query
<code>connectby(text relname, text keyid_fld, text parent_keyid_fld [, text orderby_fld], text start_with, int max_depth [, text branch_delim])</code>	setof record	Produces a representation of a hierarchical tree structure

F.38.1.1. normal_rand

`normal_rand(int numvals, float8 mean, float8 stddev)` returns set of float8

`normal_rand` produces a set of normally distributed random values (Gaussian distribution).

numvals is the number of values to be returned from the function. *mean* is the mean of the normal distribution of values and *stddev* is the standard deviation of the normal distribution of values.

For example, this call requests 1000 values with a mean of 5 and a standard deviation of 3:

```
test=# SELECT * FROM normal_rand(1000, 5, 3);
      normal_rand
-----
 1.56556322244898
 9.10040991424657
 5.36957140345079
-0.369151492880995
 0.283600703686639
      .
      .
      .
 4.82992125404908
 9.71308014517282
 2.49639286969028
(1000 rows)
```

F.38.1.2. `crosstab(text)`

```
crosstab(text sql)
crosstab(text sql, int N)
```

The `crosstab` function is used to produce “pivot” displays, wherein data is listed across the page rather than down. For example, we might have data like

```
row1    val11
row1    val12
row1    val13
...
row2    val21
row2    val22
row2    val23
...
```

which we wish to display like

```
row1    val11    val12    val13    ...
row2    val21    val22    val23    ...
...
```

The `crosstab` function takes a text parameter that is a SQL query producing raw data formatted in the first way, and produces a table formatted in the second way.

The *sql* parameter is a SQL statement that produces the source set of data. This statement must return one *row_name* column, one *category* column, and one *value* column. *N* is an obsolete parameter, ignored if supplied (formerly this had to match the number of output value columns, but now that is determined by the calling query).

For example, the provided query might produce a set something like:

```

row_name   cat    value
-----+-----+-----
row1      cat1   val1
row1      cat2   val2
row1      cat3   val3
row1      cat4   val4
row2      cat1   val5
row2      cat2   val6
row2      cat3   val7
row2      cat4   val8

```

The `crosstab` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```

SELECT * FROM crosstab('...') AS ct(row_name text, category_1 text,
category_2 text);

```

This example produces a set something like:

```

          <== value  columns  ==>
row_name  category_1  category_2
-----+-----+-----
row1      val1        val2
row2      val5        val6

```

The `FROM` clause must define the output as one `row_name` column (of the same data type as the first result column of the SQL query) followed by `N` `value` columns (all of the same data type as the third result column of the SQL query). You can set up as many output value columns as you wish. The names of the output columns are up to you.

The `crosstab` function produces one output row for each consecutive group of input rows with the same `row_name` value. It fills the output `value` columns, left to right, with the `value` fields from these rows. If there are fewer rows in a group than there are output `value` columns, the extra output columns are filled with nulls; if there are more rows, the extra input rows are skipped.

In practice the SQL query should always specify `ORDER BY 1, 2` to ensure that the input rows are properly ordered, that is, values with the same `row_name` are brought together and correctly ordered within the row. Notice that `crosstab` itself does not pay any attention to the second column of the query result; it's just there to be ordered by, to control the order in which the third-column values appear across the page.

Here is a complete example:

```

CREATE TABLE ct(id SERIAL, rowid TEXT, attribute TEXT, value TEXT);
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att1','val1');
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att2','val2');
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att3','val3');
INSERT INTO ct(rowid, attribute, value)
VALUES('test1','att4','val4');
INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att1','val5');

```

```

INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att2','val6');
INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att3','val7');
INSERT INTO ct(rowid, attribute, value)
VALUES('test2','att4','val8');

SELECT *
FROM crosstab(
  'select rowid, attribute, value
   from ct
   where attribute = 'att2' or attribute = 'att3'
   order by 1,2')
AS ct(row_name text, category_1 text, category_2 text, category_3
text);

 row_name | category_1 | category_2 | category_3
-----+-----+-----+-----
 test1   | val2       | val3       |
 test2   | val6       | val7       |
(2 rows)

```

You can avoid always having to write out a FROM clause to define the output columns, by setting up a custom crosstab function that has the desired output row type wired into its definition. This is described in the next section. Another possibility is to embed the required FROM clause in a view definition.

Note

See also the `\crosstabview` command in `psql`, which provides functionality similar to `crosstab()`.

F.38.1.3. `crosstabN(text)`

```
crosstabN(text sql)
```

The `crosstabN` functions are examples of how to set up custom wrappers for the general `crosstab` function, so that you need not write out column names and types in the calling `SELECT` query. The `tablefunc` module includes `crosstab2`, `crosstab3`, and `crosstab4`, whose output row types are defined as

```

CREATE TYPE tablefunc_crosstab_N AS (
  row_name TEXT,
  category_1 TEXT,
  category_2 TEXT,
  .
  .
  .
  category_N TEXT
);

```

Thus, these functions can be used directly when the input query produces `row_name` and value columns of type `text`, and you want 2, 3, or 4 output values columns. In all other ways they behave exactly as described above for the general `crosstab` function.

For instance, the example given in the previous section would also work as

```

SELECT *
FROM crosstab3(
  'select rowid, attribute, value
   from ct
   where attribute = 'att2' or attribute = 'att3'
   order by 1,2');

```

These functions are provided mostly for illustration purposes. You can create your own return types and functions based on the underlying `crosstab()` function. There are two ways to do it:

- Create a composite type describing the desired output columns, similar to the examples in `contrib/tablefunc/tablefunc--1.0.sql`. Then define a unique function name accepting one text parameter and returning `setof your_type_name`, but linking to the same underlying `crosstab C` function. For example, if your source data produces row names that are `text`, and values that are `float8`, and you want 5 value columns:

```

CREATE TYPE my_crosstab_float8_5_cols AS (
  my_row_name text,
  my_category_1 float8,
  my_category_2 float8,
  my_category_3 float8,
  my_category_4 float8,
  my_category_5 float8
);

CREATE OR REPLACE FUNCTION crosstab_float8_5_cols(text)
  RETURNS setof my_crosstab_float8_5_cols
  AS '$libdir/tablefunc','crosstab' LANGUAGE C STABLE STRICT;

```

- Use OUT parameters to define the return type implicitly. The same example could also be done this way:

```

CREATE OR REPLACE FUNCTION crosstab_float8_5_cols(
  IN text,
  OUT my_row_name text,
  OUT my_category_1 float8,
  OUT my_category_2 float8,
  OUT my_category_3 float8,
  OUT my_category_4 float8,
  OUT my_category_5 float8)
  RETURNS setof record
  AS '$libdir/tablefunc','crosstab' LANGUAGE C STABLE STRICT;

```

F.38.1.4. `crosstab(text, text)`

```
crosstab(text source_sql, text category_sql)
```

The main limitation of the single-parameter form of `crosstab` is that it treats all values in a group alike, inserting each value into the first available column. If you want the value columns to correspond to specific categories of data, and some groups might not have data for some of the categories, that doesn't work well. The two-parameter form of `crosstab` handles this case by providing an explicit list of the categories corresponding to the output columns.

`source_sql` is a SQL statement that produces the source set of data. This statement must return one `row_name` column, one `category` column, and one `value` column. It may also have one or more

“extra” columns. The `row_name` column must be first. The `category` and `value` columns must be the last two columns, in that order. Any columns between `row_name` and `category` are treated as “extra”. The “extra” columns are expected to be the same for all rows with the same `row_name` value.

For example, `source_sql` might produce a set something like:

```
SELECT row_name, extra_col, cat, value FROM foo ORDER BY 1;
```

row_name	extra_col	cat	value
row1	extra1	cat1	val1
row1	extra1	cat2	val2
row1	extra1	cat4	val4
row2	extra2	cat1	val5
row2	extra2	cat2	val6
row2	extra2	cat3	val7
row2	extra2	cat4	val8

`category_sql` is a SQL statement that produces the set of categories. This statement must return only one column. It must produce at least one row, or an error will be generated. Also, it must not produce duplicate values, or an error will be generated. `category_sql` might be something like:

```
SELECT DISTINCT cat FROM foo ORDER BY 1;
```

```
cat
-----
cat1
cat2
cat3
cat4
```

The `crosstab` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```
SELECT * FROM crosstab('...', '...')
AS ct(row_name text, extra text, cat1 text, cat2 text, cat3
text, cat4 text);
```

This will produce a result something like:

row_name	extra	<== value columns ==>			
		cat1	cat2	cat3	cat4
row1	extra1	val1	val2		val4
row2	extra2	val5	val6	val7	val8

The `FROM` clause must define the proper number of output columns of the proper data types. If there are N columns in the `source_sql` query's result, the first $N-2$ of them must match up with the first $N-2$ output columns. The remaining output columns must have the type of the last column of the `source_sql` query's result, and there must be exactly as many of them as there are rows in the `category_sql` query's result.

The `crosstab` function produces one output row for each consecutive group of input rows with the same `row_name` value. The output `row_name` column, plus any “extra” columns, are copied from the first row of the group. The output `value` columns are filled with the `value` fields from rows having matching `category` values. If a row's `category` does not match any output of the `cate-`

gory_sql query, its value is ignored. Output columns whose matching category is not present in any input row of the group are filled with nulls.

In practice the *source_sql* query should always specify `ORDER BY 1` to ensure that values with the same *row_name* are brought together. However, ordering of the categories within a group is not important. Also, it is essential to be sure that the order of the *category_sql* query's output matches the specified output column order.

Here are two complete examples:

```
create table sales(year int, month int, qty int);
insert into sales values(2007, 1, 1000);
insert into sales values(2007, 2, 1500);
insert into sales values(2007, 7, 500);
insert into sales values(2007, 11, 1500);
insert into sales values(2007, 12, 2000);
insert into sales values(2008, 1, 1000);

select * from crosstab(
  'select year, month, qty from sales order by 1',
  'select m from generate_series(1,12) m'
) as (
  year int,
  "Jan" int,
  "Feb" int,
  "Mar" int,
  "Apr" int,
  "May" int,
  "Jun" int,
  "Jul" int,
  "Aug" int,
  "Sep" int,
  "Oct" int,
  "Nov" int,
  "Dec" int
);
```

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2007	1000	1500					500			
	1500	2000								
2008	1000									

(2 rows)

```
CREATE TABLE cth(rowid text, rowdt timestamp, attribute text, val
text);
INSERT INTO cth VALUES('test1','01 March 2003','temperature','42');
INSERT INTO cth VALUES('test1','01 March
2003','test_result','PASS');
INSERT INTO cth VALUES('test1','01 March 2003','volts','2.6987');
INSERT INTO cth VALUES('test2','02 March 2003','temperature','53');
INSERT INTO cth VALUES('test2','02 March
2003','test_result','FAIL');
INSERT INTO cth VALUES('test2','02 March 2003','test_startdate','01
March 2003');
```

```

INSERT INTO cth VALUES('test2','02 March 2003','volts','3.1234');

SELECT * FROM crosstab
(
  'SELECT rowid, rowdt, attribute, val FROM cth ORDER BY 1',
  'SELECT DISTINCT attribute FROM cth ORDER BY 1'
)
AS
(
  rowid text,
  rowdt timestamp,
  temperature int4,
  test_result text,
  test_startdate timestamp,
  volts float8
);
rowid |          rowdt          | temperature | test_result |
test_startdate | volts
-----+-----+-----+-----+-----
test1 | Sat Mar 01 00:00:00 2003 |          42 | PASS        |
          |          2.6987
test2 | Sun Mar 02 00:00:00 2003 |          53 | FAIL        | Sat
Mar 01 00:00:00 2003 |          3.1234
(2 rows)

```

You can create predefined functions to avoid having to write out the result column names and types in each query. See the examples in the previous section. The underlying C function for this form of crosstab is named `crosstab_hash`.

F.38.1.5. connectby

```

connectby(text relname, text keyid_fld, text parent_keyid_fld
          [, text orderby_fld ], text start_with, int max_depth
          [, text branch_delim ])

```

The `connectby` function produces a display of hierarchical data that is stored in a table. The table must have a key field that uniquely identifies rows, and a parent-key field that references the parent (if any) of each row. `connectby` can display the sub-tree descending from any row.

Table F.31 explains the parameters.

Table F.31. connectby Parameters

Parameter	Description
<i>relname</i>	Name of the source relation
<i>keyid_fld</i>	Name of the key field
<i>parent_keyid_fld</i>	Name of the parent-key field
<i>orderby_fld</i>	Name of the field to order siblings by (optional)
<i>start_with</i>	Key value of the row to start at
<i>max_depth</i>	Maximum depth to descend to, or zero for unlimited depth
<i>branch_delim</i>	String to separate keys with in branch output (optional)

The key and parent-key fields can be any data type, but they must be the same type. Note that the *start_with* value must be entered as a text string, regardless of the type of the key field.

The *connectby* function is declared to return *setof record*, so the actual names and types of the output columns must be defined in the FROM clause of the calling SELECT statement, for example:

```
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
    'pos', 'row2', 0, '~')
    AS t(keyid text, parent_keyid text, level int, branch text, pos
    int);
```

The first two output columns are used for the current row's key and its parent row's key; they must match the type of the table's key field. The third output column is the depth in the tree and must be of type *integer*. If a *branch_delim* parameter was given, the next output column is the branch display and must be of type *text*. Finally, if an *orderby_fld* parameter was given, the last output column is a serial number, and must be of type *integer*.

The “branch” output column shows the path of keys taken to reach the current row. The keys are separated by the specified *branch_delim* string. If no branch display is wanted, omit both the *branch_delim* parameter and the branch column in the output column list.

If the ordering of siblings of the same parent is important, include the *orderby_fld* parameter to specify which field to order siblings by. This field can be of any sortable data type. The output column list must include a final integer serial-number column, if and only if *orderby_fld* is specified.

The parameters representing table and field names are copied as-is into the SQL queries that *connectby* generates internally. Therefore, include double quotes if the names are mixed-case or contain special characters. You may also need to schema-qualify the table name.

In large tables, performance will be poor unless there is an index on the parent-key field.

It is important that the *branch_delim* string not appear in any key values, else *connectby* may incorrectly report an infinite-recursion error. Note that if *branch_delim* is not provided, a default value of ~ is used for recursion detection purposes.

Here is an example:

```
CREATE TABLE connectby_tree(keyid text, parent_keyid text, pos
    int);

INSERT INTO connectby_tree VALUES('row1',NULL, 0);
INSERT INTO connectby_tree VALUES('row2','row1', 0);
INSERT INTO connectby_tree VALUES('row3','row1', 0);
INSERT INTO connectby_tree VALUES('row4','row2', 1);
INSERT INTO connectby_tree VALUES('row5','row2', 0);
INSERT INTO connectby_tree VALUES('row6','row4', 0);
INSERT INTO connectby_tree VALUES('row7','row3', 0);
INSERT INTO connectby_tree VALUES('row8','row6', 0);
INSERT INTO connectby_tree VALUES('row9','row5', 0);

-- with branch, without orderby_fld (order of results is not
-- guaranteed)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
    'row2', 0, '~')
    AS t(keyid text, parent_keyid text, level int, branch text);
keyid | parent_keyid | level |          branch
-----+-----+-----+-----
row2  |              |     0 | row2
row4  | row2         |     1 | row2~row4
```

```

row6 | row4          |      2 | row2~row4~row6
row8 | row6          |      3 | row2~row4~row6~row8
row5 | row2          |      1 | row2~row5
row9 | row5          |      2 | row2~row5~row9
(6 rows)

```

```

-- without branch, without orderby_fld (order of results is not
guaranteed)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
'row2', 0)

```

```

AS t(keyid text, parent_keyid text, level int);

```

```

keyid | parent_keyid | level
-----+-----+-----

```

```

row2 |          |      0
row4 | row2     |      1
row6 | row4     |      2
row8 | row6     |      3
row5 | row2     |      1
row9 | row5     |      2
(6 rows)

```

```

-- with branch, with orderby_fld (notice that row5 comes before
row4)

```

```

SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
'pos', 'row2', 0, '~')

```

```

AS t(keyid text, parent_keyid text, level int, branch text, pos
int);

```

```

keyid | parent_keyid | level |          branch          | pos
-----+-----+-----+-----+-----

```

```

row2 |          |      0 | row2                    | 1
row5 | row2     |      1 | row2~row5                | 2
row9 | row5     |      2 | row2~row5~row9          | 3
row4 | row2     |      1 | row2~row4                | 4
row6 | row4     |      2 | row2~row4~row6          | 5
row8 | row6     |      3 | row2~row4~row6~row8     | 6
(6 rows)

```

```

-- without branch, with orderby_fld (notice that row5 comes before
row4)

```

```

SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid',
'pos', 'row2', 0)

```

```

AS t(keyid text, parent_keyid text, level int, pos int);

```

```

keyid | parent_keyid | level | pos
-----+-----+-----+-----

```

```

row2 |          |      0 | 1
row5 | row2     |      1 | 2
row9 | row5     |      2 | 3
row4 | row2     |      1 | 4
row6 | row4     |      2 | 5
row8 | row6     |      3 | 6
(6 rows)

```

F.38.2. Author

Joe Conway

F.39. tcn

The `tcn` module provides a trigger function that notifies listeners of changes to any table on which it is attached. It must be used as an `AFTER` trigger `FOR EACH ROW`.

Only one parameter may be supplied to the function in a `CREATE TRIGGER` statement, and that is optional. If supplied it will be used for the channel name for the notifications. If omitted `tcn` will be used for the channel name.

The payload of the notifications consists of the table name, a letter to indicate which type of operation was performed, and column name/value pairs for primary key columns. Each part is separated from the next by a comma. For ease of parsing using regular expressions, table and column names are always wrapped in double quotes, and data values are always wrapped in single quotes. Embedded quotes are doubled.

A brief example of using the extension follows.

```
test=# create table tcndata
test=# (
test=#   a int not null,
test=#   b date not null,
test=#   c text,
test=#   primary key (a, b)
test=# );
CREATE TABLE
test=# create trigger tcndata_tcn_trigger
test=#   after insert or update or delete on tcndata
test=#   for each row execute function
test=#     triggered_change_notification();
CREATE TRIGGER
test=# listen tcn;
LISTEN
test=# insert into tcndata values (1, date '2012-12-22', 'one'),
test=#                               (1, date '2012-12-23',
test=#                               'another'),
test=#                               (2, date '2012-12-23', 'two');
INSERT 0 3
Asynchronous notification "tcn" with payload
""tcndata",I,"a"='1',"b"='2012-12-22'" received from server
process with PID 22770.
Asynchronous notification "tcn" with payload
""tcndata",I,"a"='1',"b"='2012-12-23'" received from server
process with PID 22770.
Asynchronous notification "tcn" with payload
""tcndata",I,"a"='2',"b"='2012-12-23'" received from server
process with PID 22770.
test=# update tcndata set c = 'uno' where a = 1;
UPDATE 2
Asynchronous notification "tcn" with payload
""tcndata",U,"a"='1',"b"='2012-12-22'" received from server
process with PID 22770.
Asynchronous notification "tcn" with payload
""tcndata",U,"a"='1',"b"='2012-12-23'" received from server
process with PID 22770.
test=# delete from tcndata where a = 1 and b = date '2012-12-22';
DELETE 1
Asynchronous notification "tcn" with payload
""tcndata",D,"a"='1',"b"='2012-12-22'" received from server
process with PID 22770.
```

F.40. test_decoding

`test_decoding` is an example of a logical decoding output plugin. It doesn't do anything especially useful, but can serve as a starting point for developing your own output plugin.

`test_decoding` receives WAL through the logical decoding mechanism and decodes it into text representations of the operations performed.

Typical output from this plugin, used over the SQL logical decoding interface, might be:

```
postgres=# SELECT * FROM pg_logical_slot_get_changes('test_slot',
  NULL, NULL, 'include-xids', '0');
   lsn      | xid | data
-----+-----
+-----+-----+-----
0/16D30F8 | 691 | BEGIN
0/16D32A0 | 691 | table public.data: INSERT: id[int4]:2
data[text]: 'arg'
0/16D32A0 | 691 | table public.data: INSERT: id[int4]:3
data[text]: 'demo'
0/16D32A0 | 691 | COMMIT
0/16D32D8 | 692 | BEGIN
0/16D3398 | 692 | table public.data: DELETE: id[int4]:2
0/16D3398 | 692 | table public.data: DELETE: id[int4]:3
0/16D3398 | 692 | COMMIT
(8 rows)
```

F.41. tsm_system_rows

The `tsm_system_rows` module provides the table sampling method `SYSTEM_ROWS`, which can be used in the `TABLESAMPLE` clause of a `SELECT` command.

This table sampling method accepts a single integer argument that is the maximum number of rows to read. The resulting sample will always contain exactly that many rows, unless the table does not contain enough rows, in which case the whole table is selected.

Like the built-in `SYSTEM` sampling method, `SYSTEM_ROWS` performs block-level sampling, so that the sample is not completely random but may be subject to clustering effects, especially if only a small number of rows are requested.

`SYSTEM_ROWS` does not support the `REPEATABLE` clause.

F.41.1. Examples

Here is an example of selecting a sample of a table with `SYSTEM_ROWS`. First install the extension:

```
CREATE EXTENSION tsm_system_rows;
```

Then you can use it in a `SELECT` command, for instance:

```
SELECT * FROM my_table TABLESAMPLE SYSTEM_ROWS(100);
```

This command will return a sample of 100 rows from the table `my_table` (unless the table does not have 100 visible rows, in which case all its rows are returned).

F.42. tsm_system_time

The `tsm_system_time` module provides the table sampling method `SYSTEM_TIME`, which can be used in the `TABLESAMPLE` clause of a `SELECT` command.

This table sampling method accepts a single floating-point argument that is the maximum number of milliseconds to spend reading the table. This gives you direct control over how long the query takes, at the price that the size of the sample becomes hard to predict. The resulting sample will contain as many rows as could be read in the specified time, unless the whole table has been read first.

Like the built-in `SYSTEM` sampling method, `SYSTEM_TIME` performs block-level sampling, so that the sample is not completely random but may be subject to clustering effects, especially if only a small number of rows are selected.

`SYSTEM_TIME` does not support the `REPEATABLE` clause.

F.42.1. Examples

Here is an example of selecting a sample of a table with `SYSTEM_TIME`. First install the extension:

```
CREATE EXTENSION tsm_system_time;
```

Then you can use it in a `SELECT` command, for instance:

```
SELECT * FROM my_table TABLESAMPLE SYSTEM_TIME(1000);
```

This command will return as large a sample of `my_table` as it can read in 1 second (1000 milliseconds). Of course, if the whole table can be read in under 1 second, all its rows will be returned.

F.43. unaccent

`unaccent` is a text search dictionary that removes accents (diacritic signs) from lexemes. It's a filtering dictionary, which means its output is always passed to the next dictionary (if any), unlike the normal behavior of dictionaries. This allows accent-insensitive processing for full text search.

The current implementation of `unaccent` cannot be used as a normalizing dictionary for the `thesaurus` dictionary.

F.43.1. Configuration

An `unaccent` dictionary accepts the following options:

- `RULES` is the base name of the file containing the list of translation rules. This file must be stored in `$SHAREDIR/tsearch_data/` (where `$SHAREDIR` means the PostgreSQL installation's shared-data directory). Its name must end in `.rules` (which is not to be included in the `RULES` parameter).

The rules file has the following format:

- Each line represents one translation rule, consisting of a character with accent followed by a character without accent. The first is translated into the second. For example,

À	A
Á	A
Â	A
Ã	A
Ä	A
Å	A
Æ	AE

The two characters must be separated by whitespace, and any leading or trailing whitespace on a line is ignored.

- Alternatively, if only one character is given on a line, instances of that character are deleted; this is useful in languages where accents are represented by separate characters.
- Actually, each “character” can be any string not containing whitespace, so unaccent dictionaries could be used for other sorts of substring substitutions besides diacritic removal.
- As with other PostgreSQL text search configuration files, the rules file must be stored in UTF-8 encoding. The data is automatically translated into the current database's encoding when loaded. Any lines containing untranslatable characters are silently ignored, so that rules files can contain rules that are not applicable in the current encoding.

A more complete example, which is directly useful for most European languages, can be found in `unaccent.rules`, which is installed in `$SHAREDIR/tsearch_data/` when the unaccent module is installed. This rules file translates characters with accents to the same characters without accents, and it also expands ligatures into the equivalent series of simple characters (for example, `Æ` to `AE`).

F.43.2. Usage

Installing the unaccent extension creates a text search template unaccent and a dictionary unaccent based on it. The unaccent dictionary has the default parameter setting `RULES='unaccent'`, which makes it immediately usable with the standard `unaccent.rules` file. If you wish, you can alter the parameter, for example

```
mydb=# ALTER TEXT SEARCH DICTIONARY unaccent (RULES='my_rules');
```

or create new dictionaries based on the template.

To test the dictionary, you can try:

```
mydb=# select ts_lexize('unaccent','Hôtel');
 ts_lexize
-----
 {Hotel}
(1 row)
```

Here is an example showing how to insert the unaccent dictionary into a text search configuration:

```
mydb=# CREATE TEXT SEARCH CONFIGURATION fr ( COPY = french );
mydb=# ALTER TEXT SEARCH CONFIGURATION fr
      ALTER MAPPING FOR hword, hword_part, word
      WITH unaccent, french_stem;
mydb=# select to_tsvector('fr','Hôtels de la Mer');
 to_tsvector
-----
 'hotel':1 'mer':4
(1 row)

mydb=# select to_tsvector('fr','Hôtel de la Mer') @@
 to_tsquery('fr','Hotels');
 ?column?
-----
 t
(1 row)
```

```

mydb=# select ts_headline('fr','Hôtel de la
      Mer',to_tsquery('fr','Hotels'));
      ts_headline
-----
 <b>Hôtel</b> de la Mer
(1 row)

```

F.43.3. Functions

The `unaccent()` function removes accents (diacritic signs) from a given string. Basically, it's a wrapper around `unaccent`-type dictionaries, but it can be used outside normal text search contexts.

`unaccent([dictionary regdictionary,] string text)` returns `text`

If the `dictionary` argument is omitted, the text search dictionary named `unaccent` and appearing in the same schema as the `unaccent()` function itself is used.

For example:

```

SELECT unaccent('unaccent', 'Hôtel');
SELECT unaccent('Hôtel');

```

F.44. uuid-oss

The `uuid-oss` module provides functions to generate universally unique identifiers (UUIDs) using one of several standard algorithms. There are also functions to produce certain special UUID constants.

F.44.1. uuid-oss Functions

Table F.32 shows the functions available to generate UUIDs. The relevant standards ITU-T Rec. X.667, ISO/IEC 9834-8:2005, and RFC 4122 specify four algorithms for generating UUIDs, identified by the version numbers 1, 3, 4, and 5. (There is no version 2 algorithm.) Each of these algorithms could be suitable for a different set of applications.

Table F.32. Functions for UUID Generation

Function	Description
<code>uuid_generate_v1()</code>	This function generates a version 1 UUID. This involves the MAC address of the computer and a time stamp. Note that UUIDs of this kind reveal the identity of the computer that created the identifier and the time at which it did so, which might make it unsuitable for certain security-sensitive applications.
<code>uuid_generate_v1mc()</code>	This function generates a version 1 UUID but uses a random multicast MAC address instead of the real MAC address of the computer.
<code>uuid_generate_v3(namespace uuid, name text)</code>	This function generates a version 3 UUID in the given namespace using the specified input name. The namespace should be one of the special constants produced by the <code>uuid_ns_*</code> functions shown in Table F.33. (It could be any UUID in theory.) The name is an identifier in the selected namespace.

Function	Description
	<p>For example:</p> <pre>SELECT uuid_generate_v3(uuid_ns_url(), 'http://www.postgresql.org');</pre> <p>The name parameter will be MD5-hashed, so the cleartext cannot be derived from the generated UUID. The generation of UUIDs by this method has no random or environment-dependent element and is therefore reproducible.</p>
<code>uuid_generate_v4()</code>	This function generates a version 4 UUID, which is derived entirely from random numbers.
<code>uuid_generate_v5(namespace uuid, name text)</code>	This function generates a version 5 UUID, which works like a version 3 UUID except that SHA-1 is used as a hashing method. Version 5 should be preferred over version 3 because SHA-1 is thought to be more secure than MD5.

Table F.33. Functions Returning UUID Constants

<code>uuid_nil()</code>	A “nil” UUID constant, which does not occur as a real UUID.
<code>uuid_ns_dns()</code>	Constant designating the DNS namespace for UUIDs.
<code>uuid_ns_url()</code>	Constant designating the URL namespace for UUIDs.
<code>uuid_ns_oid()</code>	Constant designating the ISO object identifier (OID) namespace for UUIDs. (This pertains to ASN.1 OIDs, which are unrelated to the OIDs used in PostgreSQL.)
<code>uuid_ns_x500()</code>	Constant designating the X.500 distinguished name (DN) namespace for UUIDs.

F.44.2. Building `uuid-oss`

Historically this module depended on the OSSP UUID library, which accounts for the module's name. While the OSSP UUID library can still be found at <http://www.oss.org/pkg/lib/uuid/>, it is not well maintained, and is becoming increasingly difficult to port to newer platforms. `uuid-oss` can now be built without the OSSP library on some platforms. On FreeBSD, NetBSD, and some other BSD-derived platforms, suitable UUID creation functions are included in the core `libc` library. On Linux, macOS, and some other platforms, suitable functions are provided in the `libuuid` library, which originally came from the `e2fsprogs` project (though on modern Linux it is considered part of `util-linux-ng`). When invoking `configure`, specify `--with-uuid=bsd` to use the BSD functions, or `--with-uuid=e2fs` to use `e2fsprogs'` `libuuid`, or `--with-uuid=oss` to use the OSSP UUID library. More than one of these libraries might be available on a particular machine, so `configure` does not automatically choose one.

Note

If you only need randomly-generated (version 4) UUIDs, consider using the `gen_random_uuid()` function from the `pgcrypto` module instead.

F.44.3. Author

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F.45. xml2

The `xml2` module provides XPath querying and XSLT functionality.

F.45.1. Deprecation Notice

From PostgreSQL 8.3 on, there is XML-related functionality based on the SQL/XML standard in the core server. That functionality covers XML syntax checking and XPath queries, which is what this module does, and more, but the API is not at all compatible. It is planned that this module will be removed in a future version of PostgreSQL in favor of the newer standard API, so you are encouraged to try converting your applications. If you find that some of the functionality of this module is not available in an adequate form with the newer API, please explain your issue to <pgsql-hacker-s@lists.postgresql.org> so that the deficiency can be addressed.

F.45.2. Description of Functions

Table F.34 shows the functions provided by this module. These functions provide straightforward XML parsing and XPath queries. All arguments are of type `text`, so for brevity that is not shown.

Table F.34. Functions

Function	Returns	Description
<code>xml_valid(document)</code>	<code>bool</code>	This parses the document text in its parameter and returns true if the document is well-formed XML. (Note: this is an alias for the standard PostgreSQL function <code>xml_is_well_formed()</code> . The name <code>xml_valid()</code> is technically incorrect since validity and well-formedness have different meanings in XML.)
<code>xpath_string(document, query)</code>	<code>text</code>	These functions evaluate the XPath query on the supplied document, and cast the result to the specified type.
<code>xpath_number(document, query)</code>	<code>float4</code>	
<code>xpath_bool(document, query)</code>	<code>bool</code>	
<code>xpath_node_set(document, query, toptag, itemtag)</code>	<code>text</code>	This evaluates query on document and wraps the result in XML tags. If the result is multi-valued, the output will look like: <pre><toptag> <itemtag>Value 1 which could be an XML fragment</ itemtag></pre>

Function	Returns	Description
		<pre><itemtag>Value 2...</itemtag> </toptag></pre> <p>If either <code>toptag</code> or <code>itemtag</code> is an empty string, the relevant tag is omitted.</p>
<code>xpath_nodeSet(document, query)</code>	text	Like <code>xpath_nodeSet(document, query, toptag, itemtag)</code> but result omits both tags.
<code>xpath_nodeSet(document, query, itemtag)</code>	text	Like <code>xpath_nodeSet(document, query, toptag, itemtag)</code> but result omits <code>toptag</code> .
<code>xpath_list(document, query, separator)</code>	text	This function returns multiple values separated by the specified separator, for example <code>Value 1, Value 2, Value 3</code> if separator is <code>,</code> .
<code>xpath_list(document, query)</code>	text	This is a wrapper for the above function that uses <code>,</code> as the separator.

F.45.3. `xpath_table`

`xpath_table(text key, text document, text relation, text xpaths, text criteria)` returns setof record

`xpath_table` is a table function that evaluates a set of XPath queries on each of a set of documents and returns the results as a table. The primary key field from the original document table is returned as the first column of the result so that the result set can readily be used in joins. The parameters are described in Table F.35.

Table F.35. `xpath_table` Parameters

Parameter	Description
<i>key</i>	the name of the “key” field — this is just a field to be used as the first column of the output table, i.e., it identifies the record from which each output row came (see note below about multiple values)
<i>document</i>	the name of the field containing the XML document
<i>relation</i>	the name of the table or view containing the documents
<i>xpaths</i>	one or more XPath expressions, separated by
<i>criteria</i>	the contents of the WHERE clause. This cannot be omitted, so use <code>true</code> or <code>1=1</code> if you want to process all the rows in the relation

These parameters (except the XPath strings) are just substituted into a plain SQL SELECT statement, so you have some flexibility — the statement is

```
SELECT <key>, <document> FROM <relation> WHERE <criteria>
```

so those parameters can be *anything* valid in those particular locations. The result from this `SELECT` needs to return exactly two columns (which it will unless you try to list multiple fields for key or document). Beware that this simplistic approach requires that you validate any user-supplied values to avoid SQL injection attacks.

The function has to be used in a `FROM` expression, with an `AS` clause to specify the output columns; for example

```
SELECT * FROM
xpath_table('article_id',
            'article_xml',
            'articles',
            '/article/author|/article/pages|/article/title',
            'date_entered > '2003-01-01' ')
AS t(article_id integer, author text, page_count integer, title
text);
```

The `AS` clause defines the names and types of the columns in the output table. The first is the “key” field and the rest correspond to the XPath queries. If there are more XPath queries than result columns, the extra queries will be ignored. If there are more result columns than XPath queries, the extra columns will be `NULL`.

Notice that this example defines the `page_count` result column as an integer. The function deals internally with string representations, so when you say you want an integer in the output, it will take the string representation of the XPath result and use PostgreSQL input functions to transform it into an integer (or whatever type the `AS` clause requests). An error will result if it can't do this — for example if the result is empty — so you may wish to just stick to `text` as the column type if you think your data has any problems.

The calling `SELECT` statement doesn't necessarily have to be just `SELECT *` — it can reference the output columns by name or join them to other tables. The function produces a virtual table with which you can perform any operation you wish (e.g. aggregation, joining, sorting etc). So we could also have:

```
SELECT t.title, p.fullname, p.email
FROM xpath_table('article_id', 'article_xml', 'articles',
                '/article/title|/article/author/@id',
                'xpath_string(article_xml, '/article/@date') >
                '2003-03-20' ')
      AS t(article_id integer, title text, author_id integer),
tblPeopleInfo AS p
WHERE t.author_id = p.person_id;
```

as a more complicated example. Of course, you could wrap all of this in a view for convenience.

F.45.3.1. Multivalued Results

The `xpath_table` function assumes that the results of each XPath query might be multivalued, so the number of rows returned by the function may not be the same as the number of input documents. The first row returned contains the first result from each query, the second row the second result from each query. If one of the queries has fewer values than the others, null values will be returned instead.

In some cases, a user will know that a given XPath query will return only a single result (perhaps a unique document identifier) — if used alongside an XPath query returning multiple results, the single-valued result will appear only on the first row of the result. The solution to this is to use the key field as part of a join against a simpler XPath query. As an example:

```

CREATE TABLE test (
  id int PRIMARY KEY,
  xml text
);

INSERT INTO test VALUES (1, '<doc num="C1">
<line num="L1"><a>1</a><b>2</b><c>3</c></line>
<line num="L2"><a>11</a><b>22</b><c>33</c></line>
</doc>');

INSERT INTO test VALUES (2, '<doc num="C2">
<line num="L1"><a>111</a><b>222</b><c>333</c></line>
<line num="L2"><a>111</a><b>222</b><c>333</c></line>
</doc>');

SELECT * FROM
  xpath_table('id','xml','test',
              '/doc/@num|/doc/line/@num|/doc/line/a|/doc/line/b|/
doc/line/c',
              'true')
  AS t(id int, doc_num varchar(10), line_num varchar(10), val1 int,
val2 int, val3 int)
WHERE id = 1 ORDER BY doc_num, line_num

```

id	doc_num	line_num	val1	val2	val3
1	C1	L1	1	2	3
1		L2	11	22	33

To get doc_num on every line, the solution is to use two invocations of xpath_table and join the results:

```

SELECT t.*,i.doc_num FROM
  xpath_table('id', 'xml', 'test',
              '/doc/line/@num|/doc/line/a|/doc/line/b|/doc/line/c',
              'true')
  AS t(id int, line_num varchar(10), val1 int, val2 int, val3
int),
  xpath_table('id', 'xml', 'test', '/doc/@num', 'true')
  AS i(id int, doc_num varchar(10))
WHERE i.id=t.id AND i.id=1
ORDER BY doc_num, line_num;

```

id	line_num	val1	val2	val3	doc_num
1	L1	1	2	3	C1
1	L2	11	22	33	C1

(2 rows)

F.45.4. XSLT Functions

The following functions are available if libxslt is installed:

F.45.4.1. xslt_process

```
xslt_process(text document, text stylesheet, text paramlist)
  returns text
```

This function applies the XSL stylesheet to the document and returns the transformed result. The `paramlist` is a list of parameter assignments to be used in the transformation, specified in the form `a=1,b=2`. Note that the parameter parsing is very simple-minded: parameter values cannot contain commas!

There is also a two-parameter version of `xslt_process` which does not pass any parameters to the transformation.

F.45.5. Author

John Gray <jgray@azuli.co.uk>

Development of this module was sponsored by Torchbox Ltd. (www.torchbox.com). It has the same BSD license as PostgreSQL.

Appendix G. Additional Supplied Programs

This appendix and the previous one contain information regarding the modules that can be found in the `contrib` directory of the PostgreSQL distribution. See Appendix F for more information about the `contrib` section in general and server extensions and plug-ins found in `contrib` specifically.

This appendix covers utility programs found in `contrib`. Once installed, either from source or a packaging system, they are found in the `bin` directory of the PostgreSQL installation and can be used like any other program.

G.1. Client Applications

This section covers PostgreSQL client applications in `contrib`. They can be run from anywhere, independent of where the database server resides. See also PostgreSQL Client Applications for information about client applications that part of the core PostgreSQL distribution.

oid2name

oid2name — resolve OIDs and file nodes in a PostgreSQL data directory

Synopsis

```
oid2name [option...]
```

Description

oid2name is a utility program that helps administrators to examine the file structure used by PostgreSQL. To make use of it, you need to be familiar with the database file structure, which is described in Chapter 68.

Note

The name “oid2name” is historical, and is actually rather misleading, since most of the time when you use it, you will really be concerned with tables' filenode numbers (which are the file names visible in the database directories). Be sure you understand the difference between table OIDs and table filenodes!

oid2name connects to a target database and extracts OID, filenode, and/or table name information. You can also have it show database OIDs or tablespace OIDs.

Options

oid2name accepts the following command-line arguments:

`-f filenode`

`--filenode=filenode`

show info for table with filenode *filenode*.

`-i`

`--indexes`

include indexes and sequences in the listing.

`-o oid`

`--oid=oid`

show info for table with OID *oid*.

`-q`

`--quiet`

omit headers (useful for scripting).

`-s`

`--tablespaces`

show tablespace OIDs.

`-S`

`--system-objects`

include system objects (those in `information_schema`, `pg_toast` and `pg_catalog` schemas).

`-t tablename_pattern`
`--table=tablename_pattern`

show info for table(s) matching *tablename_pattern*.

`-V`
`--version`

Print the oid2name version and exit.

`-x`
`--extended`

display more information about each object shown: tablespace name, schema name, and OID.

`-?`
`--help`

Show help about oid2name command line arguments, and exit.

oid2name also accepts the following command-line arguments for connection parameters:

`-d database`
`--dbname=database`

database to connect to.

`-h host`
`--host=host`

database server's host.

`-H host`

database server's host. Use of this parameter is *deprecated* as of PostgreSQL 12.

`-p port`
`--port=port`

database server's port.

`-U username`
`--username=username`

user name to connect as.

To display specific tables, select which tables to show by using `-o`, `-f` and/or `-t`. `-o` takes an OID, `-f` takes a filenode, and `-t` takes a table name (actually, it's a LIKE pattern, so you can use things like `foo%`). You can use as many of these options as you like, and the listing will include all objects matched by any of the options. But note that these options can only show objects in the database given by `-d`.

If you don't give any of `-o`, `-f` or `-t`, but do give `-d`, it will list all tables in the database named by `-d`. In this mode, the `-S` and `-i` options control what gets listed.

If you don't give `-d` either, it will show a listing of database OIDs. Alternatively you can give `-s` to get a tablespace listing.

Environment

PGHOST
PGPORT
PGUSER

Default connection parameters.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 33.14).

Notes

oid2name requires a running database server with non-corrupt system catalogs. It is therefore of only limited use for recovering from catastrophic database corruption situations.

Examples

```
$ # what's in this database server, anyway?
$ oid2name
All databases:
   Oid Database Name Tablespace
-----
 17228      alvherre  pg_default
 17255      regression pg_default
 17227      template0  pg_default
    1      templatel  pg_default

$ oid2name -s
All tablespaces:
   Oid Tablespace Name
-----
  1663      pg_default
  1664      pg_global
155151      fastdisk
155152      bigdisk

$ # OK, let's look into database alvherre
$ cd $PGDATA/base/17228

$ # get top 10 db objects in the default tablespace, ordered by
size
$ ls -lS * | head -10
-rw----- 1 alvherre alvherre 136536064 sep 14 09:51 155173
-rw----- 1 alvherre alvherre  17965056 sep 14 09:51 1155291
-rw----- 1 alvherre alvherre   1204224 sep 14 09:51 16717
-rw----- 1 alvherre alvherre   581632 sep  6 17:51 1255
-rw----- 1 alvherre alvherre   237568 sep 14 09:50 16674
-rw----- 1 alvherre alvherre   212992 sep 14 09:51 1249
-rw----- 1 alvherre alvherre   204800 sep 14 09:51 16684
-rw----- 1 alvherre alvherre   196608 sep 14 09:50 16700
-rw----- 1 alvherre alvherre   163840 sep 14 09:50 16699
-rw----- 1 alvherre alvherre   122880 sep  6 17:51 16751

$ # I wonder what file 155173 is ...
$ oid2name -d alvherre -f 155173
From database "alvherre":
  Filenode Table Name
-----
  155173   accounts

$ # you can ask for more than one object
$ oid2name -d alvherre -f 155173 -f 1155291
From database "alvherre":
  Filenode Table Name
```

```

-----
    155173      accounts
    1155291    accounts_pkey

$ # you can mix the options, and get more details with -x
$ oid2name -d alvherre -t accounts -f 1155291 -x
From database "alvherre":
  Filenode      Table Name      Oid  Schema  Tablespace
-----
    155173      accounts      155173  public  pg_default
    1155291    accounts_pkey  1155291  public  pg_default

$ # show disk space for every db object
$ du [0-9]* |
> while read SIZE FILENODE
> do
>   echo "$SIZE      `oid2name -q -d alvherre -i -f $FILENODE`"
> done
16              1155287  branches_pkey
16              1155289  tellers_pkey
17561           1155291  accounts_pkey
...

$ # same, but sort by size
$ du [0-9]* | sort -rn | while read SIZE FN
> do
>   echo "$SIZE      `oid2name -q -d alvherre -f $FN`"
> done
133466          155173   accounts
17561           1155291  accounts_pkey
1177            16717   pg_proc_proname_args_nsp_index
...

$ # If you want to see what's in tablespaces, use the pg_tblspc
directory
$ cd $PGDATA/pg_tblspc
$ oid2name -s
All tablespaces:
  Oid  Tablespace Name
-----
    1663      pg_default
    1664      pg_global
    155151    fastdisk
    155152    bigdisk

$ # what databases have objects in tablespace "fastdisk"?
$ ls -d 155151/*
155151/17228/  155151/PG_VERSION

$ # Oh, what was database 17228 again?
$ oid2name
All databases:
  Oid  Database Name  Tablespace
-----
    17228      alvherre      pg_default
    17255      regression    pg_default
    17227      template0     pg_default
    1          templatel     pg_default

```

```
$ # Let's see what objects does this database have in the
  tablespace.
$ cd 155151/17228
$ ls -l
total 0
-rw-----  1 postgres postgres 0 sep 13 23:20 155156

$ # OK, this is a pretty small table ... but which one is it?
$ oid2name -d alvherre -f 155156
From database "alvherre":
  Filenode  Table Name
-----
      155156          foo
```

Author

B. Palmer <bpalmer@crimelabs.net>

vacuumlo

vacuumlo — remove orphaned large objects from a PostgreSQL database

Synopsis

```
vacuumlo [option...] dbname...
```

Description

vacuumlo is a simple utility program that will remove any “orphaned” large objects from a PostgreSQL database. An orphaned large object (LO) is considered to be any LO whose OID does not appear in any `oid` or `lo` data column of the database.

If you use this, you may also be interested in the `lo_manage` trigger in the `lo` module. `lo_manage` is useful to try to avoid creating orphaned LOs in the first place.

All databases named on the command line are processed.

Options

vacuumlo accepts the following command-line arguments:

```
-l limit  
--limit=limit
```

Remove no more than *limit* large objects per transaction (default 1000). Since the server acquires a lock per LO removed, removing too many LOs in one transaction risks exceeding `max_locks_per_transaction`. Set the limit to zero if you want all removals done in a single transaction.

```
-n  
--dry-run
```

Don't remove anything, just show what would be done.

```
-v  
--verbose
```

Write a lot of progress messages.

```
-V  
--version
```

Print the vacuumlo version and exit.

```
-?  
--help
```

Show help about vacuumlo command line arguments, and exit.

vacuumlo also accepts the following command-line arguments for connection parameters:

```
-h host  
--host=host
```

Database server's host.

`-p port`
`--port=port`

Database server's port.

`-U username`
`--username=username`

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force `vacuumlo` to prompt for a password before connecting to a database.

This option is never essential, since `vacuumlo` will automatically prompt for a password if the server demands password authentication. However, `vacuumlo` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by `libpq` (see Section 33.14).

Notes

`vacuumlo` works by the following method: First, `vacuumlo` builds a temporary table which contains all of the OIDs of the large objects in the selected database. It then scans through all columns in the database that are of type `oid` or `lo`, and removes matching entries from the temporary table. (Note: Only types with these names are considered; in particular, domains over them are not considered.) The remaining entries in the temporary table identify orphaned LOs. These are removed.

Author

Peter Mount <peter@retep.org.uk>

G.2. Server Applications

This section covers PostgreSQL server-related applications in `contrib`. They are typically run on the host where the database server resides. See also PostgreSQL Server Applications for information about server applications that part of the core PostgreSQL distribution.

pg_standby

`pg_standby` — supports the creation of a PostgreSQL warm standby server

Synopsis

```
pg_standby [option...] archiveLocation nextwalfile walfilepath [restart-walfile]
```

Description

`pg_standby` supports creation of a “warm standby” database server. It is designed to be a production-ready program, as well as a customizable template should you require specific modifications.

`pg_standby` is designed to be a waiting `restore_command`, which is needed to turn a standard archive recovery into a warm standby operation. Other configuration is required as well, all of which is described in the main server manual (see Section 26.2).

To configure a standby server to use `pg_standby`, put this into its `postgresql.conf` configuration file:

```
restore_command = 'pg_standby archiveDir %f %p %r'
```

where `archiveDir` is the directory from which WAL segment files should be restored.

If `restartwalfile` is specified, normally by using the `%r` macro, then all WAL files logically preceding this file will be removed from `archiveLocation`. This minimizes the number of files that need to be retained, while preserving crash-restart capability. Use of this parameter is appropriate if the `archiveLocation` is a transient staging area for this particular standby server, but *not* when the `archiveLocation` is intended as a long-term WAL archive area.

`pg_standby` assumes that `archiveLocation` is a directory readable by the server-owning user. If `restartwalfile` (or `-k`) is specified, the `archiveLocation` directory must be writable too.

There are two ways to fail over to a “warm standby” database server when the master server fails:

Smart Failover

In smart failover, the server is brought up after applying all WAL files available in the archive. This results in zero data loss, even if the standby server has fallen behind, but if there is a lot of unapplied WAL it can be a long time before the standby server becomes ready. To trigger a smart failover, create a trigger file containing the word `smart`, or just create it and leave it empty.

Fast Failover

In fast failover, the server is brought up immediately. Any WAL files in the archive that have not yet been applied will be ignored, and all transactions in those files are lost. To trigger a fast failover, create a trigger file and write the word `fast` into it. `pg_standby` can also be configured to execute a fast failover automatically if no new WAL file appears within a defined interval.

Options

`pg_standby` accepts the following command-line arguments:

`-c`

Use `cp` or `copy` command to restore WAL files from archive. This is the only supported behavior so this option is useless.

`-d`

Print lots of debug logging output on `stderr`.

`-k`

Remove files from *archive_location* so that no more than this many WAL files before the current one are kept in the archive. Zero (the default) means not to remove any files from *archive_location*. This parameter will be silently ignored if *restartwalfile* is specified, since that specification method is more accurate in determining the correct archive cut-off point. Use of this parameter is *deprecated* as of PostgreSQL 8.3; it is safer and more efficient to specify a *restartwalfile* parameter. A too small setting could result in removal of files that are still needed for a restart of the standby server, while a too large setting wastes archive space.

`-r maxretries`

Set the maximum number of times to retry the copy command if it fails (default 3). After each failure, we wait for *sleeptime* * *num_retries* so that the wait time increases progressively. So by default, we will wait 5 secs, 10 secs, then 15 secs before reporting the failure back to the standby server. This will be interpreted as end of recovery and the standby will come up fully as a result.

`-s sleeptime`

Set the number of seconds (up to 60, default 5) to sleep between tests to see if the WAL file to be restored is available in the archive yet. The default setting is not necessarily recommended; consult Section 26.2 for discussion.

`-t triggerfile`

Specify a trigger file whose presence should cause failover. It is recommended that you use a structured file name to avoid confusion as to which server is being triggered when multiple servers exist on the same system; for example `/tmp/pgsql.trigger.5432`.

`-V`

`--version`

Print the `pg_standby` version and exit.

`-w maxwaittime`

Set the maximum number of seconds to wait for the next WAL file, after which a fast failover will be performed. A setting of zero (the default) means wait forever. The default setting is not necessarily recommended; consult Section 26.2 for discussion.

`-?`

`--help`

Show help about `pg_standby` command line arguments, and exit.

Notes

`pg_standby` is designed to work with PostgreSQL 8.2 and later.

PostgreSQL 8.3 provides the `%r` macro, which is designed to let `pg_standby` know the last file it needs to keep. With PostgreSQL 8.2, the `-k` option must be used if archive cleanup is required. This option remains available in 8.3, but its use is deprecated.

PostgreSQL 8.4 provides the `recovery_end_command` option. Without this option a leftover trigger file can be hazardous.

`pg_standby` is written in C and has an easy-to-modify source code, with specifically designated sections to modify for your own needs

Examples

On Linux or Unix systems, you might use:

```
archive_command = 'cp %p ../archive/%f'

restore_command = 'pg_standby -d -s 2 -t /tmp/
pgsql.trigger.5442 ../archive %f %p %r 2>>standby.log'

recovery_end_command = 'rm -f /tmp/pgsql.trigger.5442'
```

where the archive directory is physically located on the standby server, so that the `archive_command` is accessing it across NFS, but the files are local to the standby (enabling use of `ln`). This will:

- produce debugging output in `standby.log`
- sleep for 2 seconds between checks for next WAL file availability
- stop waiting only when a trigger file called `/tmp/pgsql.trigger.5442` appears, and perform failover according to its content
- remove the trigger file when recovery ends
- remove no-longer-needed files from the archive directory

On Windows, you might use:

```
archive_command = 'copy %p ...\\archive\\%f'

restore_command = 'pg_standby -d -s 5 -t C:\pgsql.trigger.5442 ...
\archive %f %p %r 2>>standby.log'

recovery_end_command = 'del C:\pgsql.trigger.5442'
```

Note that backslashes need to be doubled in the `archive_command`, but *not* in the `restore_command` or `recovery_end_command`. This will:

- use the `copy` command to restore WAL files from archive
- produce debugging output in `standby.log`
- sleep for 5 seconds between checks for next WAL file availability
- stop waiting only when a trigger file called `C:\pgsql.trigger.5442` appears, and perform failover according to its content
- remove the trigger file when recovery ends
- remove no-longer-needed files from the archive directory

The `copy` command on Windows sets the final file size before the file is completely copied, which would ordinarily confuse `pg_standby`. Therefore `pg_standby` waits `sleep_time` seconds once it sees the proper file size. GNUWin32's `cp` sets the file size only after the file copy is complete.

Since the Windows example uses `copy` at both ends, either or both servers might be accessing the archive directory across the network.

Author

Simon Riggs <simon@2ndquadrant.com>

See Also

pg_archivecleanup

Appendix H. External Projects

PostgreSQL is a complex software project, and managing the project is difficult. We have found that many enhancements to PostgreSQL can be more efficiently developed separately from the core project.

H.1. Client Interfaces

There are only two client interfaces included in the base PostgreSQL distribution:

- libpq is included because it is the primary C language interface, and because many other client interfaces are built on top of it.
- ECPG is included because it depends on the server-side SQL grammar, and is therefore sensitive to changes in PostgreSQL itself.

All other language interfaces are external projects and are distributed separately. Table H.1 includes a list of some of these projects. Note that some of these packages might not be released under the same license as PostgreSQL. For more information on each language interface, including licensing terms, refer to its website and documentation.

Table H.1. Externally Maintained Client Interfaces

Name	Language	Comments	Website
DBD::Pg	Perl	Perl DBI driver	https://metacpan.org/release/DBD-Pg
JDBC	Java	Type 4 JDBC driver	https://jdbc.postgresql.org/
libpqxx	C++	C++ interface	http://pqxx.org/
node-postgres	JavaScript	Node.js driver	https://node-postgres.com/
Npgsql	.NET	.NET data provider	http://www.npgsql.org/
pgtcl	Tcl		https://github.com/flightaware/Pgtcl
pgtclng	Tcl		https://sourceforge.net/projects/pgtclng/
pq	Go	Pure Go driver for Go's database/sql	https://github.com/lib/pq
psqlODBC	ODBC	ODBC driver	https://odbc.postgresql.org/
psycopg	Python	DB API 2.0-compliant	http://initd.org/psycopg/

H.2. Administration Tools

There are several administration tools available for PostgreSQL. The most popular is pgAdmin¹, and there are several commercially available ones as well.

¹ <https://www.pgadmin.org/>

H.3. Procedural Languages

PostgreSQL includes several procedural languages with the base distribution: PL/pgSQL, PL/Tcl, PL/Perl, and PL/Python.

In addition, there are a number of procedural languages that are developed and maintained outside the core PostgreSQL distribution. Table H.2 lists some of these packages. Note that some of these projects might not be released under the same license as PostgreSQL. For more information on each procedural language, including licensing information, refer to its website and documentation.

Table H.2. Externally Maintained Procedural Languages

Name	Language	Website
PL/Java	Java	https://tada.github.io/pljava/
PL/Lua	Lua	https://github.com/pllua/pllua
PL/R	R	https://github.com/postgres-plr/plr
PL/sh	Unix shell	https://github.com/petere/plsh
PL/v8	JavaScript	https://github.com/plv8/plv8

H.4. Extensions

PostgreSQL is designed to be easily extensible. For this reason, extensions loaded into the database can function just like features that are built in. The `contrib/` directory shipped with the source code contains several extensions, which are described in Appendix F. Other extensions are developed independently, like PostGIS². Even PostgreSQL replication solutions can be developed externally. For example, Slony-I³ is a popular master/standby replication solution that is developed independently from the core project.

² <http://postgis.net/>

³ <http://www.slony.info>

Appendix I. The Source Code Repository

The PostgreSQL source code is stored and managed using the Git version control system. A public mirror of the master repository is available; it is updated within a minute of any change to the master repository.

Our wiki, https://wiki.postgresql.org/wiki/Working_with_Git, has some discussion on working with Git.

Note that building PostgreSQL from the source repository requires reasonably up-to-date versions of bison, flex, and Perl. These tools are not needed to build from a distribution tarball, because the files that these tools are used to build are included in the tarball. Other tool requirements are the same as shown in Section 16.2.

I.1. Getting the Source via Git

With Git you will make a copy of the entire code repository on your local machine, so you will have access to all history and branches offline. This is the fastest and most flexible way to develop or test patches.

Git

1. You will need an installed version of Git, which you can get from <https://git-scm.com>. Many systems already have a recent version of Git installed by default, or available in their package distribution system.
2. To begin using the Git repository, make a clone of the official mirror:

```
git clone https://git.postgresql.org/git/postgresql.git
```

This will copy the full repository to your local machine, so it may take a while to complete, especially if you have a slow Internet connection. The files will be placed in a new subdirectory `postgresql` of your current directory.

The Git mirror can also be reached via the Git protocol. Just change the URL prefix to `git`, as in:

```
git clone git://git.postgresql.org/git/postgresql.git
```

3. Whenever you want to get the latest updates in the system, `cd` into the repository, and run:

```
git fetch
```

Git can do a lot more things than just fetch the source. For more information, consult the Git man pages, or see the website at <https://git-scm.com>.

Appendix J. Documentation

PostgreSQL has four primary documentation formats:

- Plain text, for pre-installation information
- HTML, for on-line browsing and reference
- PDF, for printing
- man pages, for quick reference.

Additionally, a number of plain-text README files can be found throughout the PostgreSQL source tree, documenting various implementation issues.

HTML documentation and man pages are part of a standard distribution and are installed by default. PDF format documentation is available separately for download.

J.1. DocBook

The documentation sources are written in *DocBook*, which is a markup language defined in XML. In what follows, the terms DocBook and XML are both used, but technically they are not interchangeable.

DocBook allows an author to specify the structure and content of a technical document without worrying about presentation details. A document style defines how that content is rendered into one of several final forms. DocBook is maintained by the OASIS group¹. The official DocBook site² has good introductory and reference documentation and a complete O'Reilly book for your online reading pleasure. The NewbieDoc Docbook Guide³ is very helpful for beginners. The FreeBSD Documentation Project⁴ also uses DocBook and has some good information, including a number of style guidelines that might be worth considering.

J.2. Tool Sets

The following tools are used to process the documentation. Some might be optional, as noted.

DocBook DTD⁵

This is the definition of DocBook itself. We currently use version 4.2; you cannot use later or earlier versions. You need the XML variant of the DocBook DTD, not the SGML variant.

DocBook XSL Stylesheets⁶

These contain the processing instructions for converting the DocBook sources to other formats, such as HTML.

The minimum required version is currently 1.77.0, but it is recommended to use the latest available version for best results.

Libxml2⁷ for `xmllint`

This library and the `xmllint` tool it contains are used for processing XML. Many developers will already have Libxml2 installed, because it is also used when building the PostgreSQL code. Note, however, that `xmllint` might need to be installed from a separate subpackage.

¹ <https://www.oasis-open.org>

² <https://www.oasis-open.org/docbook/>

³ <http://newbie.doc.sourceforge.net/metadoc/docbook-guide.html>

⁴ <https://www.freebsd.org/docproj/docproj.html>

⁵ <https://www.oasis-open.org/docbook/>

⁶ <https://github.com/docbook/wiki/wiki/DocBookXslStylesheets>

⁷ <http://xmlsoft.org/>

Libxslt⁸ for xsltproc

xsltproc is an XSLT processor, that is, a program to convert XML to other formats using XSLT stylesheets.

FOP⁹

This is a program for converting, among other things, XML to PDF.

We have documented experience with several installation methods for the various tools that are needed to process the documentation. These will be described below. There might be some other packaged distributions for these tools. Please report package status to the documentation mailing list, and we will include that information here.

You can get away with not installing DocBook XML and the DocBook XSLT stylesheets locally, because the required files will be downloaded from the Internet and cached locally. This may in fact be the preferred solution if your operating system packages provide only an old version of especially the stylesheets or if no packages are available at all. See the `--nonet` option for `xmllint` and `xsltproc` for more information.

J.2.1. Installation on Fedora, RHEL, and Derivatives

To install the required packages, use:

```
yum install docbook-dtds docbook-style-xsl fop libxslt
```

J.2.2. Installation on FreeBSD

To install the required packages with `pkg`, use:

```
pkg install docbook-xml docbook-xsl fop libxslt
```

When building the documentation from the `doc` directory you'll need to use `gmake`, because the `makefile` provided is not suitable for FreeBSD's `make`.

J.2.3. Debian Packages

There is a full set of packages of the documentation tools available for Debian GNU/Linux. To install, simply use:

```
apt-get install docbook-xml docbook-xsl fop libxml2-utils xsltproc
```

J.2.4. macOS

On macOS, you can build the HTML and man documentation without installing anything extra. If you want to build PDFs or want to install a local copy of DocBook, you can get those from your preferred package manager.

If you use MacPorts, the following will get you set up:

⁸ <http://xmlsoft.org/XSLT/>

⁹ <https://xmlgraphics.apache.org/fop/>

```
sudo port install docbook-xml-4.2 docbook-xsl fop
```

If you use Homebrew, use this:

```
brew install docbook docbook-xsl fop
```

J.2.5. Detection by configure

Before you can build the documentation you need to run the `configure` script as you would when building the PostgreSQL programs themselves. Check the output near the end of the run, it should look something like this:

```
checking for xmllint... xmllint
checking for DocBook XML V4.2... yes
checking for dbtoepub... dbtoepub
checking for xsltproc... xsltproc
checking for fop... fop
```

If `xmllint` was not found then some of the following tests will be skipped.

J.3. Building the Documentation

Once you have everything set up, change to the directory `doc/src/sgml` and run one of the commands described in the following subsections to build the documentation. (Remember to use GNU `make`.)

J.3.1. HTML

To build the HTML version of the documentation:

```
doc/src/sgml$ make html
```

This is also the default target. The output appears in the subdirectory `html`.

To produce HTML documentation with the stylesheet used on [postgresql.org](https://www.postgresql.org)¹⁰ instead of the default simple style use:

```
doc/src/sgml$ make STYLE=website html
```

J.3.2. Manpages

We use the DocBook XSL stylesheets to convert DocBook `refentry` pages to `*roff` output suitable for man pages. To create the man pages, use the command:

```
doc/src/sgml$ make man
```

J.3.3. PDF

To produce a PDF rendition of the documentation using FOP, you can use one of the following commands, depending on the preferred paper format:

¹⁰ <https://www.postgresql.org/docs/current/>

- For A4 format:

```
doc/src/sgml$ make postgres-A4.pdf
```

- For U.S. letter format:

```
doc/src/sgml$ make postgres-US.pdf
```

Because the PostgreSQL documentation is fairly big, FOP will require a significant amount of memory. Because of that, on some systems, the build will fail with a memory-related error message. This can usually be fixed by configuring Java heap settings in the configuration file `~/ .foprc`, for example:

```
# FOP binary distribution
FOP_OPTS=' -Xmx1500m '
# Debian
JAVA_ARGS=' -Xmx1500m '
# Red Hat
ADDITIONAL_FLAGS=' -Xmx1500m '
```

There is a minimum amount of memory that is required, and to some extent more memory appears to make things a bit faster. On systems with very little memory (less than 1 GB), the build will either be very slow due to swapping or will not work at all.

Other XSL-FO processors can also be used manually, but the automated build process only supports FOP.

J.3.4. Plain Text Files

The installation instructions are also distributed as plain text, in case they are needed in a situation where better reading tools are not available. The `INSTALL` file corresponds to Chapter 16, with some minor changes to account for the different context. To recreate the file, change to the directory `doc/src/sgml` and enter `make INSTALL`. Building text output requires Pandoc version 1.13 or newer as an additional build tool.

In the past, the release notes and regression testing instructions were also distributed as plain text, but this practice has been discontinued.

J.3.5. Syntax Check

Building the documentation can take very long. But there is a method to just check the correct syntax of the documentation files, which only takes a few seconds:

```
doc/src/sgml$ make check
```

J.4. Documentation Authoring

The documentation sources are most conveniently modified with an editor that has a mode for editing XML, and even more so if it has some awareness of XML schema languages so that it can know about DocBook syntax specifically.

Note that for historical reasons the documentation source files are named with an extension `.sgml` even though they are now XML files. So you might need to adjust your editor configuration to set the correct mode.

J.4.1. Emacs

nXML Mode, which ships with Emacs, is the most common mode for editing XML documents with Emacs. It will allow you to use Emacs to insert tags and check markup consistency, and it supports DocBook out of the box. Check the nXML manual¹¹ for detailed documentation.

`src/tools/editors/emacs.samples` contains recommended settings for this mode.

J.5. Style Guide

J.5.1. Reference Pages

Reference pages should follow a standard layout. This allows users to find the desired information more quickly, and it also encourages writers to document all relevant aspects of a command. Consistency is not only desired among PostgreSQL reference pages, but also with reference pages provided by the operating system and other packages. Hence the following guidelines have been developed. They are for the most part consistent with similar guidelines established by various operating systems.

Reference pages that describe executable commands should contain the following sections, in this order. Sections that do not apply can be omitted. Additional top-level sections should only be used in special circumstances; often that information belongs in the “Usage” section.

Name

This section is generated automatically. It contains the command name and a half-sentence summary of its functionality.

Synopsis

This section contains the syntax diagram of the command. The synopsis should normally not list each command-line option; that is done below. Instead, list the major components of the command line, such as where input and output files go.

Description

Several paragraphs explaining what the command does.

Options

A list describing each command-line option. If there are a lot of options, subsections can be used.

Exit Status

If the program uses 0 for success and non-zero for failure, then you do not need to document it. If there is a meaning behind the different non-zero exit codes, list them here.

Usage

Describe any sublanguage or run-time interface of the program. If the program is not interactive, this section can usually be omitted. Otherwise, this section is a catch-all for describing run-time features. Use subsections if appropriate.

Environment

List all environment variables that the program might use. Try to be complete; even seemingly trivial variables like `SHELL` might be of interest to the user.

¹¹ https://www.gnu.org/software/emacs/manual/html_mono/nxml-mode.html

Files

List any files that the program might access implicitly. That is, do not list input and output files that were specified on the command line, but list configuration files, etc.

Diagnostics

Explain any unusual output that the program might create. Refrain from listing every possible error message. This is a lot of work and has little use in practice. But if, say, the error messages have a standard format that the user can parse, this would be the place to explain it.

Notes

Anything that doesn't fit elsewhere, but in particular bugs, implementation flaws, security considerations, compatibility issues.

Examples

Examples

History

If there were some major milestones in the history of the program, they might be listed here. Usually, this section can be omitted.

Author

Author (only used in the contrib section)

See Also

Cross-references, listed in the following order: other PostgreSQL command reference pages, PostgreSQL SQL command reference pages, citation of PostgreSQL manuals, other reference pages (e.g., operating system, other packages), other documentation. Items in the same group are listed alphabetically.

Reference pages describing SQL commands should contain the following sections: Name, Synopsis, Description, Parameters, Outputs, Notes, Examples, Compatibility, History, See Also. The Parameters section is like the Options section, but there is more freedom about which clauses of the command can be listed. The Outputs section is only needed if the command returns something other than a default command-completion tag. The Compatibility section should explain to what extent this command conforms to the SQL standard(s), or to which other database system it is compatible. The See Also section of SQL commands should list SQL commands before cross-references to programs.

Appendix K. PostgreSQL Limits

Table K.1 describes various hard limits of PostgreSQL. However, practical limits, such as performance limitations or available disk space may apply before absolute hard limits are reached.

Table K.1. PostgreSQL Limitations

Item	Upper Limit	Comment
database size	unlimited	
number of databases	4,294,950,911	
relations per database	1,431,650,303	
relation size	32 TB	with the default BLCKSZ of 8192 bytes
rows per table	limited by the number of tuples that can fit onto 4,294,967,295 pages	
columns per table	1600	further limited by tuple size fitting on a single page; see note below
field size	1 GB	
identifier length	63 bytes	can be increased by recompiling PostgreSQL
indexes per table	unlimited	constrained by maximum relations per database
columns per index	32	can be increased by recompiling PostgreSQL
partition keys	32	can be increased by recompiling PostgreSQL

The maximum number of columns for a table is further reduced as the tuple being stored must fit in a single 8192-byte heap page. For example, excluding the tuple header, a tuple made up of 1600 `int` columns would consume 6400 bytes and could be stored in a heap page, but a tuple of 1600 `bigint` columns would consume 12800 bytes and would therefore not fit inside a heap page. Variable-length fields of types such as `text`, `varchar`, and `char` can have their values stored out of line in the table's TOAST table when the values are large enough to require it. Only an 18-byte pointer must remain inside the tuple in the table's heap. For shorter length variable-length fields, either a 4-byte or 1-byte field header is used and the value is stored inside the heap tuple.

Columns that have been dropped from the table also contribute to the maximum column limit. Moreover, although the dropped column values for newly created tuples are internally marked as null in the tuple's null bitmap, the null bitmap also occupies space.

Appendix L. Acronyms

This is a list of acronyms commonly used in the PostgreSQL documentation and in discussions about PostgreSQL.

ANSI

American National Standards Institute¹

API

Application Programming Interface²

ASCII

American Standard Code for Information Interchange³

BKI

Backend Interface

CA

Certificate Authority⁴

CIDR

Classless Inter-Domain Routing⁵

CPAN

Comprehensive Perl Archive Network⁶

CRL

Certificate Revocation List⁷

CSV

Comma Separated Values⁸

CTE

Common Table Expression

CVE

Common Vulnerabilities and Exposures⁹

DBA

Database Administrator¹⁰

¹ https://en.wikipedia.org/wiki/American_National_Standards_Institute

² <https://en.wikipedia.org/wiki/API>

³ <https://en.wikipedia.org/wiki/Ascii>

⁴ https://en.wikipedia.org/wiki/Certificate_authority

⁵ https://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing

⁶ <https://www.cpan.org/>

⁷ https://en.wikipedia.org/wiki/Certificate_revocation_list

⁸ https://en.wikipedia.org/wiki/Comma-separated_values

⁹ <http://cve.mitre.org/>

¹⁰ https://en.wikipedia.org/wiki/Database_administrator

DBI

Database Interface (Perl)¹¹

DBMS

Database Management System¹²

DDL

Data Definition Language¹³, SQL commands such as CREATE TABLE, ALTER USER

DML

Data Manipulation Language¹⁴, SQL commands such as INSERT, UPDATE, DELETE

DST

Daylight Saving Time¹⁵

ECPG

Embedded C for PostgreSQL

ESQL

Embedded SQL¹⁶

FAQ

Frequently Asked Questions¹⁷

FSM

Free Space Map

GEQO

Genetic Query Optimizer

GIN

Generalized Inverted Index

GiST

Generalized Search Tree

Git

Git¹⁸

GMT

Greenwich Mean Time¹⁹

¹¹ <https://dbi.perl.org/>

¹² <https://en.wikipedia.org/wiki/Dbms>

¹³ https://en.wikipedia.org/wiki/Data_Definition_Language

¹⁴ https://en.wikipedia.org/wiki/Data_Manipulation_Language

¹⁵ https://en.wikipedia.org/wiki/Daylight_saving_time

¹⁶ https://en.wikipedia.org/wiki/Embedded_SQL

¹⁷ <https://en.wikipedia.org/wiki/FAQ>

¹⁸ [https://en.wikipedia.org/wiki/Git_\(software\)](https://en.wikipedia.org/wiki/Git_(software))

¹⁹ <https://en.wikipedia.org/wiki/GMT>

GSSAPI

Generic Security Services Application Programming Interface²⁰

GUC

Grand Unified Configuration, the PostgreSQL subsystem that handles server configuration

HBA

Host-Based Authentication

HOT

Heap-Only Tuples²¹

IEC

International Electrotechnical Commission²²

IEEE

Institute of Electrical and Electronics Engineers²³

IPC

Inter-Process Communication²⁴

ISO

International Organization for Standardization²⁵

ISSN

International Standard Serial Number²⁶

JDBC

Java Database Connectivity²⁷

JIT

Just-in-Time compilation²⁸

JSON

JavaScript Object Notation²⁹

LDAP

Lightweight Directory Access Protocol³⁰

²⁰ https://en.wikipedia.org/wiki/Generic_Security_Services_Application_Program_Interface

²¹ <https://git.postgresql.org/gitweb/?p=postgresql.git;a=blob;f=src/backend/access/heap/README.HOT;hb=HEAD>

²² https://en.wikipedia.org/wiki/International_Electrotechnical_Commission

²³ <http://standards.ieee.org/>

²⁴ https://en.wikipedia.org/wiki/Inter-process_communication

²⁵ <https://www.iso.org/home.html>

²⁶ <https://en.wikipedia.org/wiki/Issn>

²⁷ https://en.wikipedia.org/wiki/Java_Database_Connectivity

²⁸ https://en.wikipedia.org/wiki/Just-in-time_compilation

²⁹ <http://json.org>

³⁰ https://en.wikipedia.org/wiki/Lightweight_Directory_Access_Protocol

LSN

Log Sequence Number, see `pg_lsn` and WAL Internals.

MSVC

Microsoft Visual C³¹

MVCC

Multi-Version Concurrency Control

NLS

National Language Support³²

ODBC

Open Database Connectivity³³

OID

Object Identifier

OLAP

Online Analytical Processing³⁴

OLTP

Online Transaction Processing³⁵

ORDBMS

Object-Relational Database Management System³⁶

PAM

Pluggable Authentication Modules³⁷

PGSQL

PostgreSQL

PGXS

PostgreSQL Extension System

PID

Process Identifier³⁸

PITR

Point-In-Time Recovery (Continuous Archiving)

³¹ https://en.wikipedia.org/wiki/Visual_C++

³² https://en.wikipedia.org/wiki/Internationalization_and_localization

³³ https://en.wikipedia.org/wiki/Open_Database_Connectivity

³⁴ <https://en.wikipedia.org/wiki/Olap>

³⁵ <https://en.wikipedia.org/wiki/OLTP>

³⁶ <https://en.wikipedia.org/wiki/ORDBMS>

³⁷ https://en.wikipedia.org/wiki/Pluggable_Authentication_Modules

³⁸ https://en.wikipedia.org/wiki/Process_identifier

PL

Procedural Languages (server-side)

POSIX

Portable Operating System Interface³⁹

RDBMS

Relational Database Management System⁴⁰

RFC

Request For Comments⁴¹

SGML

Standard Generalized Markup Language⁴²

SPI

Server Programming Interface

SP-GiST

Space-Partitioned Generalized Search Tree

SQL

Structured Query Language⁴³

SRF

Set-Returning Function

SSH

Secure Shell⁴⁴

SSL

Secure Sockets Layer⁴⁵

SSPI

Security Support Provider Interface⁴⁶

SYSV

Unix System V⁴⁷

TCP/IP

Transmission Control Protocol (TCP) / Internet Protocol (IP)⁴⁸

³⁹ <https://en.wikipedia.org/wiki/POSIX>

⁴⁰ https://en.wikipedia.org/wiki/Relational_database_management_system

⁴¹ https://en.wikipedia.org/wiki/Request_for_Comments

⁴² <https://en.wikipedia.org/wiki/SGML>

⁴³ <https://en.wikipedia.org/wiki/SQL>

⁴⁴ https://en.wikipedia.org/wiki/Secure_Shell

⁴⁵ https://en.wikipedia.org/wiki/Secure_Sockets_Layer

⁴⁶ <https://msdn.microsoft.com/en-us/library/aa380493%28VS.85%29.aspx>

⁴⁷ https://en.wikipedia.org/wiki/System_V

⁴⁸ https://en.wikipedia.org/wiki/Transmission_Control_Protocol

TID

 Tuple Identifier

TOAST

 The Oversized-Attribute Storage Technique

TPC

 Transaction Processing Performance Council⁴⁹

URL

 Uniform Resource Locator⁵⁰

UTC

 Coordinated Universal Time⁵¹

UTF

 Unicode Transformation Format⁵²

UTF8

 Eight-Bit Unicode Transformation Format⁵³

UUID

 Universally Unique Identifier

WAL

 Write-Ahead Log

XID

 Transaction Identifier

XML

 Extensible Markup Language⁵⁴

⁴⁹ <http://www.tpc.org/>

⁵⁰ <https://en.wikipedia.org/wiki/URL>

⁵¹ https://en.wikipedia.org/wiki/Coordinated_Universal_Time

⁵² <http://www.unicode.org/>

⁵³ <https://en.wikipedia.org/wiki/Utf8>

⁵⁴ <https://en.wikipedia.org/wiki/XML>

Bibliography

Selected references and readings for SQL and PostgreSQL.

Some white papers and technical reports from the original POSTGRES development team are available at the University of California, Berkeley, Computer Science Department web site¹.

SQL Reference Books

- [bowman01] *The Practical SQL Handbook*. Using SQL Variants. Fourth Edition. Judith Bowman, Sandra Emerson, and Marcy Darnovsky. ISBN 0-201-70309-2. Addison-Wesley Professional. 2001.
- [date97] *A Guide to the SQL Standard*. A user's guide to the standard database language SQL. Fourth Edition. C. J. Date and Hugh Darwen. ISBN 0-201-96426-0. Addison-Wesley. 1997.
- [date04] *An Introduction to Database Systems*. Eighth Edition. C. J. Date. ISBN 0-321-19784-4. Addison-Wesley. 2003.
- [elma04] *Fundamentals of Database Systems*. Fourth Edition. Ramez Elmasri and Shamkant Navathe. ISBN 0-321-12226-7. Addison-Wesley. 2003.
- [melt93] *Understanding the New SQL*. A complete guide. Jim Melton and Alan R. Simon. ISBN 1-55860-245-3. Morgan Kaufmann. 1993.
- [ull88] *Principles of Database and Knowledge*. Base Systems. Jeffrey D. Ullman. Volume 1. Computer Science Press. 1988.
- [sqltr-19075-6] *SQL Technical Report²*. Part 6: SQL support for JavaScript Object Notation (JSON). First Edition. 2017.

PostgreSQL-specific Documentation

- [sim98] *Enhancement of the ANSI SQL Implementation of PostgreSQL*. Stefan Simkovic. Department of Information Systems, Vienna University of Technology. Vienna, Austria. November 29, 1998.
- [yu95] *The Postgres95. User Manual*. A. Yu and J. Chen. University of California. Berkeley, California. Sept. 5, 1995.
- [fong] *The design and implementation of the POSTGRES query optimizer³*. Zelaine Fong. University of California, Berkeley, Computer Science Department.

Proceedings and Articles

- [olson93] *Partial indexing in POSTGRES: research project*. Nels Olson. UCB Engin T7.49.1993 O676. University of California. Berkeley, California. 1993.
- [ong90] "A Unified Framework for Version Modeling Using Production Rules in a Database System". L. Ong and J. Goh. *ERL Technical Memorandum M90/33*. University of California. Berkeley, California. April, 1990.
- [rowe87] "The POSTGRES data model⁴". L. Rowe and M. Stonebraker. VLDB Conference, Sept. 1987.

¹ <http://db.cs.berkeley.edu/papers/>

² http://standards.iso.org/ittf/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip

³ <http://db.cs.berkeley.edu/papers/UCB-MS-zfong.pdf>

⁴ <http://db.cs.berkeley.edu/papers/ERL-M87-13.pdf>

- [seshadri95] “Generalized Partial Indexes⁵”. P. Seshadri and A. Swami. Eleventh International Conference on Data Engineering, 6-10 March 1995. Cat. No.95CH35724. IEEE Computer Society Press. Los Alamitos, California. 1995. 420-7.
- [ston86] “The design of POSTGRES⁶”. M. Stonebraker and L. Rowe. ACM-SIGMOD Conference on Management of Data, May 1986.
- [ston87a] “The design of the POSTGRES. rules system”. M. Stonebraker, E. Hanson, and C. H. Hong. IEEE Conference on Data Engineering, Feb. 1987.
- [ston87b] “The design of the POSTGRES storage system⁷”. M. Stonebraker. VLDB Conference, Sept. 1987.
- [ston89] “A commentary on the POSTGRES rules system⁸”. M. Stonebraker, M. Hearst, and S. Potamianos. *SIGMOD Record* 18(3). Sept. 1989.
- [ston89b] “The case for partial indexes⁹”. M. Stonebraker. *SIGMOD Record* 18(4). Dec. 1989. 4-11.
- [ston90a] “The implementation of POSTGRES¹⁰”. M. Stonebraker, L. A. Rowe, and M. Hirohama. *Transactions on Knowledge and Data Engineering* 2(1). IEEE. March 1990.
- [ston90b] “On Rules, Procedures, Caching and Views in Database Systems¹¹”. M. Stonebraker, A. Jhingran, J. Goh, and S. Potamianos. ACM-SIGMOD Conference on Management of Data, June 1990.

⁵ <http://citeseer.ist.psu.edu/seshadri95generalized.html>

⁶ <http://db.cs.berkeley.edu/papers/ERL-M85-95.pdf>

⁷ <http://db.cs.berkeley.edu/papers/ERL-M87-06.pdf>

⁸ <http://db.cs.berkeley.edu/papers/ERL-M89-82.pdf>

⁹ <http://db.cs.berkeley.edu/papers/ERL-M89-17.pdf>

¹⁰ <http://db.cs.berkeley.edu/papers/ERL-M90-34.pdf>

¹¹ <http://db.cs.berkeley.edu/papers/ERL-M90-36.pdf>

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[System Processing]

Continues processing.

[Action]

Take either of the following actions.

- When parameters for abnormality monitoring of the operating system or server are not optimally tuned

Correct the value of parameters for abnormality monitoring of the operating system or server according to the message and "Tuning for Optimization of Degradation Using Abnormality Monitoring With the Arbitration Server" of "Cluster Operation Guide (Database Multiplexing)".

After that, execute the `mc_ctl` command to stop Mirroring Controller, and execute the `mc_arb` command to stop the Mirroring Controller Arbitration process.

After that, execute the `mc_arb` command to start the Mirroring Controller Arbitration process, and execute the `mc_ctl` command to start Mirroring Controller.

- When the arbitration server is not responding

Identify the cause, and then remove it.

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